UNESP - Universidade Estadual Paulista

“Júlio de Mesquita Filho”

Faculdade de Odontologia de Araraquara

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Avaliação tridimensional utilizando sobreposição por equivalência de voxel da expansão rápida maxilar assistida por mini-implantes

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Orientador: Ary dos Santos-Pinto

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Adriana Souza de Jesus

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Comissão julgadora

Tese para obtenção do grau de Doutora em Ciências Odontológicas, área de Ortodontia.

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Araraquara, 09 de Agosto de 2023.

DADOS CURRICULARES

Adriana Souza de Jesus

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RESUMO

O objetivo deste estudo é avaliar as alterações esqueléticas produzidas pela expansão rápida do palato assistida por miniparafusos (ERMAMI) com e sem corticopunção. Foi utilizada uma amostra de tomografias computadorizadas de feixe cônico (TCFCs), realizadas em pacientes que já atingiram a maturidade óssea para avaliar e comparar as mudanças tridimensionais de forma e posição na maxila foi realizada sobreposição tomográfica. Foram analisadas também as associações de sucesso ou insucesso da técnica com a morfologia do processo zigomático, estágio de maturação da sutura zigomaticomaxilar, a angulação e abertura da sutura pterigopalatina. Além disso, alguns casos de ERMAMI onde ocorreram complicações foram selecionados para serem relatados. Foram selecionadas tomografias de 36 indivíduos tratados por ERMAMI, adolescentes e adultos, com atresia maxilar, mordida cruzada posterior bilateral ou unilateral. Para as avaliações, foram utilizadas TCFCs antes (T0) e após o término da expansão (T1). Foi avaliado o desempenho das diferentes técnicas de ERMAMI comparando as médias de cada variável antes e depois do tratamento, empregando o test t-Student para comparar as médias de dois grupos com amostras dependentes. Já o teste t-Student para amostras independentes foi realizado para comparar as alterações entre os grupos. A correlação entre o efeito ortopédico de abertura ou não da sutura palatina mediana (sucesso e insucesso) com a morfologia do processo zigomático, estágio de maturação da sutura zigomaticomaxilar, a angulação e abertura da sutura pterigopalatina foram avaliados utilizando o teste de correlação de Pearson. Quando realizada a corticopunção da sutura palatina mediana, menor quantidade de expansão esquelética foi obtida e observou-se melhor paralelismo da abertura sutural. O estágio maturacional da sutura zigomático-maxilar, altura, espessura e angulação do osso zigomático e angulação da sutura pterigopalatina não foram significativamente relacionados ao sucesso da ERMAMI. A partir do manejo dos casos, sugere-se que um protocolo de higiene ideal para os pacientes seja melhor estabelecido para prevenir a formação de lesões e inflamação; A sutura frontonasal pode se romper durante a expansão com ERMAMI causando expansão assimétrica e desnivelamento do lado onde ocorreu a ruptura; Em pacientes com espessura palatina fina combinar o método de corticopuntura e alterar o protocolo de ativação para apenas ¼ de volta por dia (0,25mm) pode ajudar a enfraquecer a sutura palatina mediana e promover sua ruptura.

Palavras Chave: Técnica de expansão palatina. Procedimentos de ancoragem ortodôntica. Tomografia Computadorizada de Feixe Cônico.

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ABSTRACT

The aim of this study is, to evaluate the skeletal changes produced by miniscrew assisted rapid palatal expansion (MARPE) with and without corticopuncture. A sample of CBCTs, performed in patients who have already reached bone maturity was used. Tomographic superinposition to assess and compare three-dimensional shape and position changes in the maxilla was performed. In addition, to analyze the association (success or failure of the technique) with the morphology of the zygomatic process, stage of maturation of the zygomaticomaxillary suture, angulation and opening of the pterygopalatine suture. Furthermore, some cases of MARPE where complications occurred were selected to be reported. CT scans of 36 individuals treated by MARPE were analysed in adolescents and adults, with maxillary atresia, bilateral or unilateral posterior crossbite. For the evaluations, cone beam computed tomography were used before (T0) and after the end of the expansion (T1). The performance of different MARPE techniques was evaluated by comparing the means of each variable before and after treatment, using the t-Student test to compare the means of two groups with dependent samples. The t-Student test for independent samples was performed to compare changes between groups. The correlation between the orthopedic effect of opening or not opening of the midpalatal suture (success and failure) with the morphology of the zygomatic process, stage of maturation of the zygomaticomaxillary suture, angulation and opening of the pterygopalatine suture were evaluated using Pearson's correlation test. When corticopuncture of the midpalatal suture was performed, a smaller amount of skeletal expansion was obtained and better parallelism of the sutural opening was observed. The maturational stage of the zygomatico-maxillary suture, height, thickness and angulation of the zygomatic bone, opening and angulation of the pterygopalatine suture were not significantly related to the success of MARPE. From the case management, it is suggested that an ideal hygiene protocol for patients should be better established to prevent the formation of lesions and inflammation; The frontonasal suture can disrupt during expansion with MARPE causing asymmetrical expansion and unevenness on the side where the rupture occurred; In patients with thin palate thickness, combining the corticopuncture method and changing the activation protocol to just ¼ turn per day (0.25mm) may help to weaken the midpalatal suture and promote its rupture.

Keywords: Palatal expansion technique. Orthodontic anchorage procedures. Cone-beam computed tomography.

SUMÁRIO

1 INTRODUÇÃO

O correto relacionamento transversal entre os arcos dentários é essencial para a obtenção de uma oclusão estável e funcional. As discrepâncias transversais envolvem alterações dentárias, esqueléticas ou a combinação de ambas[1,2]. A expansão rápida da maxila (ERM) é um método estabelecido de tratamento das discrepâncias transversais que aumenta o perímetro do arco, principalmente, pelo rompimento da sutura palatina mediana, e esta se reorganiza por meio do reparo do tecido conjuntivo e formação óssea. Geralmente é utilizada para tratar a constrição da maxila, mordida cruzada posterior, discrepâncias no comprimento do arco em pacientes em crescimento[3].

A idade é um fator muito importante na ERM. Em adultos, devido à maturação das suturas palatina mediana e resistência do pilar zigomático, a resposta à expansão palatal com ERM não é bem sucedida. O alargamento resultante da largura maxilar ocorre mais devido à flexão óssea alveolar e inclinação dentária em adultos[4]. Além de sua incapacidade de produzir expansão esquelética completa em adultos, a ERM pode trazer efeitos colaterais indesejáveis, como falha na expansão do arco, inclinação vestibular da coroa, deiscência do osso alveolar, reabsorção radicular, redução da espessura óssea vestibular e perda óssea marginal[5,6].

A ERM assistida cirurgicamente (ERMAC) é o principal método cirúrgico para tratamento das deficiências transversais da maxila nos pacientes adultos. Frequentemente utilizada para superar as limitações acima mencionadas por meio da liberação cirúrgica das suturas fechadas que resistem às forças de expansão nesses pacientes [7]. No entanto, os pacientes tendem a relutar em submeter-se a múltiplos procedimentos cirúrgicos e a demanda para o tratamento não cirúrgico tem aumentado[8].

Com a finalidade de prevenir os efeitos dentoalveolares indesejáveis e otimizar o potencial de expansão esquelética em indivíduos com estágios avançados de maturação óssea, a técnica de expansão rápida da maxila assistida por mini-implantes (ERMAMI) foi proposta por Lee e colaboradores em 2010[9] e já tem sido utilizada como abordagem menos invasiva, clinicamente eficaz e estável para a correção não cirúrgica da discrepância transversal em pacientes adultos[8,10]. No entanto, mesmo usando a ERMAMI, a expansão maxilar ortopédica pode não ocorrer em alguns casos.

Ainda não está claro por que alguns casos de ERMAMI falham, mas estudos recentes apontam a idade e diferenças nos padrões de arquitetura palatina como principais fatores para maior resistência[11].

Um procedimento cirúrgico minimamente invasivo denominado de corticopuntura foi apresentado por Suzuki e colaboradores[12] como adjuvante da técnica ERMAMI em pacientes adultos que apresentam resistência da sutura palatina mediana e suturas adjacentes devido à alta interdigitação dessas estruturas. Eles concluíram que a corticopuntura na região de sutura palatina mediana foi capaz de enfraquecer a interdigitação da sutura, facilitando a divisão. Essa técnica ainda foi pouco explorada e mais estudos acerca de sua eficácia e protocolos de utilização precisam ser realizados.

Os avanços tecnológicos levaram a mudanças no método de avaliação dos efeitos do tratamento da ERM, passando de 2D para 3D e de abordagens lineares e angulares para volumétricas. O uso da tomografia computadorizada (TC) e, posteriormente, com feixe cônico (TCFC) tem sido de grande interesse e ajudam os clínicos que tentam adquirir imagens em 3D e reconstruções de objetos, a fim de poder aplicar medidas 3D e volumétricas[13]. Nesse contexto, a TCFC vem sendo utilizada para avaliar sobreposição de imagens pré e pós tratamento. Um dos objetivos da sobreposição tridimensional é entender as mudanças de forma, tamanho e posição espacial em um determinado padrão esquelético, a partir da avaliação do crescimento ou dos resultados de um tratamento. A distância entre as superfícies dos diferentes tempos avaliados pode ser usada para identificar e quantificar valores e direção das mudanças obtidas[14–16]. Magnusson e colaboradores[17] (2012) utilizaram a técnica de sobreposição 3D para avaliar as alterações esqueléticas transversais após ERMAC e observaram que a expansão ocorria paralela anteriormente, mas posteriormente houve inclinação considerável dos segmentos maxilares. Eles concluíram que o método de sobreposição tridimensional baseado no registro da base do crânio mostrou-se confiável, prevenindo projeções e erros de medidas. Até o momento, existem poucos estudos acerca do padrão de expansão após ERMAMI utilizando sobreposição de imagens[18].

O objetivo deste estudo é, a partir das TCFC, avaliar as alterações esqueléticas produzidas pela expansão rápida da maxila assistida por mini-implantes ortodônticos (ERMAMI) realizada em pacientes que já atingiram a maturidade óssea utilizando a sobreposição tomográfica para avaliar e comparar as mudanças de forma e posição tridimensional em maxila.

2 OBJETIVO

O objetivo deste estudo é, a partir das TCFC, avaliar as alterações esqueléticas produzidas pela expansão rápida da maxila assistida por mini-implantes ortodônticos (ERMAMI) realizada em pacientes que já atingiram a maturidade óssea utilizando a sobreposição tomográfica para avaliar e comparar as mudanças de forma e posição tridimensional em maxila decorrentes da ERMAMI com e sem corticopuntura da sutura palatina mediana.

2.1 Objetivos Específicos

Avaliar as mudanças esqueléticas transversais maxilares, utilizando o método de sobreposição de modelos tomográficos tridimensionais a partir do registro da base do crânio em pacientes com maturação óssea avançada tratados com ERMAMI (com e sem corticopuntura).

Observar a correlação entre os resultados do ERMAMI (sucesso e insucesso da expansão ortopédica) com a morfologia do processo zigomático.

Observar a correlação entre os resultados do ERMAMI (sucesso e insucesso da expansão ortopédica) com o estágio de maturação da sutura zigomaticomaxilar.

Observar a correlação entre os resultados do ERMAMI (sucesso e insucesso da expansão ortopédica) com a angulação e abertura da sutura pterigopalatina.

Relatar algumas complicações que ocorreram em casos clínicos tratados com MARPE e como elas foram conduzidas.

3 PUBLICAÇÕES

De forma a contemplar o objetivo geral deste trabalho, os objetivos específicos foram tratados na forma de três artigos distintos.

3.1 ARTIGO 1*

The effect of corticopuncture on miniscrew-assisted rapid maxillary expansion in patients with advanced bone maturation

Abstract

Introduction: The aim of this study was to evaluate skeletal changes by superimposing three-dimensional tomographic models in patients with advanced bone maturation treated with MARPE with and without corticopuncture of the midpalatal suture. Methods: The changes promoted by MARPE were evaluated in 44 patients (31 female 25.4 ± 7.2 years and 13 male 24.0 ± 7.6 years) with maxillary atresia without corticopuncture (n=25) and with corticopuncture (n=19) by superimposing three-dimensional tomographic images in the following regions: anterior and posterior nasal spine, incisive foramen, middle and posterior nasal cavity, anterior and posterior zygomatic bone, infraorbital region. Student's t- test for dependent samples was performed to compare the means before and after the expansion and Student's t-test for independent samples was used to compare the changes between the groups. Pearson's correlation test was used to assess the relationship of expansion in the different regions with the type of technique. Results: All regions showed significant mean changes ($p<0.001$) after expansion with MARPE in both techniques (2.4 to 5.2 mm without corticopuncture and 1.3 to 3.5 mm with corticopuncture). When MARPE was performed without corticopuncture, statistically significant greater mean expansion ($p<0.05$) was observed (1.1 to 1.6 mm) than in cases with corticopuncture in the regions of the anterior nasal spine, incisive foramen, middle nasal cavity, anterior and posterior regions of the zygomatic bone and infraorbital region. No statistically significant differences ($p>0.05$) were observed in the amount of expansion in the

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posterior nasal spine and of posterior nasal cavity. There was a negative correlation between corticopuncture and amount of opening in these regions (P=0.368 for PNE and P=0.880 for PNC). Conclusion: A better anteroposterior parallelism in sutural opening was observed in the corticopuncture group. When corticopuncture was performed, less amount of skeletal expansion was achieved, however, better parallelism of the sutural opening was observed.

Introduction

To prevent undesirable dentoalveolar effects and optimize the potential for skeletal expansion in individuals with advanced stages of bone maturation, the mini-implant-assisted rapid maxillary expansion (MARPE) technique was proposed by Lee et al. in 2010[1] and has already been used as a less invasive, clinically effective and stable approach for the non-surgical correction of transversal discrepancy in adult patients[2,3]. However, orthopedic maxillary expansion may not occur in some cases. It is still unclear why few MARPE cases fail, but recent studies point to age and differences in palatal architectural patterns as major factors for increased resistance[4,5].

A minimally invasive surgical procedure called corticopuncture was presented by Suzuki et al.[6] in a case report article as an adjuvant to the MARPE technique in adult patients who present resistance of the midpalatal suture and adjacent sutures due to the high interdigitation of these structures. They concluded that corticopuncture in the midpalatal suture region was able to weaken suture interdigitation, facilitating division[6]. This technique has been poorly explored and more studies about its effectiveness and use protocols need to be carried out.

The aim of this study is to evaluate skeletal changes, superimposing three-dimensional tomographic models in patients with advanced bone maturation treated with MARPE with and without corticopuncture.

Materials and Methods:

This study was approved by the ethics comitte of the São Paulo State University (UNESP), School of Dentistry, Araraquara – Brazil, under protocol number 39233820.7.0000.5416.The sample of this retrospective controlled study included cone-beam computed tomography (CBCT) of 44 individuals, between 15 and 39 years old (31 women 25.4 ± 7.2 years and 13 men 24.0 ± 7.6 years), treated with MARPE with and without corticopuncture (Table 1). The inclusion criteria were CBCT’s before

(T0) and after maxillary expansion (T1), of subjects presenting transverse maxillary deficiency with unilateral or bilateral posterior crossbite (a difference greater than 5 mm between the transverse distance of the palatal cusps of the first maxillary molars and the transverse distance of the first lower molars central sulcus) with complete skeletal maturation confirmed by examination of the cervical vertebrae. All subjects were in at least CVMS stage V of Hassel and Farman analysis modified by Baccetti, Franchi and McNamara [7]. Cases with previous orthodontic treatment, cleft lip and palate, and syndromic conditions were excluded.

MARPE Treatment

Patients of the group without corticopuncture were treated by RME using the same protocol previously reported by this research group[5].

In the group with corticopuncture, before installing the expander, 6 to 8 bone perforations were made in the midpalatal suture from the third palatal roughness to the end of the hard palate, with 2 mm of distance between them. The perforations were made using a manual contra-angle and a drill 6 mm long and 1.5 mm thick (PEClab® – Minas Gerais, Brazil). In the anterior part of the palate, the perforations were performed carefully to avoid the nasopalatine canal. The corticopuncture procedure was performed with anesthetic block of the greater palatine nerve.[6]

CBCT scans before (T0) and after (T1) expansion were taken using the i-CAT Next Generation scanner (Imaging Sciences International, Hatfield, PA, USA) configurated for exposure time of 7 seconds with 120 kV. The tomographic images were acquired with a field of view of 23 X 17 cm and a voxel size of 0.3 mm^3. Data were exported in the digital image and communication in medicine (DICOM) format. Figure 1 shows the CT scans of a case with and a case without perforation.

The success of the orthopedic maxillary expansion was confirmed by the opening of the medial palatine suture, verified in the tomographic examination, by the separation of the two halves of the palatine process after the activation period. Maxillary changes were obtained by the difference of the linear measurements achieved (T1-T0) as reported previously[5]. All patients in this study successfully opened the midpalatal suture.

Tomographic superimposition:

This method involves five steps: (1) model construction, (2) segmentation, (3) registration, (4) qualitative visualization of the superimposed images and (5) quantitative measurement [8].

In order to reduce the computational resource required in the analyses, the files in DICOM format (.dcm) were initially converted to .gipl.gz extension (Guys Image Processing Lab) in the free distribution software ITK-SNAP (version 3.8), to compress the file.

(1) A surface model is created using the segment editor model of the 3D slicer software to generate a volume based on the threshold.

(2) This volume is loaded in the ITK-SNAP software for the segmentation process that was performed semi-automatically, using the Active Contour Segmentation Mode tool and 3D tool bar to cut (clean) the skull. Initially, only the region of the skull base of the two treatment times was segmented.

