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Three-dimensional evaluation of periodontal effects after surgically assisted rapid maxillary expansion

Avaliação tridimensional dos efeitos periodontais após expansão rápida da maxilla assistida cirurgicamente

Evaluación tridimensional de los efectos periodontales después de la expansión maxilar rápida asistida quirúrgicamente

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Abstract
Objective: To evaluate the periodontal effects of maxillary teeth in patients who underwent surgically assisted rapid maxillary expansion (SARME) and compare the results with the amount of expansion and the surgical technique performed. Material and Methods: Cone-beam computed tomography (CBCT) of nineteen patients who underwent SARME were selected, preoperative (up to one month before surgery) and postoperative (six to eight months after surgery) to analyze measurements of bone thickness, alveolar bone level alveolar segment tilting, and tooth tipping. An analysis of all medical records was also performed, regarding the amount of expansion achieved, and surgical technique performed. The patients were divided in groups with and without pterigomaxillary disjunction. Results: Tooth upper first premolar and first molar on the left side, and second premolar and first molar on the right side all presented bone loss in the period after surgery. All teeth, with exception of first molars in both sides of the maxillae, presented dental tipping. And, it was also found that the greater the amount of expansion, the greater will be the bone loss in level and thickness (BL, ABT5). And, that the greater the angulation of the tooth, the greater the bone level

loss. Conclusions: In conclusion, after surgery and the use of the Hyrax device, the buccal alveolar bone thickness suffered statically significant losses, also, some teeth suffered segment tilting and tooth tipping. The present study also found greater bone loss in patients who suffered a greater amount of expansion.
Keywords: Palatal expansion technique; Periodontal Attachment loss; Cone-Beam Computed Tomography.

Resumo

Objetivo: Avaliar os efeitos periodontais nos dentes superiores de pacientes que se submeteram pela expansão rápida de maxilla assistida cirurgicamente (SARME) e comparar os resultados da quantidade de expansão alcançada em cada pacientes, e a técnica cirurgica realizada. Material e Métodos: tomografias computadorizadas de feixe cônico (CBCT) de dezenove pacientes que passaram pela SARME foram selecionadas, pré-operatórias (até um mês antes da cirurgica) e pós-operatórias (de seis a oito meses após a cirurgia) para analizar a espessura óssea, altura óssea alveolar, angulação dental e angulação do alvéolo. Uma análise do prontuário de todos os pacientes também foi realizada, para analisar a quantidade de expansão realizada em cada paciente, e dividi-los em dois grupos com e sem a realização da disjunção pterigomaxilar. Resultados: Os dentes primeiro pré-molar e primeiro molar esquerdo, segundo pré-molar e primeiro molar direito superiores apresentaram perda de espessura óssea após a cirurgia. Todos os dentes, com excessão dos primeiros molares de ambos os lados da maxilla apresentaram angulação dental. Além disso, também foi encontrado que quanto mais expansão realizada no paciente maior a perda de altura e espessura óssea alveolar (BL, ABT5), e quanto mais angulado o dente maior a perda de altura óssea. Conclusão: após a cirurgia e o uso do aparelho Hyrax, houve perdas estatisticamente significantes da espessura óssea, e alguns dentes sofreram angulação dental e alveolar. O presente estudo também encontrou maior perda óssea em pacientes que sofreram uma expansão maior.
Palavras-chave: Técnica de expansão palatina; Perda de inserção periodontal; Tomografia Computadorizada de Feixe Cônico.

Resumen

Objetivo: Evaluar los efectos periodontales en los dientes maxilares de pacientes que se sometieron a expansión maxilar rápida asistida quirúrgicamente (SARME) y comparar los resultados de la cantidad de expansión lograda en cada paciente y la técnica quirúrgica realizada. Material y Métodos: Se seleccionaron tomografías computarizadas de haz cónico (CBCT) de diecinueve pacientes que se sometieron a SARME, preoperatoriamente (hasta un mes antes de la cirugía) y postoperatoriamente (de seis a ocho meses después de la cirugía) para analizar el grosor óseo, la altura del hueso alveolar, angulación de dientes y angulación de alvéolos. También se realizó un análisis de las historias clínicas de todos los pacientes, para analizar la cantidad de expansión realizada en cada paciente, y dividirlos en dos grupos con y sin disyunción pterigomaxilar. Resultados: Los dientes maxilares primer premolar y primer molar a la izquierda, y maxilar segundo premolar y primer molar derechos presentaron pérdida ósea después de la cirugía. Todos los dientes, a excepción de los primeros molares de ambos lados del maxilar, presentaban angulación dentaria. Además, también se encontró que a mayor expansión realizada en el paciente, mayor pérdida de altura y espesor óseo alveolar (BL, ABT5), y cuanto más angulado el diente, mayor pérdida de altura ósea. Conclusión: después de la cirugía y el uso del aparato Hyrax, hubo pérdidas estadísticamente significativas de espesor óseo, y algunos dientes sufrieron angulación dentaria y alveolar. El presente estudio también encontró una mayor pérdida ósea en los pacientes que se sometieron a una mayor expansión.
Palabras clave: Técnica de expansión palatina; Pérdida de inserción periodontal; Tomografía Computarizada Cone Beam.

1. Introduction

Transverse maxillary deficiency is a dentofacial deformity and, in general, is characterized by a posterior crossbite that can be unilateral or bilateral (Behlfelt et al., 1989). This deformity may include clinical features such as nasal airway obstruction and swallowing changes (Bresolin et al., 1983; Behlfelt et al., 1989). To correct this skeletal deficiency, the surgically-assisted rapid maxillary expansion (SARME) is widely used in adult patients who have completed craniofacial growth, as well as ossification of the palatal suture (Cureton & Cuenin, 1999; Ramieri et al., 2008; Alves et al., 2017). The surgical technique consists of a Le Fort type I osteotomy, split of midpalatal suture, and, sometimes, a pterigomaxillary disjunction (PMD) is also performed (Cortese et al., 2009; Kilic et al., 2013). Some studies in literature argue that there is still not enough evidence to defend which technique is better. That creates a discussion between a more invasive technique (with PMD) that reduces orthodontic trauma, and a more conservative technique (without PMD) that reduces surgical complications (Koudstaal et al., 2005; Suri & Taneja, 2008). For SARME treatment orthodontic appliances, such as Hass and Hyrax devices, are usually used to assist maxillary expansion and are also used as retainers after surgery, until the ossification of midpalatal suture is complete (Haas, 1980).

