Evaluation of dentoskeletal effects of surgically assisted rapid maxillary expansion using computed tomography

Avaliação dos efeitos dentoesqueléticos da expansão rápida da maxila cirurgicamente assistida por tomografia computadorizada

Evaluación de los efectos dentoesqueléticos de la expansión maxilar rápida asistida quirúrgicamente mediante tomografía computarizada

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Victor Tieghi Neto
ORCID: https://orcid.org/0000-0002-0097-0045
Barretos's Hospital of Love, Brazil
E-mail: tieghineto@gmail.com
Carolina Gachet Barbosa
ORCID: https://orcid.org/0000-0001-9861-2037
University of Sao Paulo, Brazil
E-mail: carol.gachet@usp.br
Isadora Molina Sanches
ORCID: https://orcid.org/0000-0002-0999-2523
University of Sao Paulo, Brazil
E-mail: isadoramolina@usp.br
Déborah Rocha Seixas
ORCID: https://orcid.org/0000-0002-8170-8005
University of Sao Paulo, Brazil
E-mail: deborahrocha@usp.br
Andréa Guedes Barreto Gonçales
ORCID: https://orcid.org/0000-0003-1375-2888
University of Sao Paulo, Brazil
E-mail: andreagoncales72@gmail.com
Eduardo Sanches Gonçales
ORCID: https://orcid.org/0000-0002-6682-7006
University of Sao Paulo, Brazil
E-mail: eduardogoncales@usp.br

Abstract
Introduction: Patients with transverse maxillary deficiency may have unilateral or bilateral posterior crossbite, crowded and rotated teeth and narrow palate. The treatment for adults is surgically assisted rapid maxillary expansion, a procedure that results in changes not only to bones, but also to teeth, nasal cavity, air space, lips and surrounding soft tissues. Objective: This study evaluated dentoskeletal changes in patients that underwent surgically assisted rapid maxillary expansion (SARME). Methods: Cone beam computed tomography (CBCT) scans were obtained before and after SARME. The thickness of buccal and lingual cortical bone and the angle of the long axis of posterior maxillary teeth were measured. Data were analyzed statistically. Results showed changes in thickness of buccal and lingual cortical bone and tooth movement and tipping. Conclusion: Tooth tipping increased and buccal bone thickness decreased, although osteotomies were used.
Keywords: Transverse maxillary deficiency; Surgically assisted rapid maxillary expansion; Cone beam computed tomography.

Resumo
Introdução: Pacientes com deficiência transversal da maxila podem apresentar mordida cruzada posterior unilateral ou bilateral, dentes apinhados e rotacionados e palato ogival. O tratamento para adultos é a expansão rápida da maxila cirurgicamente assistida, procedimento que resulta em alterações não somente esqueléticos, mas também nos dentes, cavidade nasal, espaço aéreo, lábios e tecidos moles circundantes. Objetivo: Este estudo avaliou as alterações dentoesqueléticas em pacientes submetidos à expansão rápida da maxila cirurgicamente assistida (ERMCA). Métodos: Tomografias computadorizadas de feixe cônico (TCFC) foram obtidas antes e após o SARME. A espessura do osso cortical vestibular e lingual e o ângulo do longo eixo dos dentes maxilares posteriores foram medidos. Os dados foram analisados estatisticamente. Os resultados mostraram mudanças na espessura do osso cortical vestibular e lingual e

movimento e inclinação do dente. Conclusão: A inclinação do dente aumentou e a espessura do osso vestibular diminuiu, embora tenham sido utilizadas osteotomias.
Palavras-chave: Deficiência transversal da maxila; Expansão rápida da maxila cirurgicamente assistida; Tomografia computadorizada de feixe cônico.

Resumen
Introducción: Los pacientes con deficiencia maxilar transversa pueden tener mordida cruzada posterior unilateral o bilateral, dientes apiñados y rotados y paladar estrecho. El tratamiento para adultos es la expansión maxilar rápida asistida quirúrgicamente, un procedimiento que produce cambios no solo en los huesos, sino también en los dientes, la cavidad nasal, el espacio aéreo, los labios y los tejidos blandos circundantes. Objetivo: Este estudio evaluó los cambios dentoesqueléticos en pacientes que se sometieron a uma expansión rápida del maxilar quirúrgicamente asistida (ERMQA). Métodos: Se obtuvieron exploraciones de tomografía computarizada de haz cónico (TCHC) antes y después de ERMQA. Se midió el grosor del hueso cortical bucal y lingual y el ángulo del eje longitudinal de los dientes maxilares posteriores. Los datos se analizaron estadísticamente. Los resultados mostraron cambios en el grosor del hueso cortical bucal y lingual y el movimiento y la inclinación de los dientes. Conclusión: Aumentó la inclinación dentaria y disminuyó el espesor óseo bucal, aunque se utilizaron osteotomías.
Palabras clave: Deficiencia transversa maxilar; Expansión maxilar rápida asistida quirúrgicamente; Tomografía computarizada de haz cónico.