(3) The registration process was performed in the 3DSlicer software, using the Voxelbase Registration tool. The registration of the cranial base utilizes maximization of mutual information to avoid observer-dependent techniques. After the software masks the maxillary and mandibular structures, it compares the gray level intensity of each voxel in the cranial base to register the 2 CBCT images. These rotation and translation parameters are also applied to register 3D models. After registration, we can assess the overlay of the 3D models[8]. Thus, the tomographic images and the segmented skull bases are reoriented until there is a perfect superposition of the skull bases between times T0 and T1, completing the registration of the CT scans through the skull base. Once the CT scans are recorded, the skull bases are positioned in an equivalent manner at the two study times, T0 and T1.

(4) After being recorded, the CTs (T0 and T1) were loaded again in the 3D-Slicer software to create a new model with the new orientation using the Segment Editor module. This new volumetric model (3D reconstruction) was saved in .VTK for the qualitative analysis. The models generated by the Segment Editor module were loaded into the 3D-Slicer, and through the Models tool the superimposition between the two times was performed. As the two time points are registered at the cranial base, the changes observed in the maxillary region correspond to the effects of the treatment.

(5) The anatomical sites chosen bilaterally for quantitative analysis are presented in Table 2.

Note: For these measurements two points (landmarks) were used (left and right margin of the considered structure).

In the ITK-Snap program, the determined points were marked and saved (Figure 2). In the 3D Slicer software, the distances between the points were then calculated.

Statistical Analysis

To determine the intra-examiner error calculation, all scans were re-analyzed, randomly by the same examiner, with a two-week interval between the first and second evaluation. The reproducibility of the method was evaluated using the Intraclass Correlation Coefficient (ICC) and t-test for repeated measures (systematic error evaluation) for all measures used in this study.

Student's T test for dependent sample was performed to compare the means before and after the expansion. Student's T test for independent samples was used to compare the expansion changes achieved in the 2 groups. Spearman correlation test was used to assess the relationship between expansion in different regions without corticopunture (coded as 0) and with corticopuncture (coded as 1). Pearson's correlation test was also performed to assess the relationship of the variables with age according the technique used (with and without corticopuncture).

Results

The reliability of the measurements was confirmed by the intraclass correlation coefficients (ICC) greater than 0.975 and Cronbach Alfa greater than 0.992. The mean difference of replicate measurements was less than 0.2 mm (SE=0.03), indicating that the replicate measurements showed no systematic error.

The post hoc power analysis for the two-tailed, independent two-sample t-test was 0.80, for an effect size of 0.87 and alpha of 0.05 (G*Power 3.1.9.7 Heinrich-Heine-Universität Düsseldorf, 2020).

All regions showed significant mean changes ($p<0.001$) after expansion with MARPE in both techniques (Table 2) (2.4 to 5.2 mm without corticopuncture and 1.3 to 3.5 mm with corticopuncture). In cases without corticopuncture, the mean expansion (1.1 to 1.6 mm) observed was greater than in cases with corticopuncture in the regions of anterior nasal spine ($p=0.040$), incisive foramen ($p=0.036$), middle nasal cavity (p=

0.001) anterior (p=0.006) and posterior zygomatic (p=0.009) and infraorbital (p=0.003) (Table 3).

The parallelism between opening in the anterior and posterior regions was also analyzed (Table 4). In cases with corticopuncture in the regions of nasal spine and zygomatic bone, the difference in anteroposterior opening was smaller and not statistically significant, indicating parallelism. Whereas, in the group without corticopuncture, the opening in the region of the nasal spine was statistically significant, indicating greater anterior opening than posterior. In the nasal cavity region, the anteroposterior difference was significant in both groups, being greater in the middle than posterior region. However, this difference was smaller in the corticopuncture group (1.99 x 0.88 respectively). In agreement with these findings, the amount of opening in these regions was significantly correlated with cases without corticopuncture (negative correlation in Table 5).

No significant differences were observed in the amount of expansion in the posterior nasal spine (p=0.554) and posterior nasal cavity (p=0.310) regions.

Furthermore, changes in variables (T1-T0) were correlated with the age of the sample and no significant differences were found intragroup (Table 6). Between the groups, differences were found in the middle nasal cavity (0.008), anterior zygomatic region (0.007) and infraorbital region (0.018). However, this correlation can be considered weak by analyzing the r value (Table 5) and the distribution in the scatterplots (Figure 3).

The qualitative visualization of the expansions (3D superimposition) in the different techniques is shown in Figures 4 and 5.

Discussion

This study sought to evaluate craniofacial regions after expansion with MARPE and whether the performance of corticopuncture would promote a differentiated expansion.

In adult patients or in patients who have completed their growth, sutures are usually heavily interdigitated which makes disjunction difficult in rapid maxillary expansion[9]. Aiming to reduce any possible area of bone resistance during maxillary expansion with MARPE, the corticopuncture procedure was idealized to weaken suture interdigitation, in cases where sutural opening was not achieved with the conventional protocol for MARPE installation and activation. Suzuki et al. suggested that this procedure could accelerate bone remodeling to complement MARPE technique in order to facilitate suture split[6].

One of the greatest difficulties during expansion is achieving a proper disjunction in the posterior region, precisely with the aim of correcting posterior crossbites. In a previous study, our group demonstrated that the use of skeletal anchorage promotes a more parallel opening of the midpalatal suture, when compared to surgically assisted palatal expansion (SARPE)[10], which features a "v" shaped opening pattern. We reinforce in the current article the observation of an anteroposterior parallelism, as little difference in the amount of opening between anterior and posterior regions is observed analyzing the entire sample. For example, the difference in opening between the anterior and posterior nasal spine was 1mm, between the middle and posterior nasal cavity it was 1.5mm and between the anterior and posterior zygomatic region was 0.35mm. Furthermore, in cases where corticopuncture was performed, this anteroposterior parallelism was more evident (Table 4).

What would be the advantages of this parallel sutural opening? Especially in cases where we want to correct the crossbite only in the posterior region, a parallel opening is desirable. Often, when a large amount of expansion is required in the posterior region, the interincisor diastema created by the disjunction increases because the anterior region opens more than the posterior, which causes great aesthetic discomfort in patients. In addition, posterior skeletal changes with rapid maxillary expansion can also make a significant contribution to the quality of breathing by reducing the resistance in posterior nasal passage in sleep apnea patients[11,12]. Garcez et al. (2019)[13] evaluated changes in inspiratory strength after MARPE, and showed that the skeletal changes resulted in improvement in nasal and oral flow.

It would make sense to think that perforations would improve opening in the posterior region. However, when we analyzed the posterior regions in the post-expansion subjects, no significant differences were found between the two techniques. In addition, the anterior region in the cases without perforation obtained better opening results (anterior nasal spine: 1.61 mm more; incisive foramen: 1.49 mm more; middle nasal cavity: 1.55 mm more; anterior zygomatic bone: 1.17 mm more).

An important limitation that we must emphasize in this study is the difference in the mean age between the groups. The justification for this difference in age range is that, in a previous study, we observed that the success rates of the MARPE technique dropped significantly from age 25 onwards[5]. Moreover, a recent study showed that the success rate of MARPE and the suture expansion amount may depend on chronological age[14]. The perforations were performed with the aim of facilitating the disjunction phase, reducing synostosis points or large bone interdigitations, facilitating the opening of the suture with fewer days of activation. Once the opening of the suture is obtained, the expansion can be continued, avoiding the accumulation of force that precedes the disjunction, preventing the expander from being activated for a longer time which happens in more mature (older) patients. Thus, we have the advantage of activating more the expander screw before it reaches its limit and reduce the adverse effect of force accumulation on dental bone support structures (bone and gingival recession and tilting of the alveolar process). Corticopuncture performed in older patients favors earlier opening of the suture and greater use of the expander activation potential.

The regions above where expansion is necessary may also undergo alterations, such as zygomatic bone complex and frontonasal region [15,16] . In the current study we investigated points in the zygomatic and infraorbital bones and we find a small amount of expansion in them (mean values of 1.17mm for anterior zygomatic, 1.13mm posterior zygomatic and 1.12mm infraorbital regions). This increase was also greater in the group without perforation (3.16mm x 1.99, 2.80mm x 1.67 respectively). Specifically in the zygomatic bone region, anterior and posterior points were evaluated and it was observed that the opening in the anterior region was slightly larger (0.04mm). Ok et al.[16] studying conventional RME in growing patients showed that the distance between the left and right zygomatic bone was affected more on the anterior side than on the posterior side. This increase probably does not bring significant clinical differences, although changes in this direction have been reported in soft tissues[17]. However, studies on aesthetic perceptions in patients can be conducted to certify this statement. The superimposition of the 3D reconstructions (Figures 4 and 5) shows an opening pattern similar to that observed by Paredes et al.[11]. In their article, archial rotations of midcranial structures had the fulcrums located near to the frontozygomatic sutures, which explains the patters.

Together, these results of the current study showed that in cases where a parallel anteroposterior opening of the maxilla is desired, corticopuncture is indicated. However, if this parallelism is not necessary, conventional installation without perforation is indicated as it shows a greater amount of expansion and has fewer clinical steps. In addition, in the zygomatic and infraorbital bone regions, skeletal expansion is also observed after both MARPE techniques. More case-control studies are needed to confirm this finding.

Conclusion:

When corticopuncture of the midpalatal suture was performed, less amount of skeletal expansion was achieved with MARPE, however, better parallelism of the sutural opening was observed.

Tables

Table 1. Age (years) data according to gender and group (Inter-group)

	Without corticopuncture					With corticopuncture					Independent Samples T-Test		
Gender	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	Mean	SE	p
Female	16	20.9	5.5	15.0	34.0	15	30.1	5.7	19.0	39.0			
Male	9	20.2	4.9	15.0	30.0	4	32.5	5.3	27.0	37.0			
Both	25	20.6	5.2	15.0	34.0	19	30.6	5.5	19.0	39.0	10.0	1.6	**< 0.001**

Table 2. Description of the anatomical sites analyzed.

Anatomical Site	**Reference**
Anterior nasal spine (ANS)	analysis in axial section at the level of the palatal plane.
Posterior nasal spine (PNS)	analysis in axial section at the level of the mesial of the palatal plane.
Incisive foramen (IncFor)	analysis in axial section at the level of the palatal plane.
Middle nasal cavity (MNC)	analysis in coronal section at the level of the mesial of the maxillary first molars (floor of nasal cavity).
Posterior nasal cavity (PNC)	analysis in coronal section at the level of the posterior nasal spine (floor of nasal cavity).
Anterior and posterior zygomatic bone (AZ; PZ)	analysis in axial section where the zygomatic arches appeared to be thickest (according to the methodology of Furst et al.[18] 20019).
Infraorbital region (IO)	analysis in coronal section at the orbital center level.

Table 3. Effect of MARPE (T1-T0) expansion without and with corticopuncture measured in millimeters (mm). Intra group one sample t test and Inter group t test for independent samples.

	Without corticopuncture				With corticopuncture				Independent Samples t-test		
Variable	N	Mean (mm)	SD (mm)	p	N	Mean (mm)	SD (mm)	p	Mean	SE	p
ANE	25	5.18	2.83	**< 0.001**	19	3.57	1.99	**< 0.001**	1.61	0.76	**0.040**
PNE	25	3.59	1.75	**< 0.001**	19	3.26	1.98	**< 0.001**	0.34	0.56	0.554
IncFor	25	4.77	2.70	**< 0.001**	19	3.28	1.48	**< 0.001**	1.49	0.69	**0.036**
MNC	25	4.78	1.65	**< 0.001**	19	3.23	1.23	**< 0.001**	1.55	0.45	**0.001**
PNC	25	2.79	1.67	**< 0.001**	19	2.36	0.91	**< 0.001**	0.44	0.42	0.310
AZ	25	3.16	1.51	**< 0.001**	19	1.99	1.06	**< 0.001**	1.17	0.41	**0.006**
PZ	25	2.80	1.69	**< 0.001**	19	1.67	0.72	**< 0.001**	1.13	0.41	**0.009**
IO	25	2.43	1.37	**< 0.001**	19	1.32	1.16	**< 0.001**	1.12	0.35	**0.003**

Table 4. Parallelism between opening in the anterior and posterior regions measured in millimeters (mm). Comparison between variables according to the group without or with corticopuncture (paired samples t test).

Paired Samples		Without corticopuncture			With corticopuncture		
		Mean (mm)	SE (mm)	p	Mean (mm)	SE (mm)	p
ANE	PNE	1.59	0.69	**0.030**	0.31	0.65	0.635
MNC	PNC	1.99	0.32	**< 0.001**	0.88	0.34	**0.019**
AZ	PZ	0.37	0.49	0.460	0.32	0.19	0.100

Table 5. Correlation of variables with corticopuncture (0=without and 1=with corticopuncture)

Correlation Matrix	**Corticopuncture**	
	Spearman rho	p-value
ANE	-0.28	**0.062**
PNE	-0.14	0.368
IncFor	-0.30	**0.047**
MNC	-0.48	**<0.001**
PNC	-0.02	0.880
AZ	-0.45	**0.002**
PZ	-0.51	**<0.001**
IO	-0.54	**<0.001**

Table 6. Correlation of changes in the variables (T1-T0) with age

	Corticopuncture					
	Without		With		All sample	
Variable	Pearson's r	p-value	Pearson's r	p-value	Pearson's r	p-value
ANE	0.05	0.812	0.01	0.977	-0.19	0.217
PNE	0.09	0.660	-0.12	0.609	-0.07	0.648
IncFor	0.15	0.467	-0.24	0.331	-0.19	0.205
MNC	-0.11	0.615	-0.13	0.584	-0.39	**0.008**
PNC	0.01	0.967	-0.12	0.636	-0.13	0.410
AZ	-0.20	0.346	-0.19	0.446	-0.40	**0.007**
PZ	0.07	0.721	-0.09	0.701	-0.25	0.108
IO	-0.19	0.377	0.10	0.668	-0.36	**0.018**

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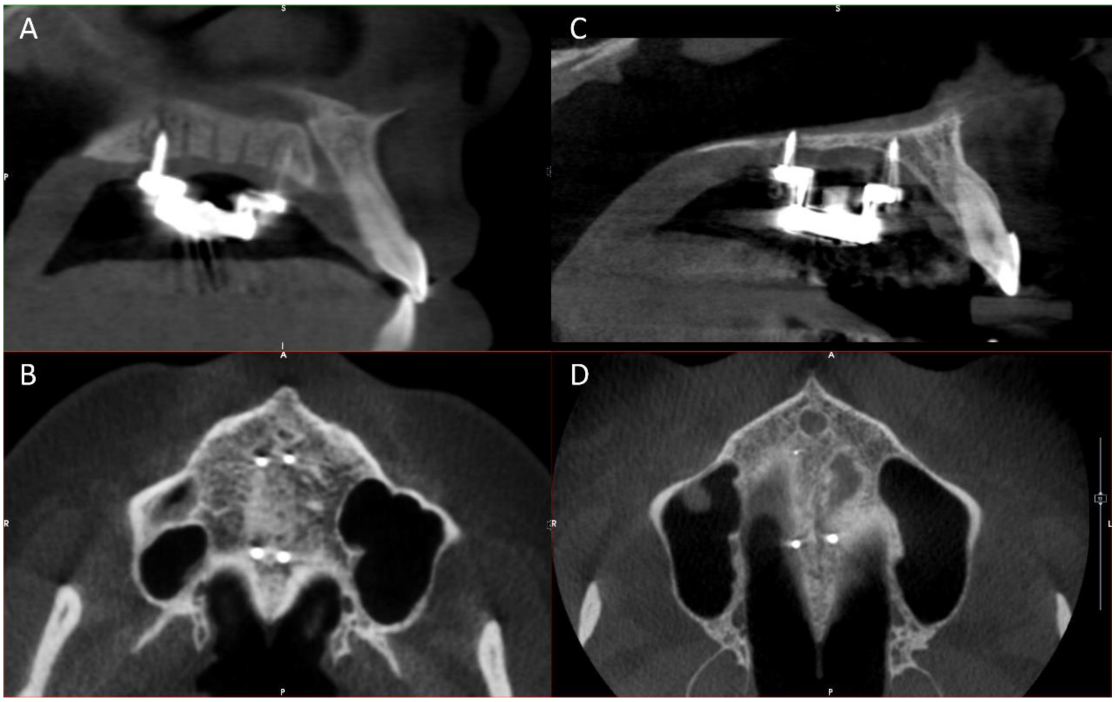
Figures

Fig 1. Cone beam computed tomography immediately after MARPE placement with corticopuncture of the midpalatal suture (A and B) and without corticopuncture (C and D).



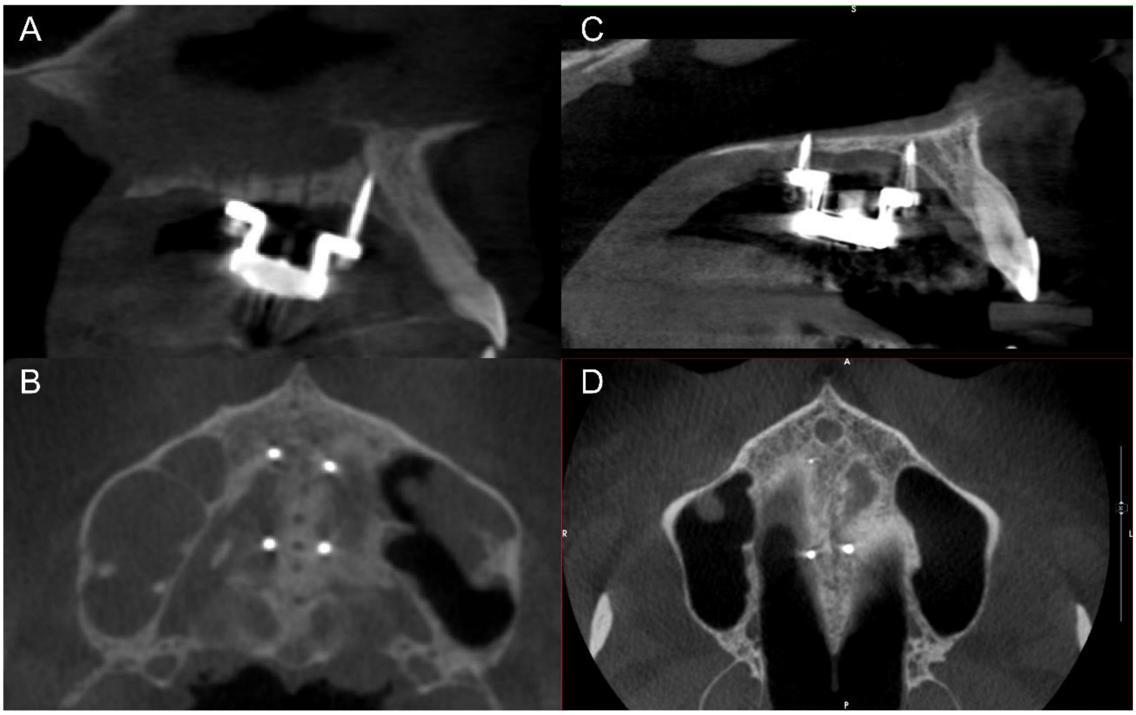


Fig 2. Bilateral landmarks in the evaluated regions: **A,** anterior nasal spine, incisive foramen and posterior nasal spine. **B,** middle nasal cavity. **C,** posterior nasal cavity. **D,** anterior and posterior zygomatic bone. **E,** infraorbital region.