Cone beam computed tomography (CBCT) are important imaging exams in pre-surgical planning, as well to document and analyze the long-term effects in surgeries (Sygouros et al., 2014). CBCT scans allow dentists to measure three-dimensional (3D) facial structures, with minimal distortion, high precision and low radiation doses. Therefore, it's possible to establish correct diagnosis and it allows better monitoring of the patients skeletal and dental structure during the treatment period (Sygouros et al., 2014). CBCT can also be used to asses side effects of SARME such as loss of bone height and thickness (Karabiber et al. 2019). Sendyk et al. (2018) analyzed the clinical damage caused in the periodontium of maxillary teeth after SARME when Haas and / or Hyrax devices were used. The results indicated that SARME can cause changes in periodontal tissue. These studies suggest that periodontal monitoring of the patient, with emphasis on oral hygiene, during and after treatment are of extreme value to minimize loss of supporting tissue.

Three-dimensional studies that analyze periodontal structures affected by SARME in maxillary teeth, and also their relationship with the amount of expansion as well as different surgical techniques are still controverse. The objective of this study was to evaluate, in CBCT scans performed up to one month before (T0) and six to eight months after surgery (T1), the periodontal bone conditions of upper canines, maxillary first and second premolar, and maxillary first molar and the angulation of the alveolus and long axis of second maxillary pre-molars and first molars, in patients who underwent SARME. Comparing those results with the amount of expansion achieved in each patient and the surgical technique performed.

2. Methodology

Ethics Committee

This retrospective and observational study was approved by the Ethics Committee for Research Involving Human Beings at the State University of Maringá (UEM) (CAAE: 15850919.0.0000.0104). This study was conducted according to the recommendations of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

Sample

A sample of 26 patients who underwent SARME, 19 (73.07%) were evaluated in this study. Six (31.57%) of them underwent PMD and thirteen (68.43) did not. There was 7 (36.84%) males and 12 (63.16%) females. And the mean age of the patients was 28.94±8.38 years. The inclusion criteria were: > 18 years, maxillary atresia, with or without facial deformities, that were indicated SARME as treatment; good health; good oral hygiene; patients with CBCT performed up to one month before surgery (T0) (Gauthier et al., 2011; Souza-Pinto et al., 2019) and between six to eight months after the surgery (T1) (Gauthier et al., 2011; Souza-Pinto et al., 2019). The exclusion criteria were as follows: patients who had already undergone any craniofacial surgery, any systemic diseases or syndromic patients (Karabiber et al., 2019), were also excluded from the sample all patients who did not have the upper canines, maxillary first and second premolar, and maxillary first molars.

The amount of expansion was measures from the distance of the palatal cusp of the right first molar to the palatal cusp of the left first molar on a plaster model, pre- and post-operatively. This information and the surgical technique performed were registered from patients' records. The patients were than divided in two groups: SARME with PMD (PMD+) and SARME without PMD (PMD-) (Sygouros et al., 2014). The amount of expansion was also registered from patients' records. The amount of expansion was measured from the palatal cusp of the right first molar to the palatal cusp of the left first molar on a plaster model, pre- and post-operatively.

Orthodontic treatment and surgical procedure

Prior to the surgery, a Hyrax-type device was fixed to the premolars and first molars (Pereira et al., 2017; Kayalar et al., 2019). Each patient received a specific amount of expansion that was determined by clinical examinations plaster models studies and CBCTs. The Hyrax activation protocol started seven days after the surgical procedure (Kunz et al., 2016). The patients were instructed to perform 2/4 turns (0.50 mm) twice a day (Kayalar et al., 2019) until each patient's goal was reached, then, the screw was locked to avoid any further movement for six months (Kayalar et al., 2019).

The Hyrax appliance was performed by different professionals, however, all surgical procedures were performed by the same team of oral and maxillofacial specialists. All surgeries with PMD were performed in a hospital environment, under general anesthesia. The surgeries without PMD were performed under local anesthesia and oral sedation (Midazolam 15mg, 45 minutes before surgery) at the Department of Dentistry.

Image acquisition

CBCT images were obtained by iCAT Next Generation® (Imaging Sciences International, Hatfield, PA, EUA), with a volume of 300µ isometric voxel, Field of View (FOV) of 17x23cm, tension at the tube of 120 kVp, and tube current of 3-8 mA. The amount of radiation was settled at a maximum of two previews (assessed using the DAP- Dose Area Product of the device) 891.4 (mGy*cm²). To perform the CBCTs, the patients were instructed to remain seated and to adopt the natural head position, breathing calmly, with the tongue and lips at rest (Yamashita et al., 2017; Souza-Pinto et al., 2019). The chin and head support were removed during image acquisition to avoid soft tissues change.

The CBCT images were imported to Dolphin Imaging & Management Solutions® 3D version 11.95 3D (Dolphin Imaging & Management Solutions, Chatsworth, CA, EUA) using the DICOM (Digital Imaging and Communications in Medicine) format all the CBCT images were analyzed by a calibrated examiner.