1. Introduction

Some dentofacial deformities result from the underdevelopment of facial bones, particularly the maxilla and the mandible, as in the case of transverse maxillary deficiency, which is characterized by maxillary hypoplasia, high palate, crowded or rotated teeth, and unilateral or bilateral posterior crossbite (Gonçales et al., 2009).

Treatments should increase transverse dimensions, and surgically assisted rapid maxillary expansion (SARME) has achieved good results in skeletally mature individuals (de Assis et al., 2010; Lanigan & Mintz, 2002). Several surgical techniques and variations for SARME have been described (Araujo et al., 2013; Basdra et al., 1995; Bell & Epker, 1976; de Assis et al., 2011; Langlais & Langland, 2002; Schwarz et al., 1985; White & Pharoah, 2000), and some (Betts et al., 1995; Woods et al., 1997) have proven to be essential for the treatment of older patients (Anttila et al., 2004).

Studies have compared skeletal changes with and without pterygomaxillary disjunction (Ferraro-Bezerra et al., 2018; Rômulo de Medeiros et al., 2017) and concluded pterygomaxillary disjunction favors greater expansion in the posterior palatal region and increased measurements for the nasopharynx volume and oropharynx.

Previous studies using different methods (Betts et al., 1995; Betts & Lisenby, 1994; Garib et al., 2006) have confirmed that the effects of SARME are not seen only on the maxillary arch (Haas, 1961), and that dental changes (Starnbach et al., 1966) may also be expected. Facial soft tissue also changes after maxillary expansion, such as widening of the nose and increased projection in the cheek (Zupan et al., 2022). Zupan et al. (2022). An evaluation of three-dimensional facial changes after surgically assisted rapid maxillary expansion (SARME): an observational study. *BMC Oral Health*, *22*(1), 155. https://doi.org/10.1186/s12903-022-02179-1

This study evaluated dentoskeletal changes in patients that underwent surgically assisted rapid maxillary expansion (SARME).

2. Methodology

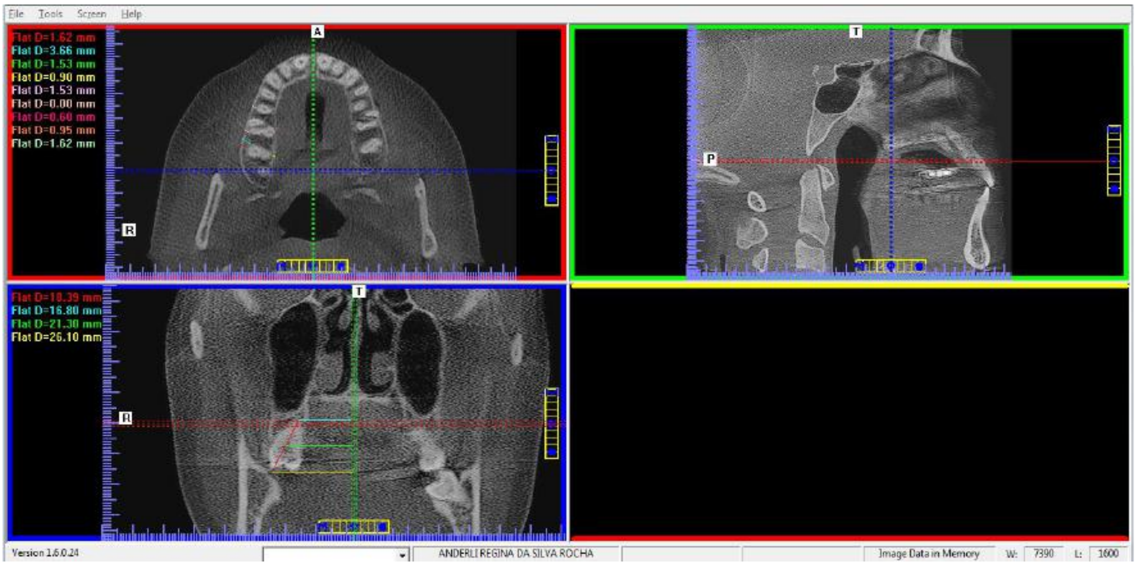
This qualitative, observational study was approved by the Ethics in Research Committee of the Bauru School of Dentistry, University of São Paulo, under no. 169/2009. It included adult individuals with transverse maxillary deficiency, an indication for SARME and no systemic disease that contraindicated the procedure. All patients underwent surgery under general anesthesia in a hospital, and the procedure consisted of a modified subtotal Le Fort I osteotomy without nasal septum osteotomy. CT scans were obtained before and 15, 60 and 180 days after surgery.