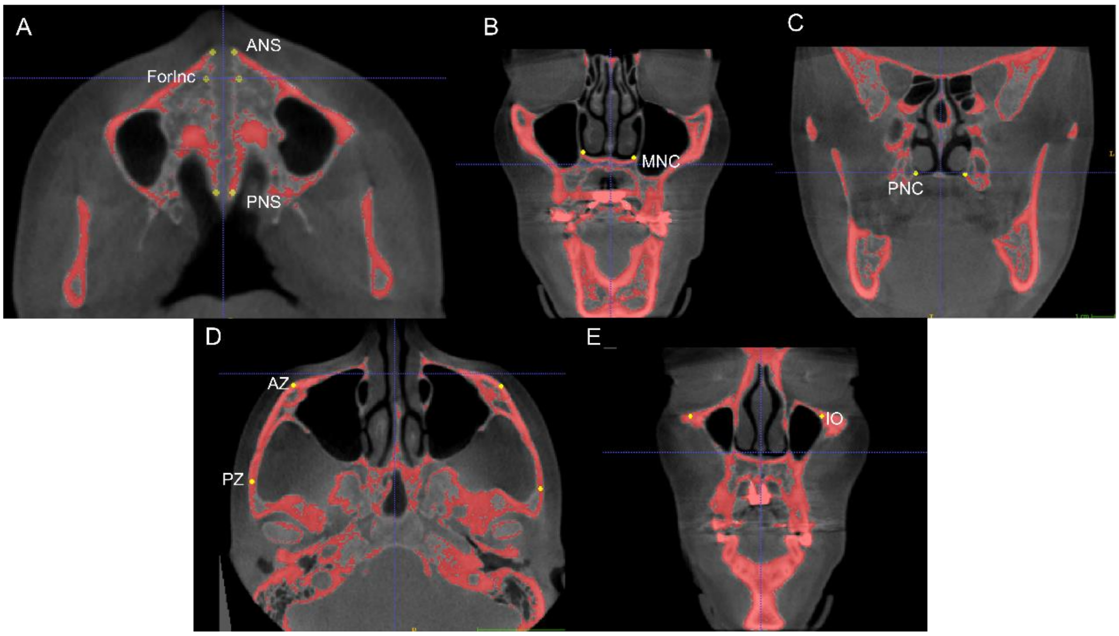


Fig 3. Scatterplots showing sample distribution in the correlation of variables with age.

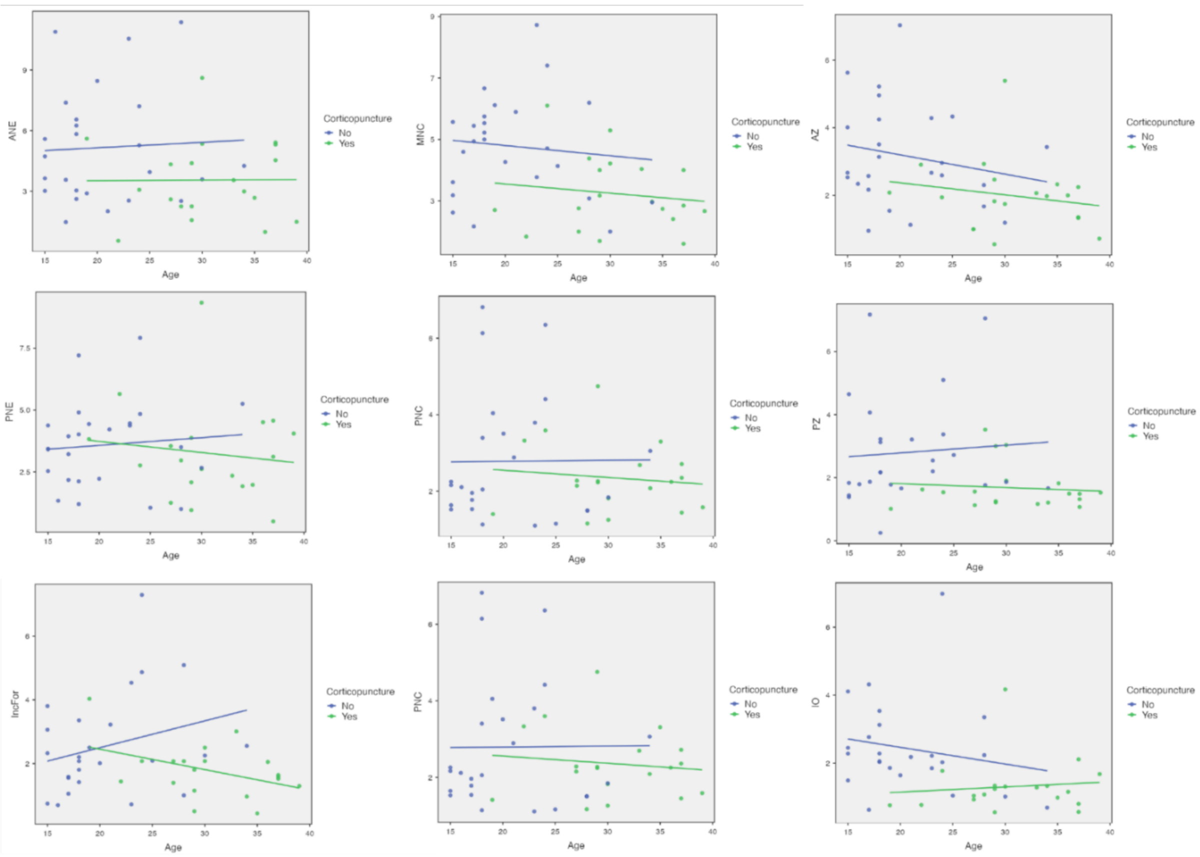


Fig 4. Superimposition of 3D reconstructions (T0-T1) of cases with corticopuncture of the midpalatal suture

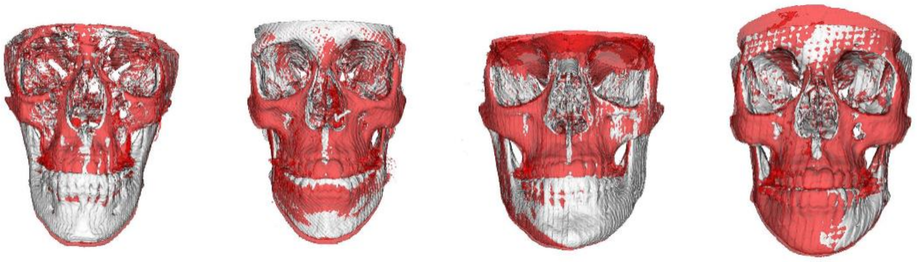


Fig 5. Superimposition of 3D reconstructions (T1-T0) of cases without corticopuncture of the midpalatal suture

3.2 ARTIGO 2*

Assessment of the maturation stage of the zygomatic-maxillary and pterygopalatine sutures as success factors for MARPE

Abstract

Introduction: The objective of this study was to evaluate if the success or failure of MARPE in patients with advanced bone maturation could be related to the maturational stage of the zygomaticomaxillary suture (ZMS), the height, thickness and angulation of the zygomatic bone and angulation of the pterygopalatine suture (PPS). Methods: CBCT of 70 individuals, both sexes, 15 to 52 years old, presenting transverse maxillary deficiency and complete skeletal maturation (CVMS stage V) treated using MARPE were evaluated. The success of MARPE was confirmed by the midpalatal suture (MPS) opening and failure when no opening or limited separation of MPS occurred. Data were analyzed using t-test for independent samples for differences in the variables of success and failure cases. ZMS maturation was based on Algelieri's study. Zygomatic bone height and angulation were measured in the same coronal slice where the coronal plane was aligned to a midline through the most superior aspect of the suture joining the nasal bones and the midline crest of the maxilla. Zygomatic bone width was the projection of the line that passes through center of both maxillary first molar teeth on the axial image. PPS angulation was evaluated in an axial section parallel to the palatal plane, at a level where it was possible to visualize in its greatest aspect. Results: Most cases were in stage C of ZMS maturation. None of the studied variables showed a statistically significant difference in the zygomatic region (height, thickness and angulation), as well as there was no relation between the success of MARPE with the ZMS maturation and angulation of the PPS. Conclusion: MARPE success was not related to the maturational stage of the zygomaticomaxillary suture, the height, thickness and angulation of the zygomatic bone and angulation of the pterygopalatine suture.

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Introduction

The renewed interest in the skeletal and sutural effects of rapid maxillary expansion (RME) stems from the introduction of three-dimensional radiographic techniques such as computed tomography, making it possible to verify the exact amount and location of bone remodeling and sutural structures after the expansion therapy. The most used sutural analysis in orthodontics was developed by Angelieri et al.[1], and is applied to evaluate possible effects of RME according to the different stages of the midpalatal suture maturation. However, it is now known that RME-associated skeletal remodeling is not strictly limited to the midpalatal suture [2,3].

The analysis of the sutures surrounding the midpalatal suture needs to be better applied in order to make the results of treatment with RME more predictable. To prevent undesirable dentoalveolar effects and optimize the potential of RME in older individuals, the mini-implant-assisted rapid maxillary expansion (MARPE) technique was proposed by Lee et al.[4] and it has already been used as a less invasive, clinically effective and stable approach for the non-surgical correction of maxillary transverse discrepancy in adult patients. [5]. However, even using MARPE, orthopedic maxillary expansion may not occur in some cases. Recent studies have tried to point the main factors for the success of the MARPE technique, with age and differences in palatal architectural patterns being the most associated so far [6,7].

The aim of this study was to investigate other factors that may be associated with the success or failure of MARPE, such as the maturational stage of the zygomaticomaxillary suture (ZMS), the height, thickness and angulation of the zygomatic bone and angulation of the pterygopalatine suture (PPS).

Materials and Methods

This study was approved by the ethics comitte of the São Paulo State University (UNESP), School of Dentistry, Araraquara, Brazil under protocol number 39233820.7.0000.5416. The sample of this retrospective controlled study included success and failure cases of MARPE treatment. Cone-beam computed tomography (CBCT) of 70 individuals, between 15 and 52 years old treated with MARPE were analyzed. Descriptive data regarding the age of the individuals in the sample are detailed in Table 1. The inclusion criteria were CBCT's before (T0) and after maxillary expansion (T1), of subjects presenting transverse maxillary deficiency with unilateral or bilateral posterior crossbite (a difference greater than 5 mm between the transverse distance of the palatal cusps of the first maxillary molars and the transverse distance of the first lower molars central sulcus) with complete skeletal maturation confirmed by examination of the cervical vertebrae. All subjects were in CVMS stage V of Hassel and Farman analysis modified by Baccetti, Franchi and McNamara [8]. Cases with previous orthodontic treatment, cleft lip and palate, and syndromic conditions were excluded.

MARPE Treatment

Patients were treated with MARPE using the same protocol previously reported by this research group[9].

CBCT scans before (T0) and after (T1) expansion were taken using the i-CAT Next Generation scanner (Imaging Sciences International, Hatfield, PA, USA) configurated for exposure time of 7 seconds with 120 kV. The tomographic images were acquired with a field of view of 23 X 17 cm and a voxel size of 0.3 mm^3. Data were exported in the digital image and communication in medicine (DICOM) format.

The success of the orthopedic maxillary expansion was confirmed by the opening of the medial palatine suture, verified in the tomographic examination, by the separation of the two halves of the palatine process after the activation period. Treatment failure was defined when the separation of the MPS was not observed in the tomographic examination. In cases on which moderate MPS separation was observed anteriorly but the posterior portion of the palate did not show significant changes (≤ 1.0 mm), it was considered a limited result and it was included as a failure of the technique. Maxillary changes were obtained by the difference of the linear measurements achieved (T1-T0) as reported previously[9].

Maturational Stage of the Zygomaticomaxillary Suture:

This analysis follows the protocol proposed by Angelieri et al.[10]. It was performed using RealGUIDE 5.1™ software in the pre-expansion CBCTs. The interpretation is made by rolling the tomographic sections because this suture is tortuous. There are 5 possible classifications (A, B, C, D or E) going from lowest to highest interdigitation state.

Height, thickness and angulation of the zygomatic bone:

These standardized measures were based on the work of Furst et al.[11] and Kamburoglu et al.[12] and were performed at the RealGUIDE 5.1™ software in the pre-expansion CBCTs.

For zygomatic bone height, the coronal plane was aligned to a midline through the most superior aspect of the suture joining the nasal bones and the midline crest of the maxilla. A second line perpendicular to the first was aligned on the grid through the most superior aspect of the superior orbital rims. This was referred to as the horizontal reference line (Figure 1A). The angulation was measured on the same slice. This angle is formed by a plane passing through the floor of the nasal cavity and another through the center of the frontozygomatic suture (Figure 1B). In some CT scans, it was not possible to perform these measurements because the field of view (FOV) was reduced and the region of interest did not appear.

The zygomatic bone width was the projection of the line that passes through center of both maxillary first molar teeth on the axial image (Figure 2).

Angulation and opening of the pterygopalatine suture:

The angulation was evaluated in the pre-expansion CBCTs in an axial section parallel to the palatal plane, at a level where it was possible to visualize the PPS in its greatest aspect (Figure 3). The opening of this suture was analyzed by comparing the pre- and post-expansion CBCTs by rolling the axial slices parallel to the palatal plane (Figure 4). These assessments were made in the ITK snap software, version 3.8.

Statistical Analysis:

A priori power analysis for two-tailed, independent two-sample t-test (N1=22 and N2= 44), effect size of 0.85 and alpha of 0.05 give a power of 0.894 (*jamovi* 2.3 Computer Software 2022 Retrieved from https://www.jamovi.org).

To determine the intra-examiner error calculation, all scans were re-analyzed, randomly by the same examiner, with a two-week interval (at least) between the first and second evaluation. The reproducibility of the method was evaluated using the

Intraclass Correlation Coefficient (ICC) and t-test for repeated measures (systematic error evaluation) for all measures used in this study.

In order to verify the normality of the data, they were submitted to the Shapiro-Wilk test. Mean and standard deviation were calculated for the variables with normal distribution. Median and confidence intervals at 95% probability were calculated for the variables that did not exhibit a normal distribution. Data were analyzed using the t-test for independent samples to evaluate differences in the variables between cases of success and failure of the maxillary expansion.

The correlation of the success of the maxillary expansion according to the maturational stage of the zygomaticomaxillary suture, the height, thickness and angulation of the zygomatic bone, angulation and opening of the pterygopalatine suture were observed using the Pearson correlation test.

The level of significance adopted for the rejection of the hypotheses examined was 0,05. The calculations for the statistical analysis were performed by the SPSS program - version 16.0 for Windows (release 16.01 - nov. 2007). SPSS Inc. 1989-2007.

Results:

To determine the intra-examiner error, all scans were re-analyzed, randomly by the same examiner, with a two-week interval (at least) between the first and second evaluation. The Kappa test was used to evaluate the consistency of the evaluation of the Zygomatic Maxillary (ZM) sutural maturation and the effect of the Marpe on the Zygomatic Maxillary (ZM) and Pterigo Palatine (PP) sutures. Intraclass correlation coefficient (ICC), complemented by a paired t-test, was used to evaluate the quantitative method reliability.

The Kappa test was greater than 0.96 (SE 0.03) indicating excellent intra-examiner reproducibility for ZM classification and for the effect of Marpe on ZM and PP sutures. The reliability of the measurements was confirmed by the intraclass correlation coefficients ICC greater than 0.90 and Cronbach Alfa greater than 0.94 (Confidence interval: Lower > 0.82 and Upper > 0.93) Complementary t tests for paired samples applied to replicate measurements showed mean differences less than 0.09mm and 0.17 degrees, evidencing acceptable and very low systematic error and indicating excellent intra-examiner reliability.

When comparing the success and failure groups, none of the studied variables showed a statistically significant difference in the zygomatic region (height, thickness and angulation), as well as there was no relation between the success of MARPE with the angulation of the pterygopalatine suture (Table 2).

Regarding the maturation stage of the ZMS, most cases were in stage C, on both left and right sides, followed by stages E and D (Table 3 and Figure 5). This variable also showed no significant relationship with the success or failure of MARPE.

Concerning the rupture or not of the PPS, most openings were observed in cases of success with 21.3% of success cases opening in the right side and 14.9% in the left side (Table 4 and Figure 6). Opening of this suture was not observed in cases of failure. Association of the PPS opening with the success or failure of MARPE technique showed a significant result only on the right side ($p=0.017$), the left side had a p-value of 0.051.