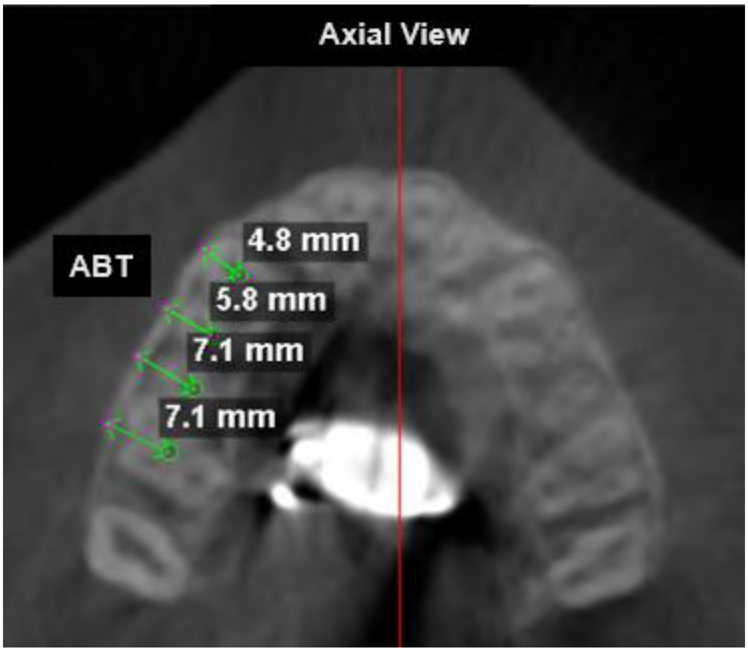
To transfer the CBCT images to the virtual environment, a spatial orientation was performed, the axial plane was repositioned to coincided with the Frankfort Horizontal Plane (FHP) and the midsagittal plane coincided with the midline perpendicular to the FPH, passing through the nasion cephalometric point (most anterior point of the nasofrontal suture). In cases of asymmetry, orientation was performed so that these measurements were as close as possible to the orientation planes. These virtual orientations allowed to obtain the correct head position in such a way the bilateral structures were coincident (Yamashita et al., 2017; Souza-Pinto et al., 2019).

After standardization of the head position on the preoperative CBCT, postoperative images were superimposed over preoperative ones using the Dolphin software 3D voxel-based superimpositions tool. Initially, the two CBCT images were approximated using three landmarks in the neurocranium based on the methodology of Souza-Pinto et al., 2019 and Yamashita et al., 2017. The base of the skull (region unaffected by the surgery) was used as a reference to maintain a standard pre- and post-operative positions using the auto-superimposition tool. (Yamashita et al., 2017; Bazina et al., 2018; Souza-Pinto et al., 2019). Through the superimposition method, in a pre set area the Dolphin 3D software combines the voxels and superimpose automatically (Bazina et al., 2018).

Image analysis

Using the same software, the thickness of buccal alveolar bone and the height of buccal alveolar bone were measured in the following regions: the upper canines, maxillary first and second premolar, and maxillary first molar. The axial view was used as reference at the level of furcation of upper first molar to measure the thickness of the buccal alveolar bone (ABT) (Figure 2). The measurement was performed from the most central point of each tooth to the most buccal bone wall (Figure 2) (Gauthier et al., 2011).

Figure 1. Measurement of bone thickness in axial reconstruction.



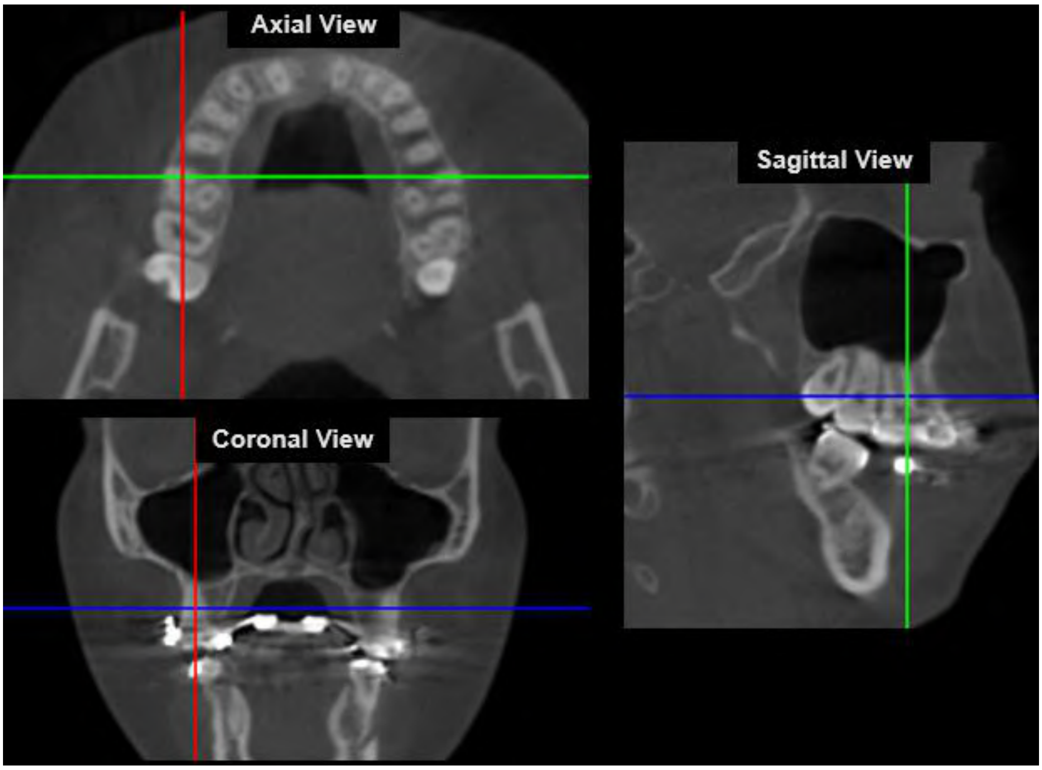
Source: Authors.

The upper molar mesiobuccal root was set as reference to measure buccal alveolar bone. In the axial view at the level of furcation, the reference line was drawn parallel (coronal view (green line)) and perpendicular (sagittal view (red line)) to upper molar mesiobuccal root.

For the measurement of the buccal alveolar bone in coronal reconstruction, the mesiobuccal root of the maxillary first molar was used as a reference. First, in axial reconstruction, where it was possible to visualize the furcation of the first maxillary molar, the coronal reconstruction reference line (green line) was placed parallel to the mesiobuccal root of the maxillary first molar and the line of sagittal reconstruction (red line) perpendicular to it.

In the sagittal reconstruction, the reference line of coronal reconstruction (green line) was placed on the long axis of the mesiobuccal root of the first molar, so that in the coronal reconstruction the standardized image was established. For the other teeth, the same standardization was used (Figure 3) (Brunetto et al., 2013).

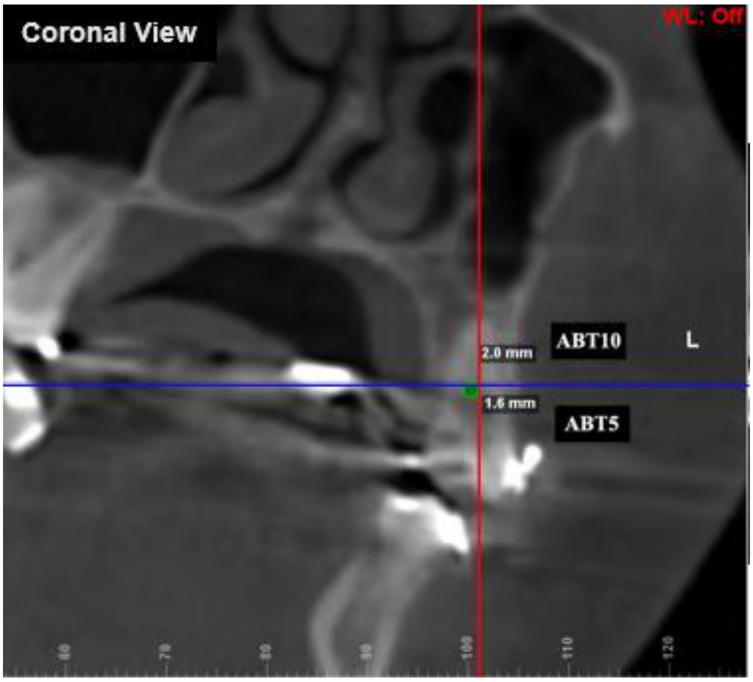
Figure 2. Standardization of reconstruction for measuring the buccal bone alveolar thickness and buccal alveolar bone height.



Source: Authors.

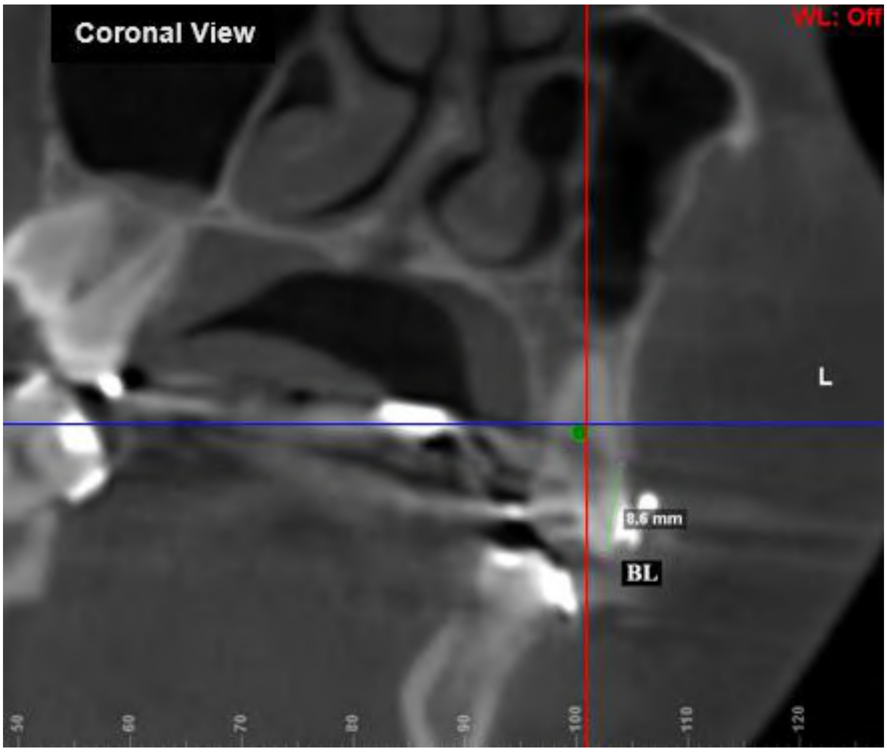
After the standardization two levels was set at 5 mm (ABT5) and 10 mm (ABT10) from the cementoenamel junction, then, the thickness of buccal alveolar bone was measured in the coronal view. To measure the distance between cementoenamel junction and buccal cusp a line was drawn in the coronal view (Figure 5). (Brunetto et al., 2013; Karabiber et al., 2019).

Figure 3. Measurement of bone thickness, at heights 5mm and 10mm above the cementoenamel junction.



Source: Authors.

Figure 4. Bone level measurement performed from the tip of the cusp to the highest alveolar bone level.