Discussion

To achieve success in maxillary expansion, the search for the exact point where the fulcrum of maxillary movement occurs remains with several works pointing to different regions [13–17], what these works have in common is the fact that zygomaticomaxillary articulation and the pterygoid plates are pointed as primary sources of increased resistance to maxillary expansion. Cantarella et al.[16] studying changes in the zygomaticomaxillary complex after expansion with miniscrew-supported maxillary expansion concluded that the center of rotation for the zygomaticomaxillary complex was located near the proximal portion of the zygomatic process of the temporal bone, more posteriorly and more laterally than what has been described in the literature for tooth-borne expanders. They also report a significant “bone bending” happening in the zygomatic process of the temporal bone during the expansion. In other words, not only the maxilla but the zygomatic bone and the whole zygomatic arch present displacement in a lateral direction, after expansion treatment with skeletal anchorage [16]. In the present study, we evaluated some measurements in pre-expansion CBCt’s of the zygomatic bone at the coronal level (its height and angle with the maxilla) and at the axial level (thickness) in order to verify whether there is any influence of these variables on the success of MARPE. However, we did not observe a statistically significant relationship.

Previous findings indicated that the zygomatic bone complex resists to RME forces, and that RME increases cellular activity in the region of the ZMS [2]. In addition, displacement of sutures and rotation have already been observed after expansion in this region [13]. It has been suggested that the ZMS evaluation could be helpful in predicting individual response to maxillary protraction forces applied to growing Class III cases [10]. Ok et al. [18] analyzed the maturation stage of ZMS, midpalatal suture (MPS), the and the closure degree of the spheno-occipital synchondrosis (SOS) in 312 individuals between 7 and 30 years of age aiming to check whether there is a correlation between maturation stages of these structures. In their sample, for ranges between 14-30 years old, the most common stages for ZMS were E (158), D (33) and C (23). These results are similar to our sample where stages E (20), D(25) and C(43) of maturation were the most observed in the ZMS's analysed. They found a simultaneous progress of the maturation of SOS, MPS, and ZMS and concluded that late or early maturation of one of these anatomic units could be a useful parameter to predict the individual outcomes in response to orthopedic force applications. Perhaps evaluating the maturation of this suture could also help us to predict the success of the MARPE technique. However, in the present study, no relationships were found.

The literature discuss the role of pterygopalatine suture in preventing posterior expansion, stating that this suture may cause restricted mobility of the maxillary segment in LeFort I osteotomies [19], limits the amount of expansion and dictates the pattern of expansion with RPE [20]. In the present article, the opening of this suture was evaluated and we observed its opening in different patterns in the successful cases, some cases with unilateral opening, others with disarticulation between medial and lateral pterygoid plates on both right and left pterygopalatine suture (Figure 4) and the absence of opening in the failure cases (which was already expected). Other studies analyzing CT scans after expansion with skeletal anchorage had already reported this finding and related it to a more parallel opening of the MPS [21,22]. Colak et al. [21] assessed the MPS opening and the pterygopalatine suture disarticulation pattern in the tomographic axial plane after expansion with skeletal anchorage and suggested that if the pterygopalatine suture direction was parallel with the rotational movement of maxilla, the disarticulation of this suture would not materialize as the opening on axial cuts. Based on this suggestion, in the current article we decided to test the hypothesis that the angulation of this suture can interfere with the success of the opening (a smaller angle would be less favorable since the suture would be positioned more parallel to the maxillary movement). However, the average of this angle in our sample was smaller (25.53° in cases of success against 28.80° in cases of failure) and no statistically significant differences were found that would indicate the sutural angulation as important for success in the MARPE technique. More studies should be performed to try to understand this difference in the opening pattern of these sutures, and how this influences the success of the MARPE technique, whether it is related to some facial asymmetry of the individual, with the proximity of the miniimplants or the expander screw to this suture, among other possibilities.

Moreover, a research investigating the relationship between circummaxillary sutures and MARPE success in adult male patients showed that greater circummaxillary suture widths before MARPE expansion, especially ZMS and PPS, resulted in a better chance of successful suture separation and more maxillary expansion. ZMS presented 0.36mm of difference and PPS 0.18 mm post-expansion [17].

The retrospective design of the present study where a convenience sample was used is a limitation that undermines the ability to make generalizations to the population of interest. Also, the amount of expansion was adapted and not standardized for each patient. Nevertheless, the activation protocol was standardized for all subjects overcoming these limitations.

Conclusion

In conclusion, factors such the maturational stage of the zygomaticomaxillary suture, the height, thickness and angulation of the zygomatic bone and angulation of the pterygopalatine suture were not significantly related to MARPE success.

Tables

Table 1. Sample description: age according to the effect (success or failure) of the Marpe procedure.

	Age in years				
Efficiency	N	Mean	SD	Min	Max
Failure	23	33.1	9.9	17	52
Success	47	25.6	8.1	15	50

Table 2. Height. thickness and angulation of the zygomaticomaxillary suture and angulation of the pterygo-palatine suture in cases of success and failure in the Marpe procedure.

		Success			Failure			Difference				
Suture	Variable	N	Mean	SD	N	Mean	SD	Mean	SE	Student's t	df	p
Zygomatic Maxillary	Height Right (mm)	34	43.58	3.11	17	44.51	4.33	0.94	1.06	0.886	49	0.380
	Height Left (mm)	34	43.53	2.43	17	43.88	4.00	0.34	0.90	0,378	49	0.707
	Height (mm)	34	44.57	2.62	17	44.19	4.04	0.64	0.94	0.681	49	0.499
	Thickness Right (mm)	46	7.37	1.36	22	7.16	1.64	-0.21	0.38	-0.558	66	0.579
	Thickness Left(mm)	46	7.11	1.31	22	6.85	1.57	-0.26	0.36	-0.707	66	0.482
	Thickness (mm)	46	7.24	1.29	22	7.01	1.59	-0.23	0.36	-0.647	66	0.520
	Angulation Right (degrees)	34	100.18	3.44	17	100.29	3.33	0.12	1.01	0.111	49	0.912
	Angulation Left* (degrees)	34	99.56	2.85	17	101.10	3.97	1.54	0.97	1.595	49	0.117
	Angulation (degrees)	34	98.87	2.57	17	100.69	3.29	0.83	0.84	0.986	49	0.329

Pterygo-palatine	Angulation Right (degrees)	47	25.20	7.72	23	28.44	7.19	3.24	1.92	1.684	68	0.097
	Angulation Left (degrees)	47	25.85	8.55	23	29.17	8.10	3.32	2.14	1.552	68	0.125
	Angulation (degrees)	47	25.53	7.45	23	28.80	6.45	3.28	1.82	1.804	68	0.076

* Levene's test is significant (p < .05) suggesting a violation of the assumption of equal variances

Table 3. Cross table of the relation of the zygomatico maxillary suture maturation and the effect of the Marpe (success or failure)

Maturation	Failure (N=22)	Success (N=46)	Total (N=68)
Right side			
B	0 (0.0%)	2 (4.3%)	2 (2.9%)
C	10 (45.5%)	21 (45.7%)	31 (45.6%)
D	3 (13.6%)	15 (32.6%)	18 (26.5%)
E	9 (40.9%)	8 (17.4%)	17(25.0%)
Pearson's Chi-squared test		**p value**	0.099[1]
Left side			
B	0 (0.0%)	2 (4.3%)	2 (2.9%)
C	8 (36.4%)	22 (47.8%)	30 (44.1%)
D	4 (18.2%)	10 (21.7%)	14 (20.6%)
E	10 (45.5%)	12 (26.1%)	22 (32.4%)
Pearson's Chi-squared test		**p value**	0.359[1]

Table 4. Cross table of the Marpe effect (success or failure) in the pterigo palatine suture

opening	Failure (N=23)	Success (N=47)	Total (N=70)
Right side			
Did not open	23 (100.0%)	37 (78.7%)	60 (85.7%)
Opened	0 (0.0%)	10 (21.3%)	10 (14.3%)
Pearson's Chi-squared test		**p value**	0.017[1]
Left side			
Did not open	23 (100.0%)	40 (85.1%)	63 (90.0%)
Opened	0 (0.0%)	7 (14.9%)	7 (10.0%)
Pearson's Chi-squared test		**p value**	0.051[1]

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Figures

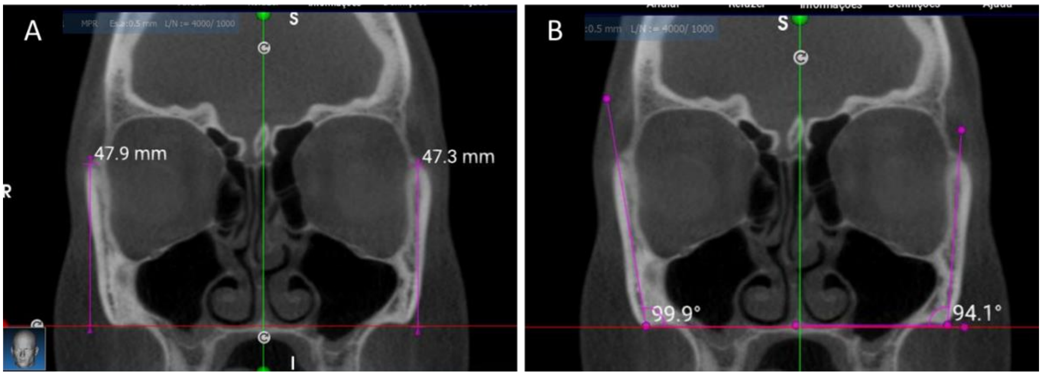

Fig 1. Coronal view sections to measure the height **(A)** and angulation **(B)** of the zygomatic bone on the right and left sides.

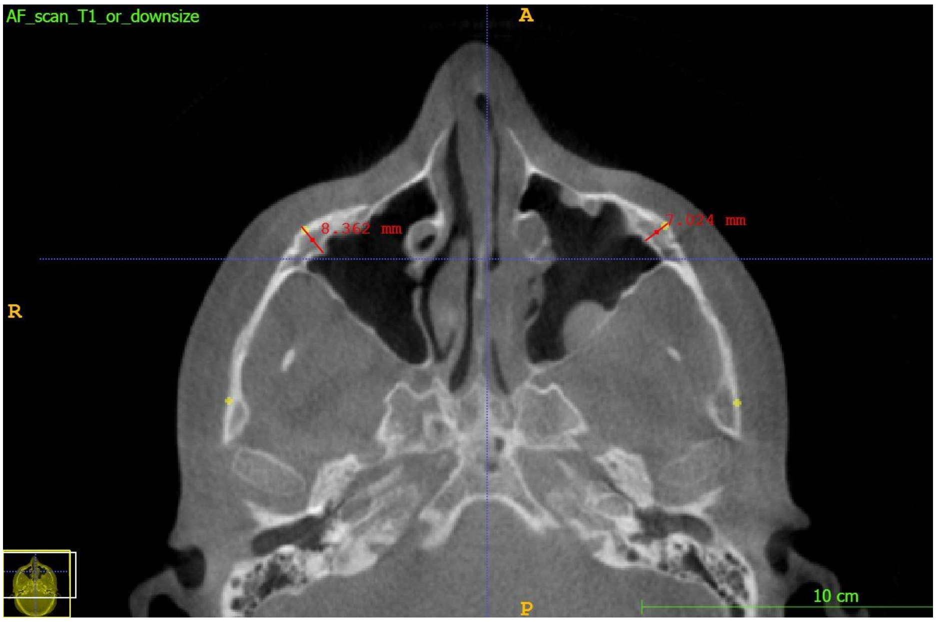

Fig 2. Section in the axial view showing the measurement of the thickness of the zygomatic bone on the right and left sides.

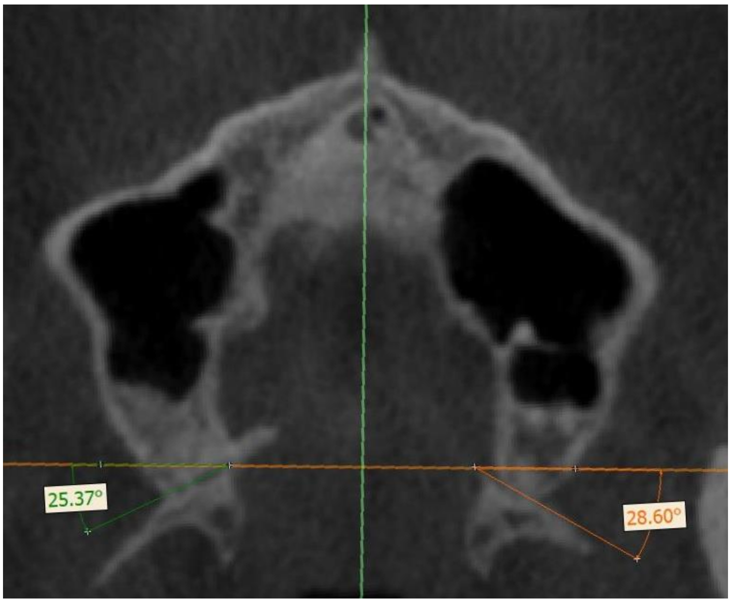

Fig 3. Axial view section showing the measurement of the pterygopalatine suture angulation on the right and left sides.

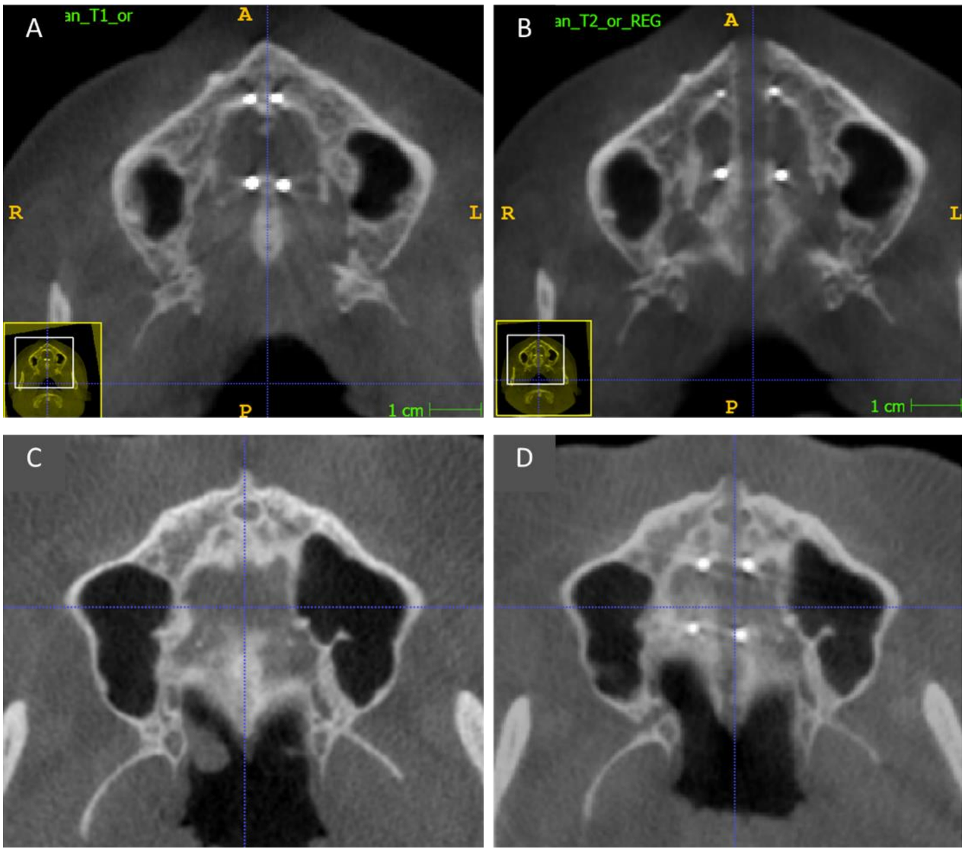

Fig 4. Axial view sections showing rupture in the pterygopalatine suture region. **A,** pre-expansion case; **B,** post expansion with bilateral ruptures of the pterygopalatine suture; **C,** pre-expansion case; **D,** post expansion showing unilateral rupture of the pterygopalatine suture.

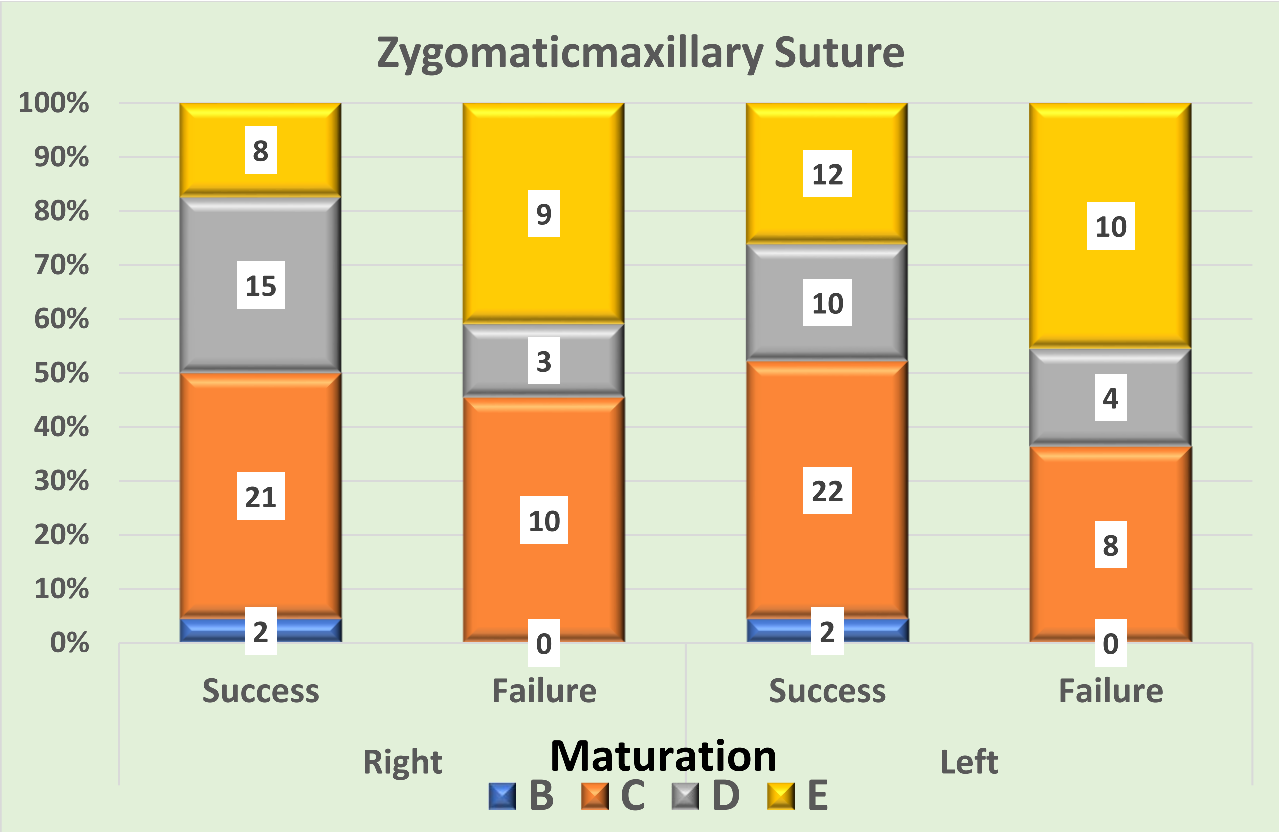

Fig 5. Graph showing the distribution of the of Zygomatic Maxillary Suture maturational stages in the sample.