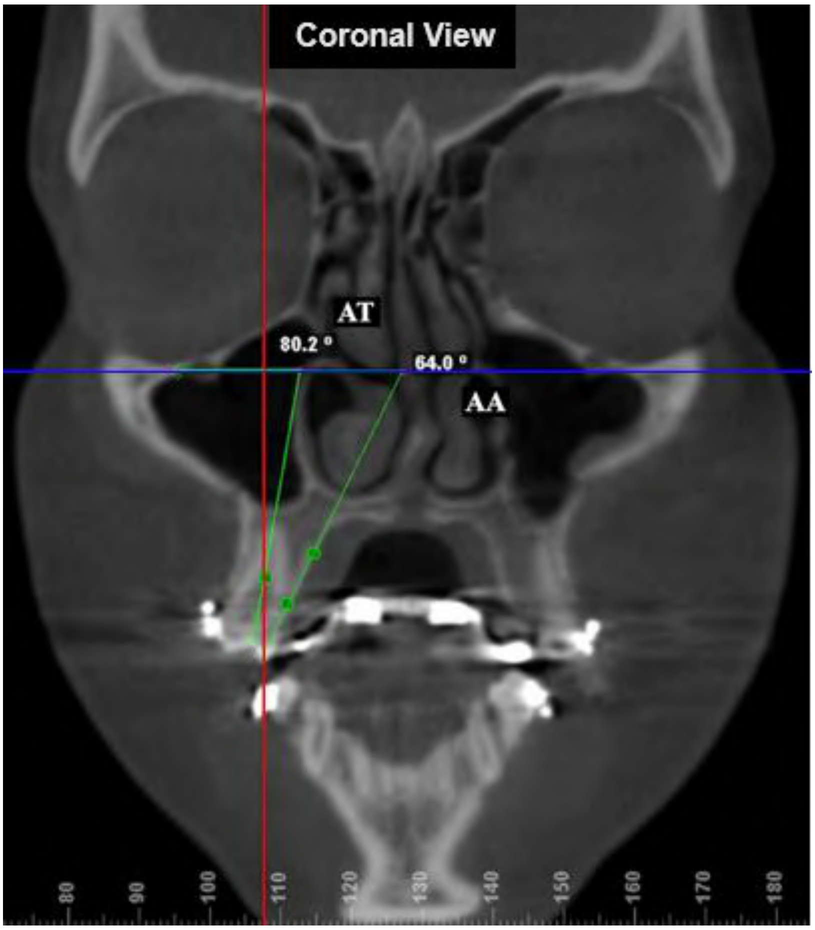


Source: Authors.

In coronal view to measure the angular values, the reference line was drawn in the deepest infra-orbital margin (blue line) and the lowest point of palatine alveolar bone.

In the coronal view, the angle between the alveolus and the long axis of the tooth was measured using the first and second premolars on both sides as references (Figure 6). The reference was the infra-orbital margin, the deepest points of the palatal alveolar process, and the lower point of the margin of the palatine alveolar bone crest. The angle between the long axis of the tooth (AT) and the angle of the alveolus were measured (AA) (Karabiber et al., 2019).

Figure 5. Measurement of the angle of the alveolus and the long axis of the tooth.



Source: Authors.

Statistical Analysis

The statistical analysis was performed using software R version 4.0.2 (R., Auckland, NZL). The intra-examiner agreement was performed using the intraclass correlation coefficient (ICC). The Mann-Whitney U test comparison of medians was used to assess possible differences between T0 and T1, right and left sides, and between PDM+ and PMD- groups. Gamma regression model was used, with the log link function. For the diagnostic analysis of residuals of the adjusted models, the half-normal probability plot with simulated envelope was used, using the "hnp" package and the graph of residuals vs. order. The adopted level of significance in all tests was 5% (p-value <0.05).

3. Results

The ICC results was satisfactory, since the coefficients ranged from 0.82 to 0.94 (Landis & Koch, 1977). Tables 1 and 2, show the results of the Mann-Whitney U test. To the left side the first premolar showed loss in alveolar bone thickness 10 mm from the cementoenamel junction, and the first molar showed loss in bone thickness 5 mm from the cementoenamel junction.

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Table 1. Evaluation of periodontal measurements of the canine, first premolar, second premolar and first molar on the **right side** of the maxilla between periods T0 and T1 of groups PMD+ and PMD-.

Tooth	Variables	PMD+			PMD-		
		T0	T1	p-value	T0	T1	p-value
		Mean (min-max)	Mean (min-max)		Mean (min-max)	Mean (min-max)	
Canine	BL	13.1 (12.5-18.9)	13.1 (12.0-13.9)	0.96	11.3 (0.0-16.8)	11.8 (0.0-18.9)	0.68
	ABT5	0.8 (0.0-1.1)	0.4 (0.0-1.4)	0.55	0.4 (0.0-1.7)	0.3 (0.0-1.8)	0.42
	ABT10	0.7 (0.2-1.2)	0.5 (0.2-0.8)	0.19	0.4 (0.0-1.6)	0.5 (0.0-1.5)	0.63
	ABT	4.6 (3.4-5.1)	4.2 (3.2-5.9)	0.62	4.2 (3.5-5.6)	4.2 (3.1-5.1)	0.99
First premolar	BL	4.7 (0.0-11.9)	5.3 (0.0-11.6)	0.80	10.1 (0.0-12.1)	9.4 (0.0-10.0)	0.90
	ABT5	0.3 (0.0-1.7)	0.3 (0.0-1.2)	0.90	1.0 (0.0-2.2)	0.7 (0.0-0.9)	0.82
	ABT10	0.2 (0.0-1.6)	0.1 (0.0-0.5)	0.37	0.6 (0.0-1.4)	0.4 (0.0-1.5)	0.71
	ABT	4.8 (3.3-5.8)	4.3 (3.3-5.1)	0.49	4.5 (3.2-5.1)	4.2 (3.5-4.8)	0.77
Second premolar	BL	9.0 (0.0-11.1)	9.5 (0.0-11.7)	0.56	9.1 (7.6-11.9)	9.9 (7.9-11.6)	0.94
	ABT5	0.7 (0.0-3.6)	0.7 (0.0-2.4)	0.85	1.5 (0.0-3.3)	2.0 (0.0-2.8)	0.70
	ABT10	1.0 (0.0-2.9)	0.8 (0.0-1.9)	0.64	1.4 (0.4-2.4)	1.5 (0.4-2.6)	0.68
	ABT	5.2 (3.5-7.1)	4.3 (3.5-5.8)	0.33	5.3 (3.5-6.5)	4.9 (3.6-5.9)	0.44
First molar	BL	9.5 (0.0-12.8)	8.9 (0.0-14.7)	0.28	9.0 (0.0-10.7)	8.8 (0.0-10.9)	0.63
	ABT5	0.6 (0.0-1.9)	0.2 (0.0-0.6)	0.42	0.9 (0.0-3.0)	0.4 (0.0-2.0)	0.28
	ABT10	0.7 (0.0-2.7)	0.3 (0.0-2.7)	0.39	0.6 (0.0-2.7)	0.3 (0.0-2.1)	0.69
	ABT	6.6 (4.2-7.5)	5.7 (4.2-6.2)	0.51	6.3 (4.2-7.5)	5.4 (4.4-6.7)	0.58