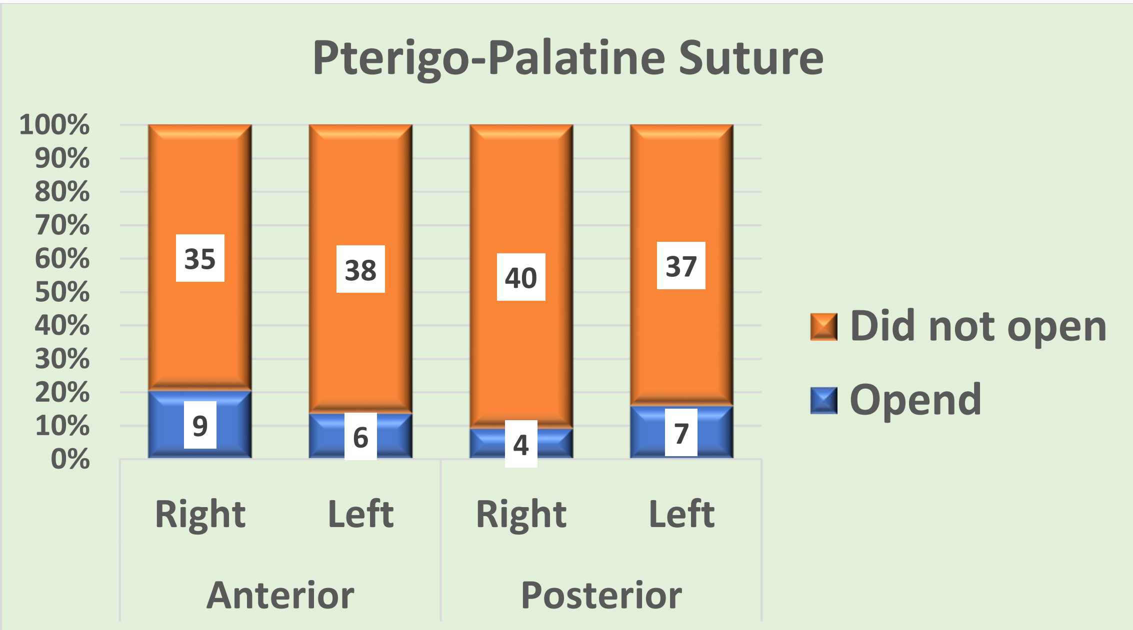

Fig 6. Graph showing the distribution of the opening of the pterygopalatine suture in the sample.

3.3 ARTIGO 3*

Complications associated with MARPE: Series of case reports and conduct guidelines

Abstract

The aim of this article is to report a series of cases where rapid palatal expansion was performed with MARPE and complications arose during the treatment. Five cases were included in this report where two had mucosal inflammation and hyperplasia, one had occlusal changes due to unevenness and two had sutural opening failure. One last case where the expansion technique was completely successful without complications by changing the activation protocol. From the management of the cases, the authors suggest that an optimal hygiene protocol for MARPE patients should be better established to prevent the formation of lesions and inflammation; the frontonasal suture can rupture during MARPE expansion causing asymmetrical expansion and unevenness on the side where the rupture occurred; in patients with a thin palatal thickness combining the corticopuncture method and changing the activation protocol to just ¼ of a turn per day (0.25mm) can help weaken the midpalatal suture and promote its rupture.

Keywords

orthodontics, malocclusion, palatal expansion technique, complications

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* Artigo escrito conforme as normas bibliográficas da revista *Journal of Orthodontics* para a qual será submetido.

Introduction

Rapid palatal expansion (RPE) has been used for many years effectively as a treatment for transverse maxillary discrepancies. In adult patients, the reason for the conventional RPE failures may be due to greater rigidity in craniofacial structures in skeletally mature patients[1]. In these cases, surgically assisted rapid maxillary expansion (SARPE) was the most indicated option. Unfortunately, this treatment is often rejected because it is an invasive surgical procedure, with risks and high costs for the patient[2].

In 2010, Lee et al.[3] introduced MARPE (Miniscrew-Assisted Rapid Palatal Expander), launching the concept of bone anchorage for expanders, promoting better control of posterior tooth inclination. Furthermore, in this type of device, the midpalatal suture opens in a more parallel and homogeneous way compared to SARPE technique[4,5].

Technological advances have led to changes in the evaluation method of the effects of RPE, going from 2D to 3D and from linear and angular to volumetric approaches. The use of computed tomography (CT) and, later, cone beam (CBCT) has been of great interest and helps clinicians to acquire 3D images and object reconstructions in order to improve diagnoses and individualize treatments to optimize results[6]. This has been happening with MARPE treatment. With CBCT, planning the best position of the expander screws in the vertical and horizontal direction, position and size of miniscrews, amount of bone and soft tissue available, possibility of bicorticalization and different activation protocols have been studied and proposed to optimize the results of the technique[7–10].

However, even using MARPE and with digital planning, orthopedic maxillary expansion may not occur in some cases. It is still unclear why few cases fail, but recent studies point to age and differences in palatal architectural patterns as the main factors for greater resistance[11]. Furthermore, during the expansion process, some complications may arise, making the procedure difficult or leading to failure. Few studies or case reports comment on these complications[7,12] or indicate how they can be managed.

The aim of this work is to present a series of cases where complications arose during therapy with MARPE, some leading to the failure of the technique and to show some clinical approaches that were taken. Lastly, report a case of success in the disjunction with a differentiated opening protocol.

Material and method

In these reports, we show 5 cases and analyzed some complications that could arise during miniscrew-assisted rapid palatal expansion. One last case where the expansion technique was completely successful without complications was reported at the end.

For a better organization, the complications were separated in sections: Mucosal Inflammation and hyperplasia, occlusal changes and sutural opening failure.

All patients in the reports underwent cone beam computed tomography (CBCT) examination before the treatment aiming to establish the best anatomical place to insert de device, select size of miniscrews and the degree of suture maturation. They were treated by orthodontists in their private clinics or were part of research samples of MARPE studies. Information regarding signs and symptoms were retrieved from medical record.

Mucosal Inflammation and hyperplasia

Case 1

Female patient, 19 years old presenting unilateral crossbite. Before initiating fixed orthodontic therapy with braces, a RPE procedure was indicated. The device used was a 11-mm jackscrew expander and 4 miniscrews (7x4 mm anterior and 5x4 mm posterior) inserted paramedian to the midpalatal suture (Peclab, Belo Horizonte, Minas Gerais, Brazil). Activation protocol was ¼ turns twice a day (0.5mm per day). After 5 days of installation and activation, the patient reported difficulty in cleaning the region and formation of "yellow dirt" around the device.

In the clinical evaluation by the dentist, a yellow conglomerate was observed in the MARPE region of slightly calcified consistency (Figure 1A). When questioned, the patient confirmed that the rapid formation of calcifications in her teeth was common, especially in the antero-inferior region. The yellow mass was removed and the cleaning orientation of the region was reinforced. Pressure irrigation of the region with saline solution constantly and the application of 2% chlorhexidine gel three times a day during 2 weeks around the miniscrews were also prescribed. Until this moment, none of the miniscrews had mobility and the expansion process was not interrupted. 13 days after installation, the midpalatal suture had opened, the posterior crossbite solved and the device was locked (Figure 1B). After 3 months, during the device's containment period, due to careless hygiene in the region, the calcifications were not being removed, the two anterior miniscrews showed great mobility and were removed. In addition, the patient complained of discomfort in the region of the posterior miniscrews where an increase in volume with a reddish color and soft consistency was observed (Figure 1C).

Other cleaning sessions were performed during the retention period and it was decided to maintain the expander device. The lesion diminished and after 6 months since installation the device was removed (Figure 1D). The patient continued her orthodontic treatment and the region with increased volume gradually decreased until disappearing. Figure 1E shows the patient's palate 2 months after device removal with small points of scars in the regions where the miniscrews were. The patient's occlusion remained stable in the posterior region and there was no significant recurrence of crossbite or even edge-to-edge occlusion.

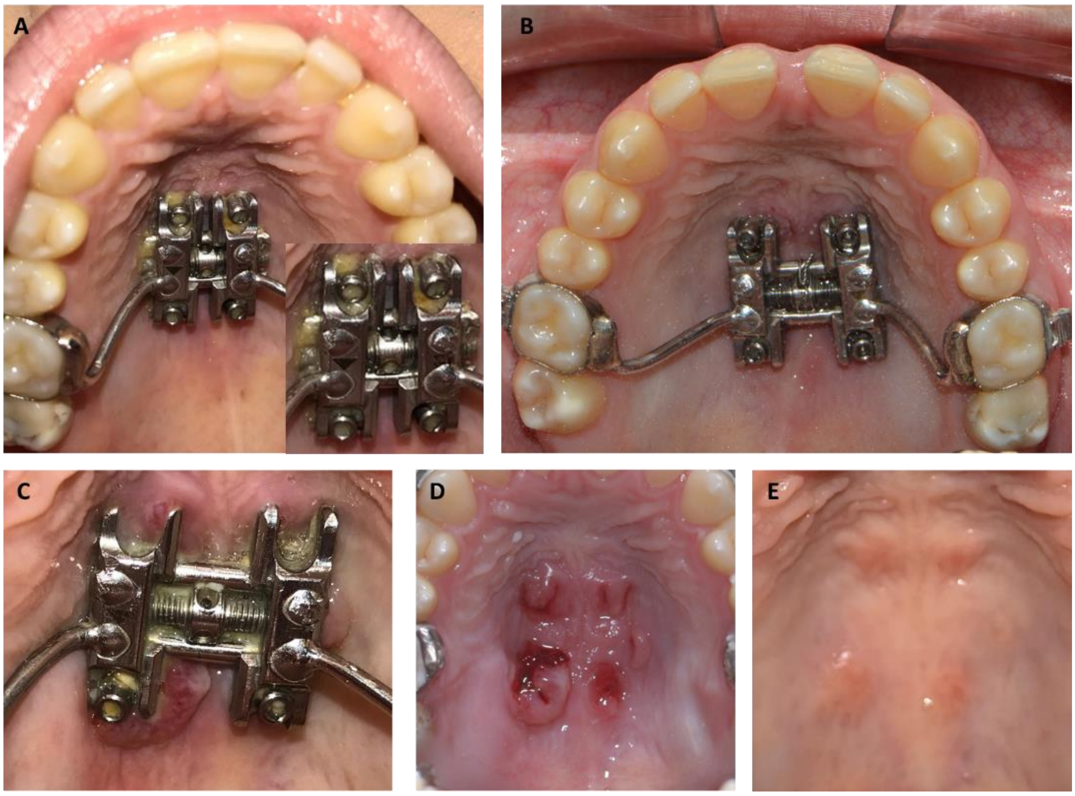

Fig 1. Formation and healing of a hyperplastic lesion on the palate during MARPE: **A,** Calcified yellow dirt around the device during activation of the jackscrew. **B,** Aspect of

the case on the day of jackscrew locking, interincisive diastema attesting to the success of the disjunction. **C,** During the containment phase of the expansion, 2 anterior mini-implants were lost and a hyperplastic lesion was formed around a posterior mini-implant. **D,** Palate aspect on the day of MARPEs' removal after 6 months of containment. **E,** Aspect of the palate 2 months after MARPE removal, small points of scars in the region of the miniscrews.

Case 2

A female patient 23 years old with main concern of crossbite and mild dental and skeletal Class III. CBCT sagittal cross-sectional show both midpalatal suture and paramedian thickness and demonstrated thin palatal bone thickness on both regions (Figure 2).

For transverse maxillary correction, micro-implant assisted rapid palatal expansion device was planned that included a rigid 11mm jackscrew and 4 miniscrews (MSE, Biomaterials Korea, South Korea) inserted paramedian to the midpalatal suture.

MARPE installation procedure started with local anesthesia at the greater palatine nerve. MARPE device was placed as well as four 1.8 diameter and 11 length miniscrews (MSE, Biomaterials Korea, South Korea) (Figure 3A). Activation protocol involved 2 turns (0.13mm per turn) four times a day for a total of 20 days.

After 20 days of activation, no diastema was observed between incisors (Figure 3B). MSE was left in position as anchorage for Class III elastics for total distalization of the lower arch for the following 5 months. Hereafter, one day patient visit the office for an urgent appointment saying that an inflammation took place around the miniscrews and expander (Figure 3C). Patient reported presenting a diagnosis of sinusitis at the hospital with the following symptoms: facial pain, headache, nasal congestion, fever and pain around posterior teeth and at the palatal area. Patient was medicated with antibiotics and analgesics.

After local anesthesia, expander and miniscrews were removed (Figure 3D). Fixed appliance was bonded on the upper arch and compensatory dental expansion using Mulligan overlay wire, since patient refused to undergo surgically assisted rapid palatal expansion (Figure 4A). Healing of the palatal mucosa was observed during the following months, so that full recover was observed by the end of treatment (Figure

4B).

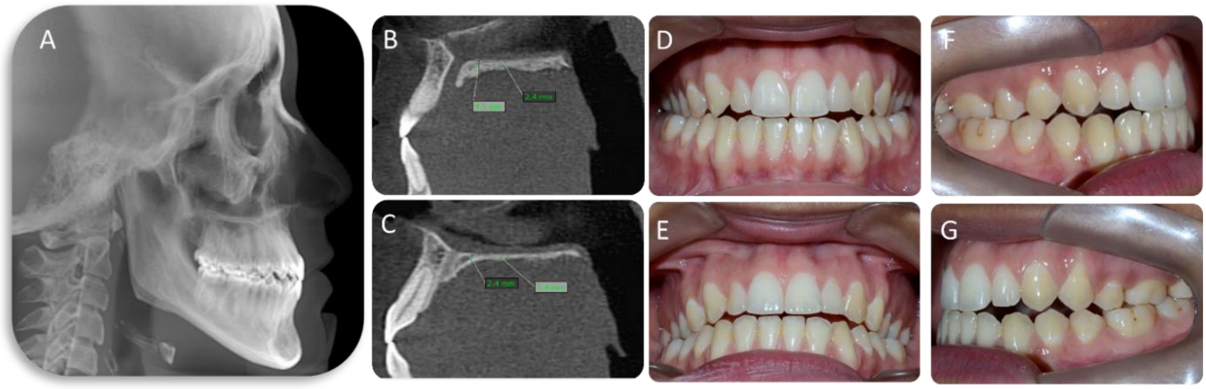

Fig 2. Pre-treatment documentation: **A,** lateral xray. **B,** sagittal section of the maxilla from the midpalatal suture region with bone thickness measurements. **C,** sagittal section of the maxilla from the paramedian region with bone thickness measurements. **D,E,F,G** patient’s intraoral clinical pictures.

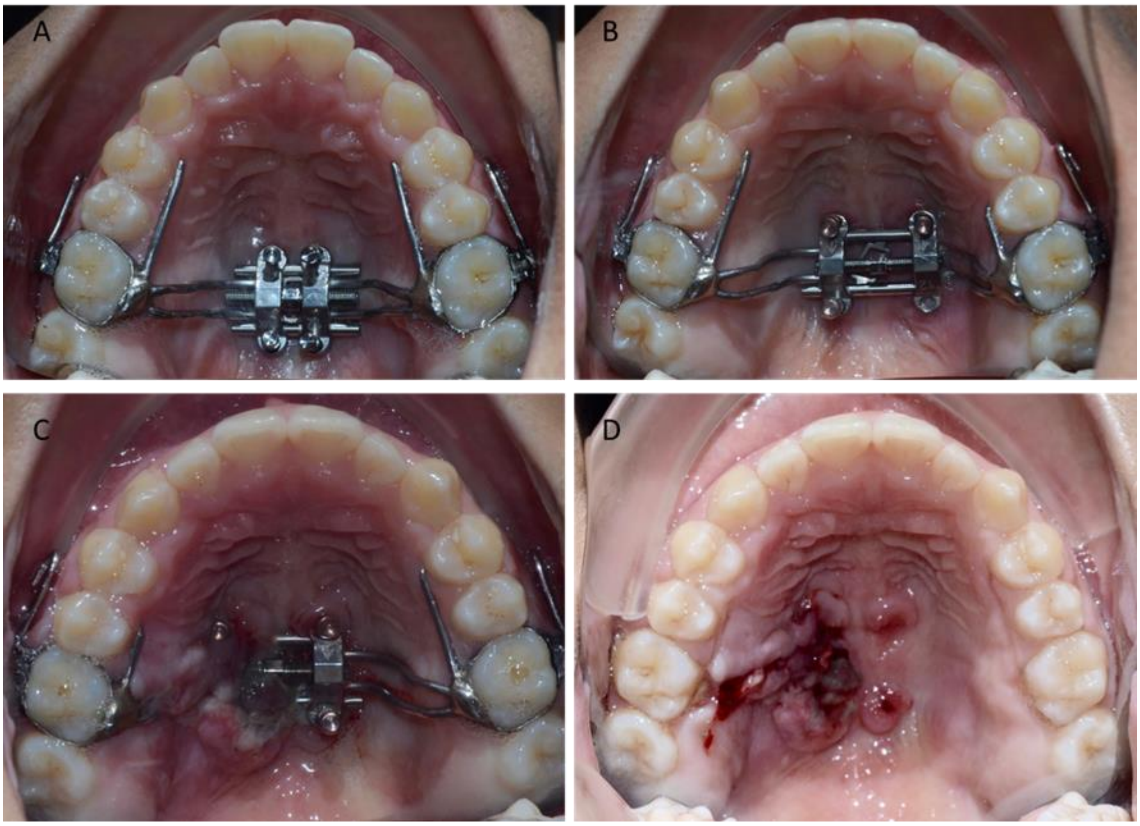

Fig 3. Formation of inflammation and mucosal damage during MARPE therapy accompanied by sinusitis. **A,** MARPE immediately after installation**. B,** MARPE after 20 days of activation without suture opening sign. **C,** Palatal mucosa irritation during treatment, patient diagnosed with sinusitis. **D,** Palate mucosa aspect immediately after MARPE removal.

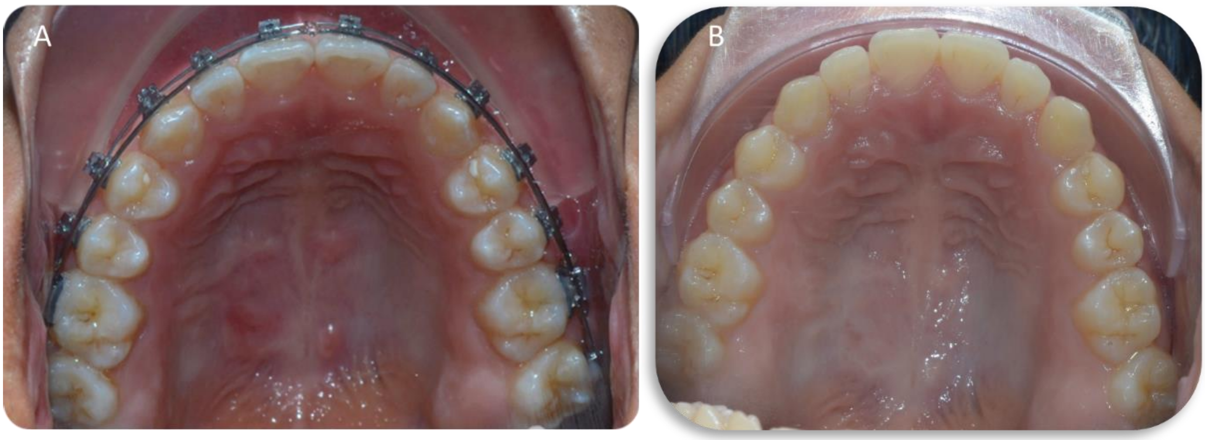

Fig 4. Post MARPE Removal Photos. **A,** after remission of the lesion, a Mulligan overlay wire was used to continue the treatment. **B**, the palatal mucosa healed completely after MARPE removal.

Occlusal changes

Case 3

A 28-year-old female patient sought orthodontic treatment to improve her smile and dental occlusion. The patient had a bilateral crossbite and maxillary discrepancy (Fig 5 A and B). The initial treatment planning proposed was MARPE as an alternative to surgical maxillary expansion to correct the transverse maxillary discrepancy.

The maxillary expansion was performed by a 11-mm jackscrew expander supported by 4 miniscrews (size 1.8 mm in diameter, transmucosal of 4 mm and 7 mm thread length for anterior and posterior miniscrews with 5 mm of thread length) from Peclab® (Belo Horizonte, Minas Gerais, Brazil) as show in Fig 2C. The activation protocol applied was 2/4 of a turn daily, being 1/4 in the morning and 1/4 in the night (0.5mm per day) until the correction of the transverse discrepancy.

After 22 days of activation, the presence of a diastema was clinically observed (Fig 5D) and correction of the crossbite was partially solved. We can highlight an asymmetric maxillary expansion with crossbite correction on the left side and end-to-end incisor relationship of the molars on the right side (Fig 5E). There was an asymmetric skeletal opening resulting in a step in the occlusion plane, however without repercussions on the face. This asymmetry arose because there was rupture of the frontonasal suture only on the left side, as observed in 3D reconstruction of tomography image (Fig 6 A and B). In the axial cuts of the tomography, the asymmetrical sutural opening can also be observed (Fig 6 C and D).

In the absence of facial complications, the approach adopted was the correction of the step in the occlusal plane and the improvement of the posterior teeth relationship on the left side by means of intermaxillary cross elastic, which only produces a unilateral dental effect (Fig 2F).

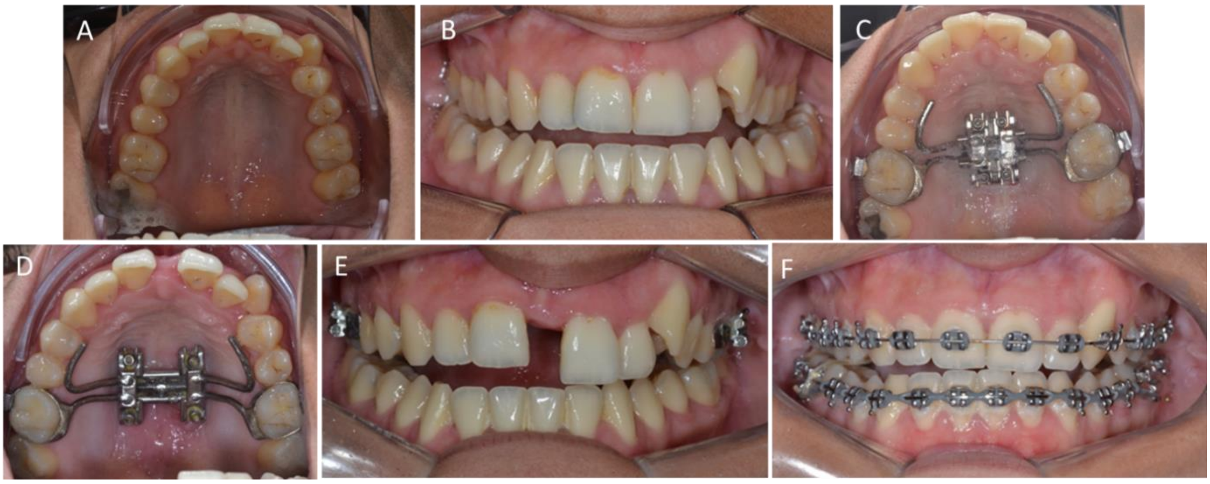

Fig 5. Clinical sequence of expansion attempt with MARPE: **A,** initial upper occlusal photo. **B,** initial occluding photo showing the bilateral posterior crossbite. **C,** MARPE immediately after installation. **D**, occlusal photo 22 days after installation, diastema demonstrating sutural rupture. **E,** occluding photo showing an asymmetric maxillary expansion. F, Finalizing the case with the remaining transverse correction being made with crossed elastics.

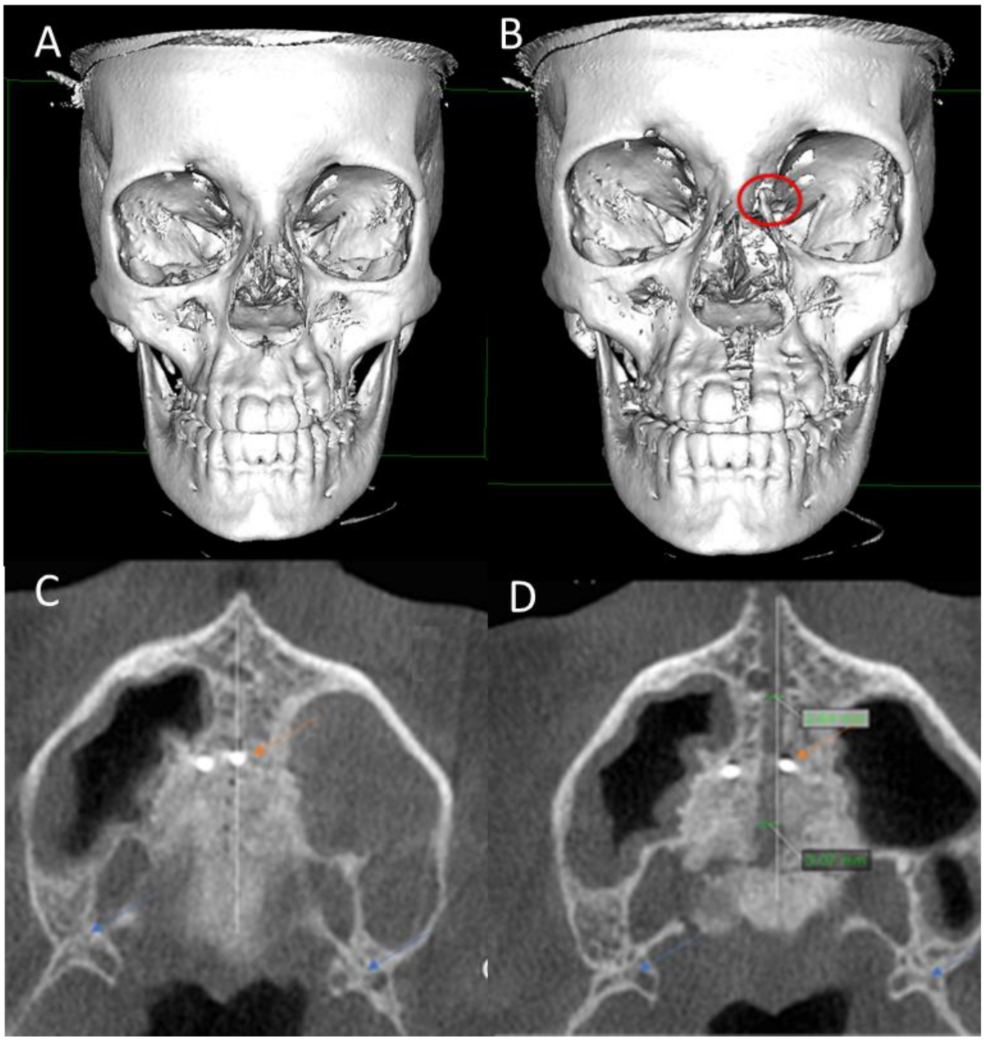

Fig 6. CT scans pre and post treatment with MARPE: **A,** initial 3D reconstruction. **B**, 3D reconstruction after MARPE expansion, frontonasal suture rupture is evident and is circled in red. **C,** axial section in the midpalatal suture region pre-expansion. **D,** Axial section in the midpalatal suture region after expansion.

Sutural opening failure

Case 4

A 39-year-old female patient sought orthodontic treatment to improve her smile and correct the anterior open bite. The patient had an anterior open bite, crowding, Class III left subdivision and a maxillary atresia resulting in a bilateral posterior and anterior crossbites (Fig. 7). Facial analysis revealed that the patient presents Class III facial pattern with small projection of the upper lip and protrusion of the lower lip.

The treatment planning proposed was orthodontic preparation for orthognathic surgery, with a previous disjunction of maxilla by MARPE to correct the transverse maxillary discrepancy.

Rapid palatal expansion was performed with a modified expander to support 4 orthodontic miniscrews inserted into the palatine region surrounding the MS. The specifications of the miniscrews used were: 2 anterior miniscrews with size 1.8 mm in diameter, transmucosal of 4 mm and 7 mm thread length and 2 posterior miniscrews with a size of 1.8 mm in diameter, transmucosal of 4 mm and 5 mm of thread length. Both the expander and miniscrews were used by Peclab® (Belo Horizonte, Minas Gerais, Brazil). The activation protocol applied was 2/4 of a turn immediately after the installation of the miniscrews and 2/4 daily on the subsequent days, being 1/4 in the morning and 1/4 in the night (0.5mm per day) until the correction of the transverse discrepancy.

The attempt of maxillary disjunction was not successful, resulting in an expansion in the region of the first molars which were supported on the apparatus (dentoalveolar effect) (Fig. 8B). Because it is an adult patient with complete sutural maturation and poor primary stability of the miniscrews observed during implant installation (miniscrew insertion torque less than 10N), the bone support was not sufficient to overcome the forces required for disjunction. The expander was deactivated and then removed, allowing relapse for a second attempt.

New approach was undertaken after 2 months, however, with additional changes. The first one refers to the anterior positioning of the MARPE, which allowed the insertion of the miniscrews into a thicker bone region of the palate, also avoiding the perforation areas of the previous procedure. The other change was the association of the corticopuncture technique in the region of the midpalatal suture with the purpose of weakening it and generating an inflammatory stimulus to favor its separation. Prior to the installation of the expander, anesthesia of the entire length of the midpalatal suture was performed at the level of the third palatine fold and 6 perforations in the middle of the suture were performed using a miniscrew measuring 5 mm in length by 1.8 mm thick (Peclab) (Fig. 9). After this procedure, the same protocol of installation and activation of MARPE (already described) was followed.

In the second approach, perforations probably helped in the success of the procedure clinically evidenced by the formation of a diastema in the region between the upper central incisors (Fig. 10). Regarding the anterior positioning of MARPE, it can be said that this also aided in the success of the procedure, although the insertion torque did not reach 10N and the primary stability of the miniscrews still remained low.

Tomographic examination confirmed the maxillary disjunction (Fig.11).

Fig 7. Pre-expansion intraoral photos showing anterior open bite, crowding, Class III left subdivision and a maxillary atresia resulting in a bilateral posterior and anterior crossbites.

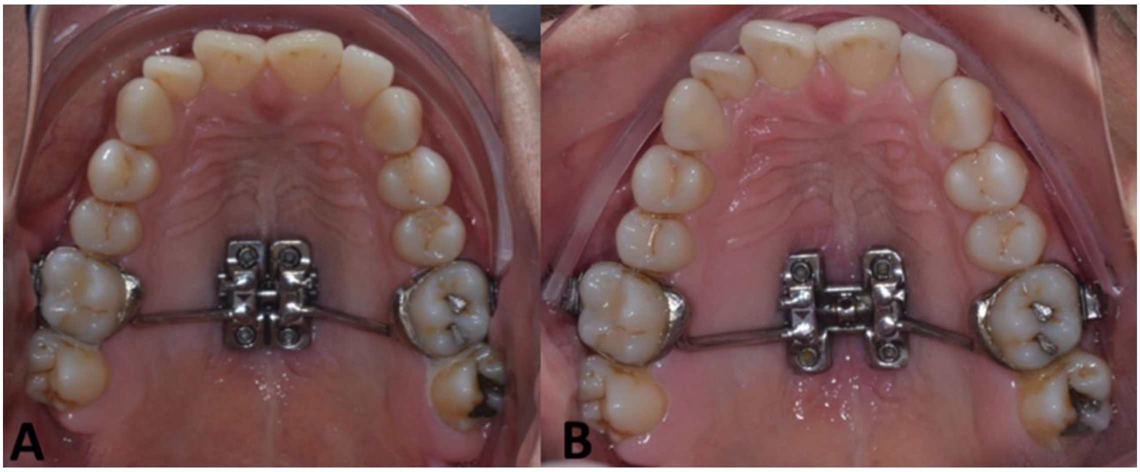

Fig 8. Pre and post expansion occlusal photos: **A,** immediately after installing MARPE. **B,** failure of the suture rupture, only dentoalveolar expansion effect was observed on first molars.