*Considered significant if <0.05. BL – Bone level. ABT – Alveolar bone thickness. ABT 5 – Alveolar bone thickness 5 mm from the cementoenamel junction. ABT10 - Alveolar bone thickness 10 mm from the cementoenamel junction. PMD+ - With pterigomaxillary disjunction. PMD - - Without pterigomaxillary disjunction.

Table 2. Evaluation of periodontal measurements of the canine, first premolar, second premolar and first molar on the **right side** of the maxilla between periods T0 and T1 of groups PMD+ and PMD-.

Tooth	Variables	PMD+			PMD-		
		T0	T1	p-value	T0	T1	p-value
		Mean (min-max)	Mean (min-max)		Mean (min-max)	Mean (min-max)	
Canine	BL	13.1 (12.5-18.9)	13.1 (12.0-13.9)	0.96	11.3 (0.0-16.8)	11.8 (0.0-18.9)	0.68
	ABT5	0.8 (0.0-1.1)	0.4 (0.0-1.4)	0.55	0.4 (0.0-1.7)	0.3 (0.0-1.8)	0.42
	ABT10	0.7 (0.2-1.2)	0.5 (0.2-0.8)	0.19	0.4 (0.0-1.6)	0.5 (0.0-1.5)	0.63
	ABT	4.6 (3.4-5.1)	4.2 (3.2-5.9)	0.62	4.2 (3.5-5.6)	4.2 (3.1-5.1)	0.99
First premolar	BL	4.7 (0.0-11.9)	5.3 (0.0-11.6)	0.80	10.1 (0.0-12.1)	9.4 (0.0-10.0)	0.90
	ABT5	0.3 (0.0-1.7)	0.3 (0.0-1.2)	0.90	1.0 (0.0-2.2)	0.7 (0.0-0.9)	0.82
	ABT10	0.2 (0.0-1.6)	0.1 (0.0-0.5)	0.37	0.6 (0.0-1.4)	0.4 (0.0-1.5)	0.71
	ABT	4.8 (3.3-5.8)	4.3 (3.3-5.1)	0.49	4.5 (3.2-5.1)	4.2 (3.5-4.8)	0.77
Second premolar	BL	9.0 (0.0-11.1)	9.5 (0.0-11.7)	0.56	9.1 (7.6-11.9)	9.9 (7.9-11.6)	0.94
	ABT5	0.7 (0.0-3.6)	0.7 (0.0-2.4)	0.85	1.5 (0.0-3.3)	2.0 (0.0-2.8)	0.70
	ABT10	1.0 (0.0-2.9)	0.8 (0.0-1.9)	0.64	1.4 (0.4-2.4)	1.5 (0.4-2.6)	0.68
	ABT	5.2 (3.5-7.1)	4.3 (3.5-5.8)	0.33	5.3 (3.5-6.5)	4.9 (3.6-5.9)	0.44
First molar	BL	9.5 (0.0-12.8)	8.9 (0.0-14.7)	0.28	9.0 (0.0-10.7)	8.8 (0.0-10.9)	0.63
	ABT5	0.6 (0.0-1.9)	0.2 (0.0-0.6)	0.42	0.9 (0.0-3.0)	0.4 (0.0-2.0)	0.28
	ABT10	0.7 (0.0-2.7)	0.3 (0.0-2.7)	0.39	0.6 (0.0-2.7)	0.3 (0.0-2.1)	0.69
	ABT	6.6 (4.2-7.5)	5.7 (4.2-6.2)	0.51	6.3 (4.2-7.5)	5.4 (4.4-6.7)	0.58

*Considered significant if <0.05. BL – Bone level. ABT – Alveolar bone thickness. ABT 5 – Alveolar bone thickness 5 mm from the cementoenamel junction. ABT10 - Alveolar bone thickness 10 mm from the cementoenamel junction. PMD+ - With pterigomaxillary disjunction. PMD - - Without pterigomaxillary disjunction.

Tables 3 and 4 shows that for the left and right sides of the AT variable, only the first molar showed no increased angulation of the alveolus between T0 and T1.

Table 3. Evaluation of changes in the angles of the second premolar and first molar on the right side of the maxilla, between the periods T0 and T1 of the groups PMD+ and PMD-.

Tooth	Variables	PMD+ T0	PMD+ T1	p-value	PMD- T0	PMD- T1	p-value
		Mean (min-max)	Mean (min-max)		Mean (min-max)	Mean (min-max)	
Second premolar	AA	76.4 (66.4-83.4)	67.2 (57.6-73.1)	0.21	75.8 (57.5-84.5)	69.6 (55.4-81.7)	0.68
	AT	75.8 (61.8-93.1)	77.2 (59.8-87.9)	0.76	86.2 (80.1-91.0)	78.4 (69.8-94.5)	0.55
First molar	AA	61.5 (51.3-76.3)	73.0 (58.7-84.7)	0.59	69.2 (66.2-80.1)	70.0 (54.1-80.0)	0.96
	AT	62.1 (54.8-69.2)	69.8 (63.7-80.4)	0.90	54.6 (51.1-78.2)	65.2 (48.3-78.1)	0.47

* Considered significant if < 0.05. AA – Angle of the longa xis of the tooth. AT – Angle of the alveolus. PMD+ - With pterigomaxillary disjunction. PMD - - Without pterigomaxillary disjunction.