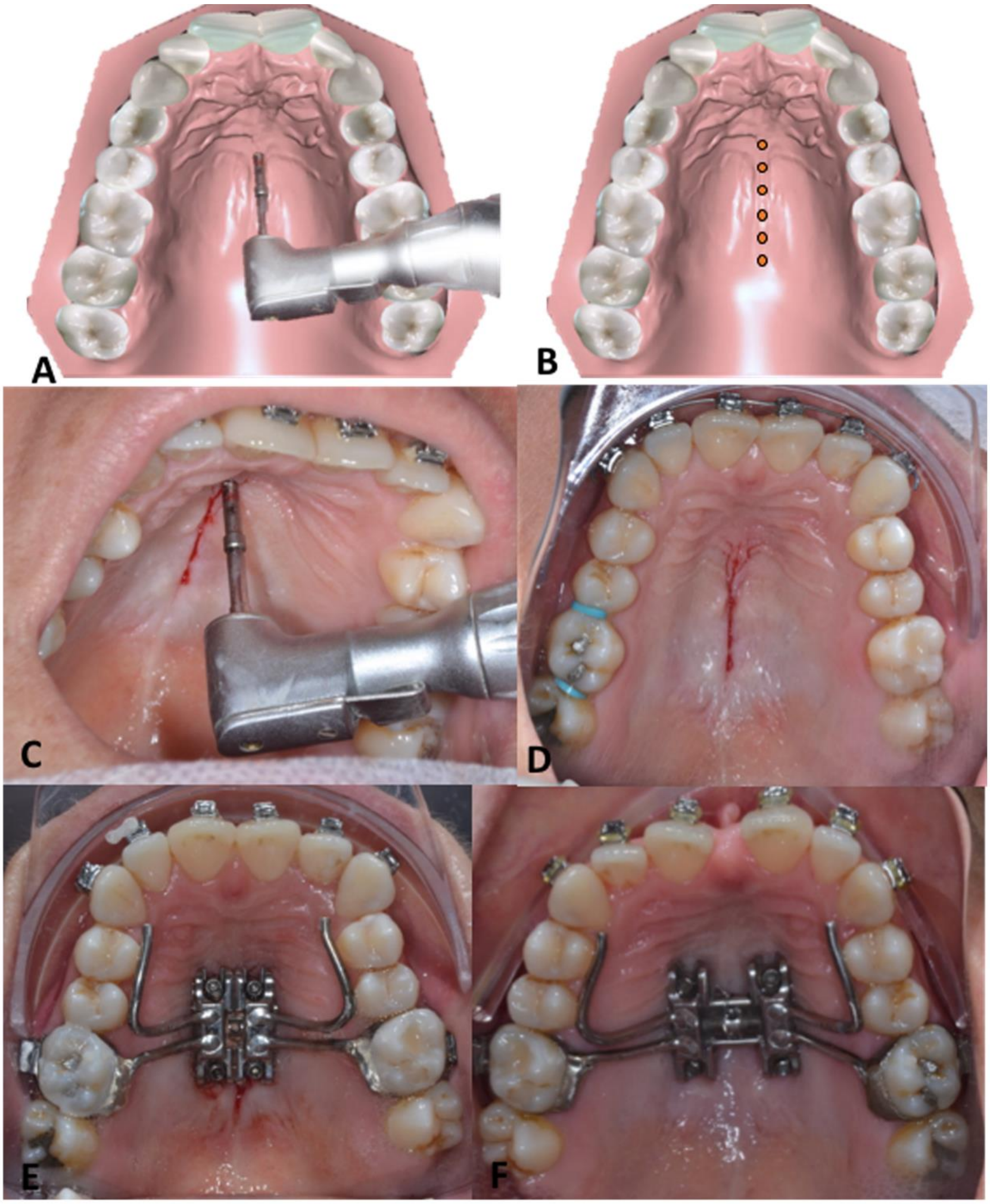

Fig 9. Installation of MARPE with the corticopuncture technique: **A and B,** schematic drawings of the region where the 6 corticopunctures were performed. **C,** performing corticoperforations with a miniscrew. **D,** corticopunctures performed at 6 points along the midpalatal suture. **E,** immediately after installing MARPE. F, MARPE locking after successful suture rupture.

Fig 10. Post-expansion occlusion showing transverse gain and interincisor diastema.

Fig 11. 3D reconstructions of the case. A, pre-expansion. B, post expansion.

Case 5

A 30-year-old man presented a Class III malocclusion with anterior crossbite, lower midline deviation to the left side and missing tooth 16 and 37 (Figure 12 A-D). During examination, it was found that patient showed CO/CR (central occlusion/central relation) discrepancy with a mandibular shift to the left side. Lateral x-ray showed a skeletal Class III and brachyfacial profile (Figure 12E). Initial midpalatal suture and paramedian cross-sectional images showed very thin bone thickness for anchorage and measurement.

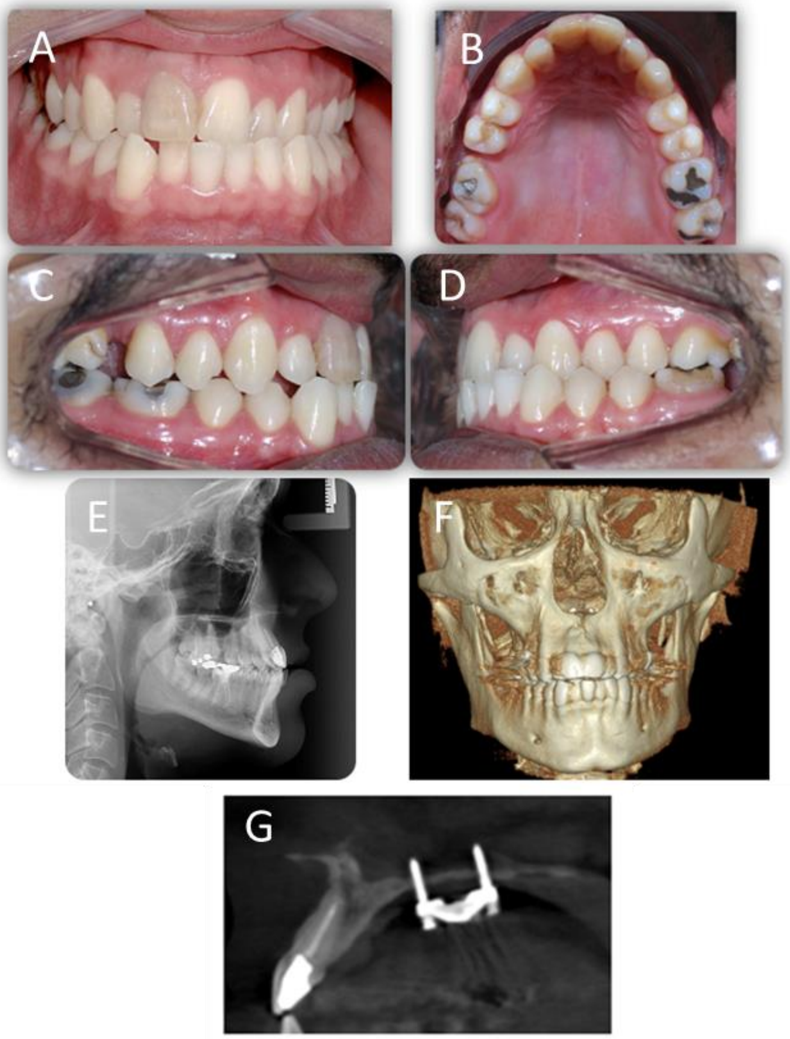

Fig 12. Pre-expansion photographs and imaging: **A-D,** intraoral photographs. **E,** lateral skull teleradiography. **F,** 3D reconstruction. G, sagittal tomographic section of the paramedian region showing the thin thickness of the palatine bone.

Transverse treatment included a 11mm maxillary skeletal expander - MSE II (Biomaterials Korea, Seoul, South Korea) with four 11mm miniscrews. Before MSE installation, patient received local block anesthesia and Corticopucture procedure was performed using a contra-angle electric screwdriver (Model ISD900, NSK, Japan) set in 25min−1 speed and 40Ncm torque and a 1.5 diameter and 6mm tip bur (Peclab, Belo Horizonte, Brasil).

Orientation regarding hygiene of the MSE device consisted of gentle use of extra soft small tooth brush and if any sign of inflammation, mouth rinse with chlorhexidine solution. No anti-inflammatory medication was prescribed.

Patient was oriented to start activation after one week and activations to be performed twice in the morning and twice at night. According to manufactory's instruction, one turn of MSE expander corresponds to 0.13mm of activation due to the presence of a hexagon and modified key instead of conventional hole and key. Therefore, a total of 0.52mm activation was done per day.

After 20 days of activation, no diastema was present and there was a mild impingement of the palatal mucosa on the right side (Figure 13C). Since patient referred a small discomfort on the palate, activation was interrupted and asked to return after 14 days of resting. On the following visit, a close examination found a very small diastema between incisors and also, an improvement on the impingement of the mucosa. Patient reported no discomfort. Activation was then restarted but this time, only half of the previous activations was performed, i.e., two activations (0.26mm) per day.

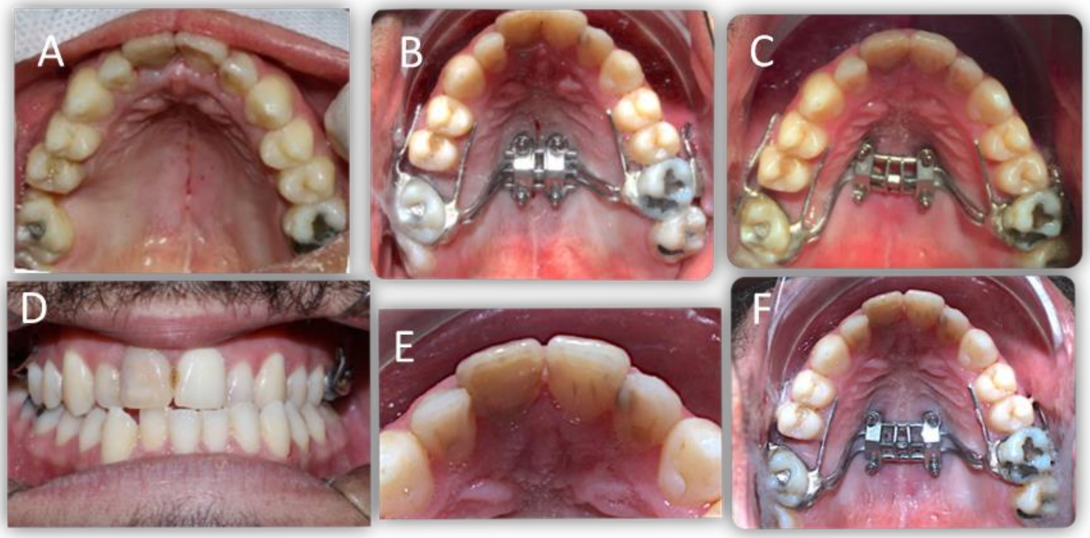

Fig 13. Installation of MARPE with the corticopuncture technique: **A,** corticopuncture along the midpalatal suture. **B,** immediately after MARPE installation. **C,** after 20 days of activation no diastema was present. **D,E,F,** after 14 days of rest without activations a slight diastema was observed between the central incisors.

Figures 14 displays the result of second activation protocol after one week and after 2 weeks. Showing a progressively increase on the diastema and expansion of the maxillary basal bone (initial and final midpalatal suture opening.), even though mandibular shift was still present.

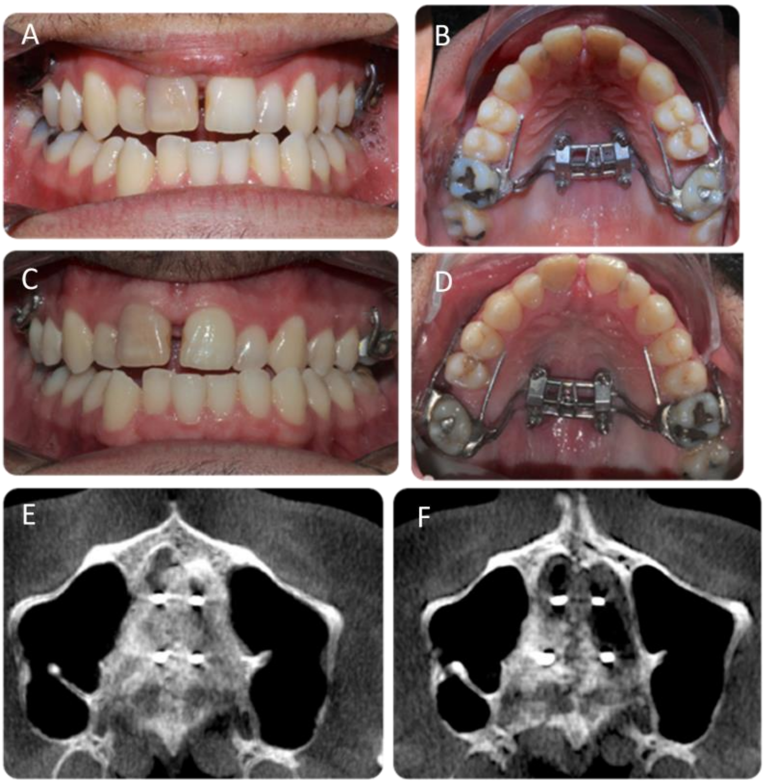

Fig 14. Progressively increase on the diastema and maxillary expansion. **A,B** One week with the new activation protocol. **C,D** Two weeks with the new activation protocol. **E,** axial tomographic section pre-expansion. **F,** axial tomographic section post expansion.

Case 6 – Successful Corticopuncture Facilitated MARPE case with New Activation Protocol

A female patient (28 years old) presented a chief complain of narrow maxilla and respiratory problems. She has been treated previously for constant acute crisis of rhinitis and reported mainly oral breathing during day and sleeping. Patient also reported snoring every night.

Intra-oral examination showed posterior crossbite on the left side and edge-to-edge bite on the right side, lower midline deviation to the right side producing a Class III relationship on the right side and a Class I relation on the left side. Transverse basal bone width on the maxilla and mandible visually perceived by the vertical lines (yellow and blue) confirm the need for skeletal expansion. Occlusal image shows a severe maxillary constriction promoting flaring of the upper incisors (Figure 15).

Lateral x-ray shows a straight profile and a skeletal Class III relationship, as well as a acute nasolabial angle and a protrusion on the lower lip. Photo during smile shows an increase of buccal corridor (Figure 15). Both midpalatal suture and paramedian thickness were measured.

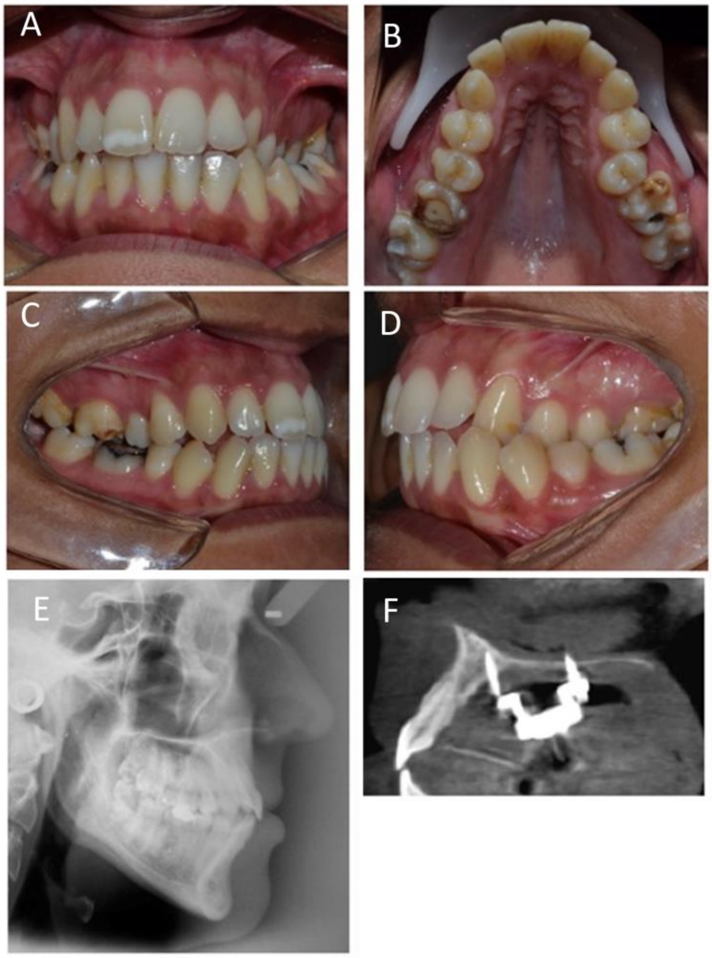

Fig 15. Pre-expansion photographs and imaging: **A-D,** intraoral photographs. **E,** lateral skull teleradiography. **F,** sagittal tomographic section of the paramedian region showing the thin thickness of the palatine bone.

Maxillary transverse correction was performed using a MARPE EX device and 4 miniscrews: two 1.8 diameter x 11 length anterior miniscrews and 1.8 diameter x 9 length posterior miniscrews (Peclab, Belo Horizonte, Brasil). Corticopuncture procedure was done before MARPE placement as previously described on Case 5.

Learning from the previous case, in this case a modified activation protocol was set: from the start was ¼ turns (0.25mm) per day. Figure 15A and B show progress of activation after 20 days. A 3mm diastema can be noticed and a slight improvement on arch width. After 30 days of activation (Figure 15 C and D), it can be observed the presence of a larger diastema and transverse width, also no sign of discomfort on the palate or gingival inflammation. Figure 15 E and F shows end of activation after 40 days with opening of 7mm diastema and a proper maxillary width in respect of mandibular width.

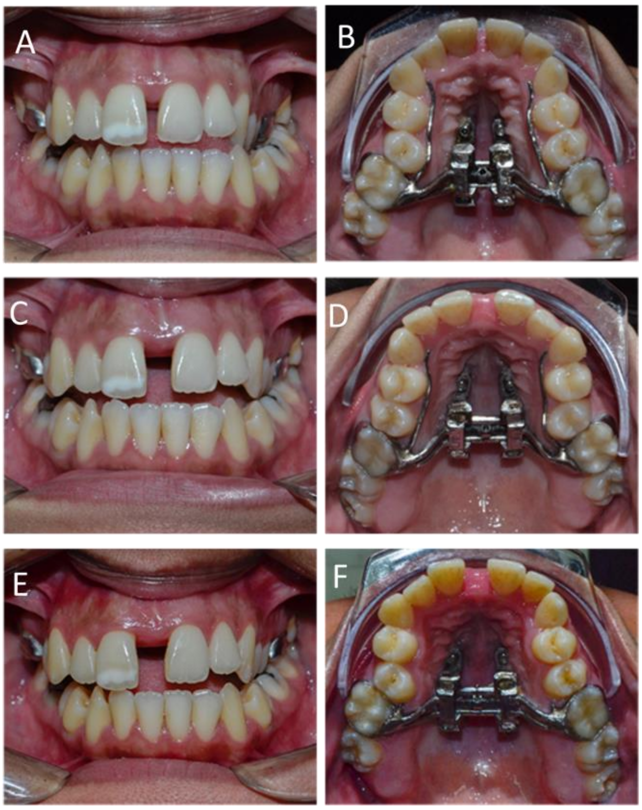

Fig 15. Progressively increase on the diastema and maxillary expansion. **A,B** 20 days of activation. **C,D** 30 days of activation. **E,F** 40 days of activation.

CBCT images show the amount of midpalatal suture split anterior and posteriorly (Figure 16 A and B). On the frontal 3D reconstructed images, a relatively parallel opening can be observed (Figure 16 C and D) meaning that maxillary expansion had a high impact on the nasal cavity enlargement.