Table 4. Evaluation of changes in the angles of the second premolar and first molar on the left side of the maxilla, between the periods T0 and T1 of the groups PMD+ and PMD-.

Tooth	Variable	PMD+ T0	PMD+ T1	p-value	PMD- T0	PMD- T1	p-value
		Mean (min-max)	Mean (min-max)		Mean (min-max)	Mean (min-max)	
Second premolar	AA	69.2 (63.6-80.8)	66.2 (55.0-72.9)	0.90	69.5 (57.2-76.1)	67.9 (55.5-73.9)	0.82
	AT	79.3 (66.8-93.5)	76.4 (72.2-87.3)	0.96	71.8 (60.1-77.3)	73.1 (61.4-79.8)	0.73
First molar	AA	91.5 (81.2-103.2)	97.0 (88.3-104.0)	0.42	82.4 (76.6-98.5)	95.9 (74.6-102.6)	0.16
	AT	90.2 (80.4-105.6)	93.5 (71.8-101.2)	0.77	87.2 (71.4-91.2)	93.4 (74.6-100.9)	0.42

* Considered significant if < 0.05. AA – Angle of the longa xis of the tooth. AT – Angle of the alveolus. PMD+ - With pterigomaxillary disjunction. PMD - - Without pterigomaxillary disjunction. Source: Authors.

Regarding the comparison between both sides of the maxilla, in the postoperative period, of the variables of second premolar and first molar angles, it was observed that there is no increased angulation.

Considering the postoperative period, in each tooth and on both sides of the maxilla, there were no significant differences in the variables BL, ABT5, ABT10, and ABT between groups PMD+ and PMD-. On the left side, there were differences between the group with PMD and the group without PMD, where the second premolar and first molar showed increased angulation of the alveolus.

Table 5. Evaluation of changes in angles of second premolars and first molars on both sides of maxilla between groups PMD+ and PMD-.

Tooth	Variable	Left Side PMD+	Left Side PMD-	P-Value	Right Side PMD+	Right Side PMD-	P-Value
		Mean (min-max)	Mean (min-max)		Mean (min-max)	Mean (min-max)	
Second premolar	AA	66.2 (55.0-72.9)	67.9 (55.5-73.9)	0.96	67.2 (57.6-73.1)	69.6 (55.4-81.7)	0.28
	AT	76.4 (72.2-87.3)	73.1 (61.4-79.8)	0.03*	77.2 (59.8-87.9)	78.4 (69.8-94.5)	0.79
First molar	AA	97.0 (88.3-104.0)	95.9 (74.6-102.6)	0.22	73.0 (58.7-84.7)	70.0 (54.1-80.0)	0.46
	AT	93.5 (71.8-101.2)	93.4 (74.6-100.9)	0.01*	69.8 (63.7-80.4)	65.2 (48.3-78.1)	0.76

* Considered significant if <0.05. AA – Angle of the longa xis of the tooth. AT – Angle of the alveolus. PMD+ - With pterigomaxillary disjunction. PMD - - Without pterigomaxillary disjunction. Source: Authors.

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The results also showed that, regarding the adjustment of the BL, ABT5, ABT, and ABT10, depending on the amount of expansion achieved in each patient. On the right side of the maxilla, the first premolar and first molar showed significant differences in BL, ABT5, and BL, respectively. Therefore, employing the regression coefficient, it is found that the greater the amount of expansion, the greater the bone level and the thickness loss (BL, ABT5). Regarding the left side of the maxilla, the upper canine and second premolar showed significant effects of the amount of expansion on the BL. That is, through the regression coefficient, it seems that the greater the amount of expansion the greater the loss of bone level. The other adjusted models did not show significant effects on the amount of expansion. Regarding the right and left sides, for the first molar, significant effects of the AT on BL were observed. Showing that, using the regression coefficient, it is verified that the greater the angulation of the AT, the greater the loss of bone level (Tables 6 and 7).

Table 6. Estimates of the regression coefficients of the Gamma model with log connection function for the first molar on the right side considering the BL variable.

Effect	Estimates	Standard Error	P-Value
Intercepto	2.36	0.18	<0.05*
AT	-0.05	0.02	<0.05*

* Considered significant if <0.05. AT – Angle of the alveolus. Source: Authors.

Table 7. Estimates of the regression coefficients of the Gamma model with log connection function for the first molar on the left side considering the BL variable.

Effect	Estimates	Standard Error	P-Value
Intercepto	0.63	0.47	<0.05*
AT	-0.13	0.05	<0.05*

* Considered significant if <0.05. AT – Angle of the alveolus. Source: Authors.

The other adjusted models showed no significant effects on the amount of expansion. As for the diagnosis of the adjusted models, there was no violation of the necessary assumptions, since the residuals vs order showed no trend, showing that the assumption that the residuals are independent was satisfied. The semi-normal probability plot with a simulated envelope also showed that all residuals are within the confidence bands, that is, observing an appropriate behavior, validating the results found.

4. Discussion

The aim of this study was to evaluate the effects that SARME can cause in the periodontal tissue of maxillary teeth. The results were related to the amount of expansion achieved in each patient, and the groups PMD+ and PMD-. It was not found in literature any articles that correlate all of these measurements. In our study the Mann-Whitney U test, showed significant decrease in the left side of the maxilla, in the medians between periods T0 and T1 in variable ABT10 in the first premolar and variable ABT5 in the first molar (p-value <0.05). Regarding the right side, significant decrease were noticed in the medians between periods T0 and T1 in ABT5 in the first molar and ABT in the second premolar and first molar (p <0.05).

In respect of the angulations changes before and after SARME, all variables, in their respective teeth and sides, showed significant increased angulation (p <0.05), except for the variable AT in the first molar.

Considering the group PMD+, decreased values were observed between the T0 and T1 for the variable BL in the upper first premolar, in the left side of the maxilla. And for the group PMD-, also on the left side of the maxilla, decreased values were observed between T0 and T1 for the variable BL in the first molar (p-value <0.05) It was also verified by employing the regression coefficient, that the greater the amount of expansion, the greater the loss in level and bone thickness (BL, ABT5). And, that the greater the angulation of the AT, the greater the loss of bone level.

The literature, agree with our results (Brunetto et al., 2013; Sygouros et al., 2014; Baka et al., 2015; Karabiber et al., 2019). These studies also analyzed the clinical damage caused to the periodontium in maxillary teeth after SARME and placement of Haas and/or Hyrax devices. Gauthier et al. (2011) associated the analysis with the analyzes performed on CBCTs. The data obtained by these authors demonstrated decrease in the vestibular alveolar bone in most maxillary teeth. They also showed an increase of thickness in the palatine alveolar bone, a decreased bone level in the interproximal alveolar bone between the central incisors, and loss of interdental papilla in this region (Gauthier et al., 2011). A possible hypothesis for the cause of alveolar bone loss is due to the angulation caused in these teeth by orthodontic movement (Coatoam et al., 1981; Gauthier et al., 2011; Steiner et al., 1981).

Karabiber et al. (2019) also found a statistically significant difference in the values of vestibular alveolar bone thickness in the first maxillary molars and second premolars in patients who have not undergone disjunction of the pterygomaxillary suture. These authors measured the alveolar and dental angulation, and a statistical difference was found in the values between T0-T1. This indicates a greater vestibular angulation in these regions after surgery (Karabiber et al., 2019), corroborating with the results found in our study

The surgical procedure with PMD must be justified as long as it does not pose additional risks to patients (Williams et al., 2012). But still, there are few studies in the literature that evaluate and compare skeletal and dentoalveolar changes comparing patients undergoing SARME with and without PMD (Laudemann et al., 2009; Sygouros et al., 2014; Zanutto et al., 2021). Sygouros et al. (2014) compared two groups of patients, with and without PMD. It was observed that there was a dental angulation of all posterior teeth in the post-surgical period from three to six months. Furthermore, still according to our results, it was also found that in both patient groups there was statistically significant bone loss in the thickness of the buccal alveolar bone in maxillary second molars and first molars. Bone loss was found in the first molars in the disjunction group, and in the canine without PMD. Their results suggest that if pterygoid plate disjunction is not performed, periodontal support may be compromised. (Sygouros et al., 2014).

The same results were found by Laudemann et al. (2009). The authors suggest that PMD should be performed in patients older than 20 years old, knowing that this procedure decreases alveolar bone loss and tooth tipping (Laudemann et al., 2009). Zandi et al., (2016) conducted a study comparing both SARME techniques, with and without PMD, the authors concluded that SARME without PMD is recommended due to the fact that it decreases the risk of postperative complications and has a more favorable surgical outcome (Zandi et al., 2016). Other bone structures can be affected by SARME. Recently Zanutto et al., (2021) published a study, where they performed a morphometric analysis of the pterygopalatine fossa, in patients with and without PMD. Their findings indicated a morphometric reduction of the pterygopalatine fossa after SARME, especially in the groups where PMD were performed (Zanutto et al., 2021).

Sendyk et al (2018) indicated that SARME can cause changes in the periodontal tissue, such as bone defects, reduction of the interproximal papillae, and gingival recession. The authors explore the possibility that these effects may have been caused by surgical trauma, or in the case of teeth used as support of the orthodontic appliance. (Sendyk et al., 2018). As well as the damage in periodontal tissue caused by orthodontic movement (Baka et al., 2015; Brunetto et al., 2013). Brunetto et al., (2013) performed a three-dimensional evaluation in patients submitted to orthodontic maxillary expansion and concluded that the upper teeth suffer a loss of height and thickness of the buccal alveolar bone, in addition to the vestibular angulation caused to the posterior teeth. Baka et al. (2014) also concluded that orthodontic movement for maxillary expansion caused the angulation of posterior teeth in their sample. These two studies suggested that further studies should be carried out with different activation protocols, and orthodontic appliances with different brackets. In order to explore the consequences that these different appliances may or may not cause to the supporting periodontal tissue. Based on the results of these studies it is suggested that the vestibular angulation caused in the posterior maxillary teeth by orthodontic movement may be the cause of the damage that occurred in the height and thickness of the buccal alveolar bone (Gauthier et al., 2011; Brunetto et al., 2013; Baka et al., 2015; Sendyk et al., 2018; Karabiber et al., 2019).

Clinically, the angulation caused in the teeth results in gingival recession, especially in those teeth that served as support for the orthodontic appliance (Gauthier et al., 2011; Sendyk et al., 2018). Losses in the thickness of the alveolar bone and the consequences in the height are the loss of clinical attachment and inserted gingiva (Gauthier et al., 2011; Sendyk et al., 2018). Therefore, we suggest that periodontal monitoring of the patient, with emphasis on oral hygiene, during and after treatment with SARME, is of extreme value to minimize the loss of periodontal supporting tissue in the upper teeth. And given that greater bone loss was found in patients who underwent a greater amount of expansion, we believe that patients who present bone loss before SARME and need large expansions should be properly evaluated in order not to generate significant periodontal problems in the postoperative period.

This study was limited by a small sample, however, most studies looking at patients who have undergone SARME have small sample sizes (Kilic et al., 2013; Sygouros et al., 2014; Sendyk et al., 2018; Karabiber et al., 2019) due to the specificity of this surgical procedure, and the difficulty in finding these patients. Also, the findings in CBCTs were not compared with clinical findings in our patients. Therefore, further studies correlating the CBCT and clinical outcomes, with a larger sample size, and longer follow-up are still needed.

5. Conclusion

As a conclusion, in this study it was found that after SARME there was a loss in alveolar bone thickness in upper teeth, and statistically significant bone loss. In addition, alveolar segment inclination was observed in all premolars. There were no significant differences between the groups of PMD+ and PMD-, therefore SARME without PMD could be a better option for patients, since it decreases the risk of postoperative complications. The present study also found greater bone loss in patients who underwent a greater amount of expansion.

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