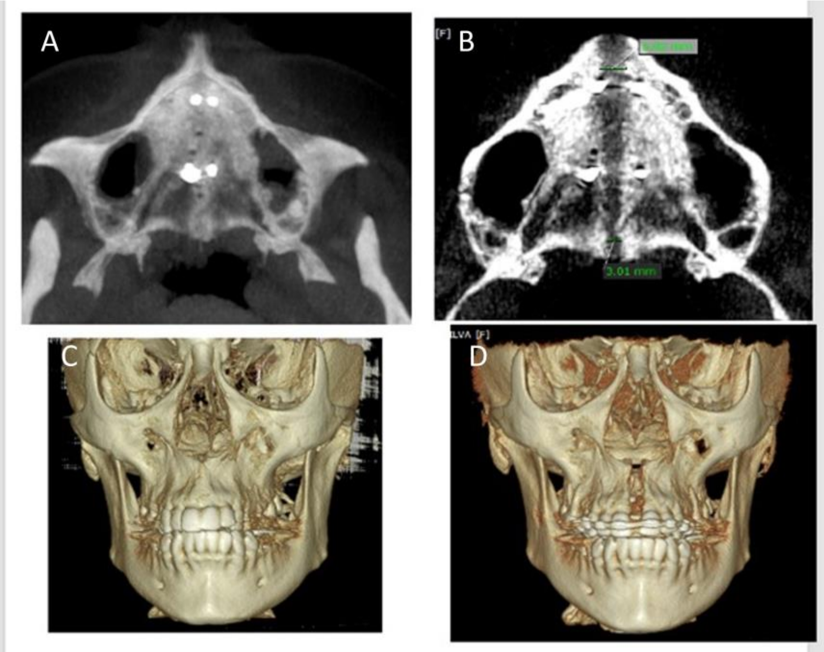

Fig 16. CBCT images: **A,** axial tomographic section pre-expansion. **B,** axial tomographic section post expansion. **C,** 3D reconstruction pre-expansion. **D,** 3D reconstruction post expansion.

Discussion

The current article shows some clinical cases were complications happened during maxillary expansion with MARPE.

Case 1 shows how the accumulation of dirt from food remains, together with lack of cleaning and bacterial plaque calcification can lead to inflammation of the mucosa around the region where the skeletal anchorage of the expander (miniscrews) is installed. Constant inflammation in the region led to increased mucous volume, loss of miniscrew stability and consequent loss of two anterior miniscrews. The difficulty in cleaning the expander for patients who are using this type of device has been previously reported in the literature[13,14]. Tsai et al. reported that 41.4% of subjects in their study complained of difficulty in cleaning[14]. However, so far, there is no well-defined cleaning protocol in the literature about how orthodontists should guide their patients to properly clean the MARPE. The patient in case 1 also lost two miniscrews during the expansion containment period and the device was maintained. The literature suggests that the stability of all miniscrews should be checked regularly and, in case any mobility is found, it should be removed and the treatment may continue, although extra carefully, even if there is only one miniscrew on each side [15].

Moreover, the soft tissue inflammation seems to be the most common problem associated with MARPE therapy [14–18] although a study over the complications reported with the use of orthodontic miniscrews pointed that the palatal site was less affected by complications[19]. Brunetto et al. advised that at all visits, the distance of the expander from the mucosa should be checked and in case of contact, tissue inflammation develops rapidly[20]. Choi et al. advised that mucosal swelling can be prevented by accurate placement of the miniscrews and hooks, elaboration of appliance fabrication, and scrupulous oral hygiene maintenance, including copious saline irrigation followed by gingival massage [15].

A recent study on MARPE complications by Yoon et al.[18] pointed gingival inflammation around the appliance as the most common MARPE complication (83.9% of patients). Mild inflammation was managed with a 0.12% chlorhexidine gluconate oral mouth rinse and improved oral hygiene. Antibiotics were prescribed to 5% of patients with inflammation of the palatal tissue, and MARPE was prematurely removed in 8% of patients with severe inflammation[18].

In case 2 the patient developed sinusitis during the treatment. Tsai et al. [14] reported one subject with acute sinusitis one week after MARPE activation, however, dental origin infection with periapical abscess was diagnosed on patient's upper left first molar. They advised that thorough examinations of all endodontically treated or largely restored tooth/ teeth should be done before all types of rapid palatal expansions. The patient in clinical case 2 had no apparent odontogenic infection. MARPE miniscrews, especially when bicorticalized, are in close contact with the floor of the nasal cavity. In sinusitis, there is inflammation of the mucous membranes of the sinuses, these sinuses are covered by a mucosa, rich in mucus-producing glands and covered by cilia with vibrating movements that conduct the “foreign material” retained in the mucus to the posterior part of the nose in order to eliminate it [21]. The proximity of the device to the region may have contributed to the migration of the inflammation/infection, leading to sinusitis.

In both cases 1 and 2 of the present article, after the MARPE removal, inflammation and hyperplasia of the mucosa decreased and the regions healed completely, leaving only small scars where the miniscrews were. Visible scars on soft tissues may develop after the use of temporary anchoring devices. While this scar is restricted to the insertion site and small in size, it can cause aesthetic problems[22].

Thus, it is important to report to patients who underwent MARPE the possibility of scar formation at the site.

During rapid maxillary expansion, it is not only the midpalatal suture that offers resistance to opening. Other resistance areas have been cited to maxillary expansion throughout the oromaxillofacial area, with the pterygomaxillary, zygomaxillary, and nasomaxillary buttresses offering the strongest resistance[23,24]. In case 3 of the present article, there was an occlusal unevenness after maxillary disjunction with MARPE, resulting from the rupture of the frontonasal suture. A study using the technique of photoelasticity reported that the stresses generated by the hyrax expansion appliance activation during rapid maxillary expansion produced a demonstrable increase in the stresses at the frontonasal suture[25]. Possible explanations for the rupture of this suture after the stress received is that perhaps it was "weaker" at a lower stage of maturation, with less interdigitations or by some trauma. Nevertheless, the maturation stage of this patient's suture was not quantified and she had no history of trauma.

Bud et al.[12] analyzing possible complications at the skeletal and dentoalveolar level after MARPE, observed occlusal planes change in 10 cases of the study sample (37%). They stated that although occlusal modifications occur after palatal split, especially in unilateral cross-bite cases, these changes can be treated with the help of fixed orthodontic appliances[12], corroborating the conduct adopted in clinical case 3 of the current article. However, frontonasal suture rupture was not analyzed in the study. It would be interesting, in cases where unevenness is observed between the two sides of the maxilla, to analyze the frontonasal suture. Or else, perform an analysis of this region before and after expansion. Yoon et al.[18] found asymmetric expansion of ≥1 mm in 47.8% patients of their sample and the frequency of asymmetric maxillary expansion was higher in patients that needed a greater amount of expansion. In most patients in which asymmetric expansion was clinically apparent, the occlusion was successfully managed with subsequent orthodontic treatment[18].

Success of MARPE technique may be related to many factors related to age, midpalatal suture characteristics and palatal length[11,26]. Although anchorage is the main advantage of micro-implant assisted rapid palatal expansion, so far few studies have correlated MARPE success to bone thickness surrounding miniscrew [27].

Studies on miniscrews inserted on dentoalveolar areas have suggested that miniscrew failure might be associated with the amount of cortical bone surrounding the screw and recommend apical angulation to the long axis of the tooth to increase the interdigitation of these miniscrews[28,29]. Regarding palatal miniscrew, it has been suggested that stability of miniscrew implants depends on the quality and quantity of the cortical bone. One study discovered thicker boner thickness at the area immediately behind incisive canal zone both median and paramedian to the suture. Thin bone thickness was found 2mm and beyond laterally to midpalatal suture at the posterior region of the palate. A significant difference in thickness was found between sexes and was approximately 0.5 mm and 1 mm greater in men at the median and paramedian, respectively. And among ethnic groups, thickness tended to decrease as follows: Caucasian > Hispanic > African-American > Asian[30].

Since miniscrew stability may be close related to the amount of available bone, patients presenting thin palatal bone thickness need special attention in terms of MARPE anchorage. Therefore, it has been suggested corticopuncture procedure as a method to weaken midpalatal suture interdigitation[9] as illustrated on both Cases 4, 5 and 6. Considering that many cases of skeletal maxillary constriction may present thin bone thickness to serve as anchorage for MARPE, Cases 5 and 6 of the present study proposed two modifications: one regarding a period of rest during activation in case opening of midpalatal suture has not been achieved in the first 14-20 days of activation and the second modification is related to the daily activation on the activation protocol, reducing to ¼ turn/day (0.2-0.25mm/day). Thus, Case 6 showed great expansion resulted from ¼ turn only of the jackscrew performed daily. Although it took longer time to obtain suture separation, it may have a positive effect since no miniscrew tipping or mobility was noticed and still provided the skeletal results to obtain correction of the transverse discrepancy.

In conclusion, this article shows that good hygiene in the region of the MARPE miniscrews is important to prevent the formation of lesions and inflammation that, if not well controlled, can spread to other regions of the face such as the sinus, causing sinusitis. An optimal hygiene protocol for MARPE patients should be better established. The frontonasal suture is one of many that undergoes stress and promotes resistance to rapid maxillary expansion, and can also be ruptured during expansion. When this occurs, asymmetrical expansion can be observed on the side where the rupture occurred. Patients with a thin palate have more cortical bone than medullary bone to anchor the miniiscrews, making the miniscrew insertion in the bone more difficult due to the lower amount and quality of bone available. In these cases, we suggest combining the corticopuncture method and changing the activation protocol to just ¼ of a turn per day (0.25mm) to help weaken the midpalatal suture and promote its rupture.

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4 CONSIDERAÇÕES FINAIS

Quando realizada a corticopunção da sutura palatina mediana, menor quantidade de expansão esquelética foi obtida com MARPE, porém, observou-se melhor paralelismo da abertura sutural.

Fatores como estágio maturacional da sutura zigomático-maxilar, altura, espessura e angulação do osso zigomático e angulação da sutura pterigopalatina não foram significativamente relacionados ao sucesso do MARPE.

A partir do manejo dos casos, os autores sugerem que um protocolo de higiene ideal para pacientes com MARPE seja melhor estabelecido para prevenir a formação de lesões e inflamação; A sutura frontonasal pode se romper durante a expansão do MARPE causando expansão assimétrica e desnivelamento do lado onde ocorreu a ruptura; Em pacientes com espessura palatina fina combinar o método de corticopuntura e alterar o protocolo de ativação para apenas ¼ de volta por dia (0,25mm) pode ajudar a enfraquecer a sutura palatina mediana e promover sua ruptura.

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ANEXO A - CERTIFICADO DO COMITÊ DE ÉTICA

UNESP - FACULDADE DE ODONTOLOGIA - CAMPUS ARARAQUARA

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Avaliação tridimensional utilizando sobreposição por equivalência de voxel da expansão rápida maxilar assistida cirurgicamente e por mini-implantes

Pesquisador: Ary dos Santos Pinto

Área Temática:

Versão: 1

CAAE: 39233820.7.0000.5416

Instituição Proponente: Faculdade de Odontologia de Araraquara - UNESP

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 4.402.668

Apresentação do Projeto:

Trata-se apresentação do projeto de pesquisa cujo resumo consta: "O objetivo deste estudo é, a partir das TCFC, avaliar as alterações esqueléticas produzidas pela expansão rápida da maxila assistida por miniimplantes ortodônticos (ERMAMI) com e sem corticopuntura realizada em pacientes que já atingiram a maturidade óssea e compará-los aos efeitos

encontrados com a expansão rápida da maxila assistida cirurgicamente (ERMAC) utilizando a sobreposição tomográfica para avaliar e comparar as mudanças de forma e posição tridimensional em maxila além de usar a dinâmica dos fluidos computacional nas TCFC para esclarecer com mais precisão a quantidade de melhora da ventilação das vias aéreas superiores. Além disso, nos casos de ERMAMI, analisar a associação (de sucesso ou insucesso da técnica) com a morfologia do processo zigomático, estágio de maturação da sutura zigomaticomaxilar, posição do parafuso expansor com relação ao osso zigomático e a angulação e quantidade de inserção dos mini-implantes. Serão selecionadas tomografias de 36 indivíduos tratados por ERMAMI e 24 tratados com ERMAC, adolescentes e adultos, com atresia maxilar, mordida cruzada posterior bilateral ou unilateral. Para as avaliações, serão utilizadas tomografias computadorizadas de feixe cônico antes (T0) e após o término da expansão (T1). Serão avaliados o desempenho dos sistemas ERMAC e ERMAMI comparando as médias de cada variável antes e depois do tratamento, empregando o test t-Student para comparar as médias de dois grupos com amostras dependentes. Já o teste t-Student para amostras independentes será realizado para comparar as alterações entre os grupos.

A correlação entre o efeito ortopédico de abertura ou não da sutura palatina mediana (sucesso e insucesso) com a morfologia do processo zigomático, estágio de maturação da sutura zigomaticomaxilar, posição do parafuso expansor com relação ao osso zigomático e a angulação e quantidade de inserção dos mini-implantes serão avaliados utilizando o teste de correlação de Pearson.

Objetivo da Pesquisa:

O objetivo deste estudo é, a partir das TCFC, avaliar as alterações esqueléticas produzidas pela expansão rápida da maxila assistida por miniimplantes ortodônticos (ERMAMI) realizada em pacientes que já atingiram a maturidade óssea e compará-los aos efeitos encontrados com a expansão rápida da maxila assistida cirurgicamente (ERMAC) utilizando a sobreposição tomográfica para avaliar e comparar as mudanças de forma

e posição tridimensional em maxila decorrentes da ERMAMI e ERMAC além de usar a dinâmica dos fluidos computacional nas TCFC para esclarecer com mais precisão a quantidade de melhora da ventilação das vias aéreas nasais.

Avaliação dos Riscos e Benefícios:

Riscos:

Não há risco de ocorrência de dano uma vez que todos pacientes incluídos na amostra já finalizaram seu tratamento. Os riscos previstos para a pesquisa são mínimos, uma vez que serão usados os exames tomográficos necessários para o planejamento e avaliação do tratamento já finalizado (estudo retrospectivo).Para minimizar os riscos de constrangimento pelo acesso aos dados do prontuário clínico, o pesquisador responsável

garantirá o sigilo das informações confidenciais, zelando pela privacidade do paciente de forma que sua identidade não será revelada de forma

alguma quando a pesquisa for exposta em congressos ou em publicações científicas.

Benefícios:

Baseado nos resultados deste estudo, ao realizar o planejamento, diagnóstico e tratamento das atresias maxilares será possível identificar se variáveis como maturação sutural ou anatomia de estruturas faciais podem influenciar na expansão rápida maxilar. Os resultados poderão indicar quais mudanças esperadas nos vias aéreas superiores em indivíduos com maturidade esquelética avançada e em função da técnica adotada (utilizando miniimplantes ou cirurgicamente assistida).

Comentários e Considerações sobre a Pesquisa:

A pesquisa é um estudo retrospectivo que utilizará dados tomográficos, existentes nos arquivos do curso de Ortodontia da escola de especialidades odontológica COESP em João Pessoa (PB) e do banco de dados do departamento de cirurgia da Faculdade de Odontologia de Araraquara (UNESP), obtidos para avaliação e planejamento de tratamentos de discrepâncias esqueléticas ou dentes retidos.

Considerações sobre os Termos de apresentação obrigatória:

Os seguintes documentos foram apresentados:

1. autorização para seleção, avaliação e análise da documentação tomográfica de pacientes tratados na Faculdade de Odontologia de Araraquara e na escola de especialidades COESP, localizada em João Pessoa - PB;
2. cronograma;
3. orçamento;
4. solicitação de dispensa do TCLE;
5. folha de rosto;
6. informações básicas do projeto;
7. projeto completo;
8. termo de cumprimento das normas de acordo com a resolução CNS 466/12, que versa sobre as Diretrizes e Normas Regulamentadoras de Pesquisas Envolvendo Seres Humanos;
9. autorização para utilização do programa Dolphin® Imaging (Dolphin Imaging and Management Solutions, Chatsworth, Calif., EUA), pertencente ao Departamento de Morfologia
Clínica Infantil, Faculdade de Odontologia FOAr-UNESP-Araraquara.

Todos os documentos foram apresentados adequadamente.

Recomendações:

Vide campo conclusões ou pendências.

Conclusões ou Pendências e Lista de Inadequações:

Sem pendências.

Considerações Finais a critério do CEP:

Protocolo APROVADO em reunião de 13 de Novembro de 2020.

O pesquisador deverá encaminhar relatórios parciais a cada 01 (um) ano até o prazo final da pesquisa, quando deverá encaminhar o relatório final.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1646747.pdf	15/10/2020 22:35:37		Aceito
Cronograma	Cronograma.pdf	15/10/2020 22:35:21	Adriana Souza de Jesus	Aceito
Projeto Detalhado / Brochura Investigador	Projeto.pdf	15/10/2020 22:34:58	Adriana Souza de Jesus	Aceito
Folha de Rosto	folhaDeRosto.pdf	11/10/2020 20:27:22	Adriana Souza de Jesus	Aceito
Declaração de Pesquisadores	Termo_cump_normas.pdf	11/10/2020 12:24:57	Adriana Souza de Jesus	Aceito
Outros	Uso_do_Dolphin.pdf	11/10/2020 12:24:32	Adriana Souza de Jesus	Aceito
Outros	Autorizacaotomosmarpe.pdf	11/10/2020 12:23:48	Adriana Souza de Jesus	Aceito
Outros	Autorizacaotomoscirurgia.pdf	11/10/2020 12:21:41	Adriana Souza de Jesus	Aceito
Orçamento	Orcamento.pdf	11/10/2020 12:11:11	Adriana Souza de Jesus	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Dispensa_do_TCLE.pdf	11/10/2020 12:11:01	Adriana Souza de Jesus	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

ARARAQUARA, 17 de Novembro de 2020

Assinado por:
Andréa Gonçalves
(Coordenador(a))

Araraquara, 9 de agosto de 2023

Adriana Souza de Jesus