Immediately before surgery, patients underwent cone beam computed tomography (CBCT) using an i-CAT (Kavo) scanner. CT scans were also obtained 15 (PO15), 60 (PO60) and 180 (PO180) days after surgery.

After obtaining the scans, a linear measurement tool (DISTANCE) of the i-CAT Vision software was used to measure the thickness (in millimeters) of the buccal and lingual cortical bone at the level of the second molar, first molar, second premolar and fist premolar in both sides, as well as the distance between the buccal and lingual surfaces of the roots and the external portion of the cortical bone in the region. When the tooth root extended beyond the cortical layer, a value of zero was assigned to it.

For measurements, axial reformatting was standardized as described below: sagittal reformatting at the center of the incisive foramen (green line on the axial and coronal reformatting view) (Figure 1); coronal reformatting at the level of the pterygomaxillary joint (blue line on the sagittal and axial reformatting view) (Figure 1); and axial reformatting at the cervical third of the maxillary central incisor (red line on the sagittal and coronal reformatting view) (Figure 1). All the measurements described above were made according to these views.

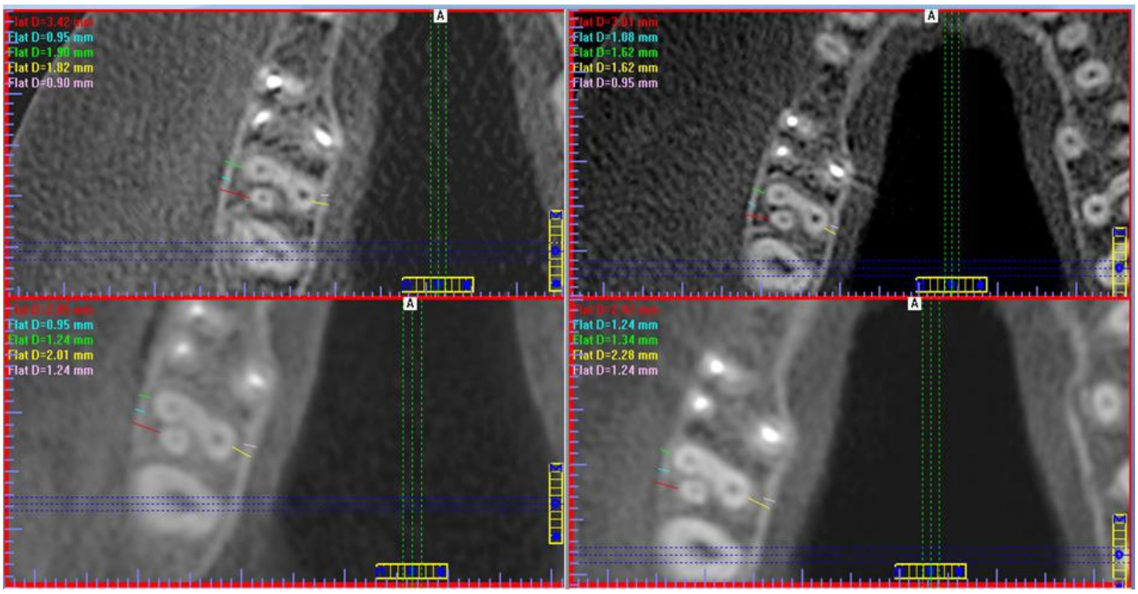
Figure 1 - Buccal and lingual bone thickness and distance of buccal and lingual surfaces from roots to external portion of buccal and lingual cortical bone (left upper corner), and tipping of long axis of tooth (left lower corner).



Source: Authors.

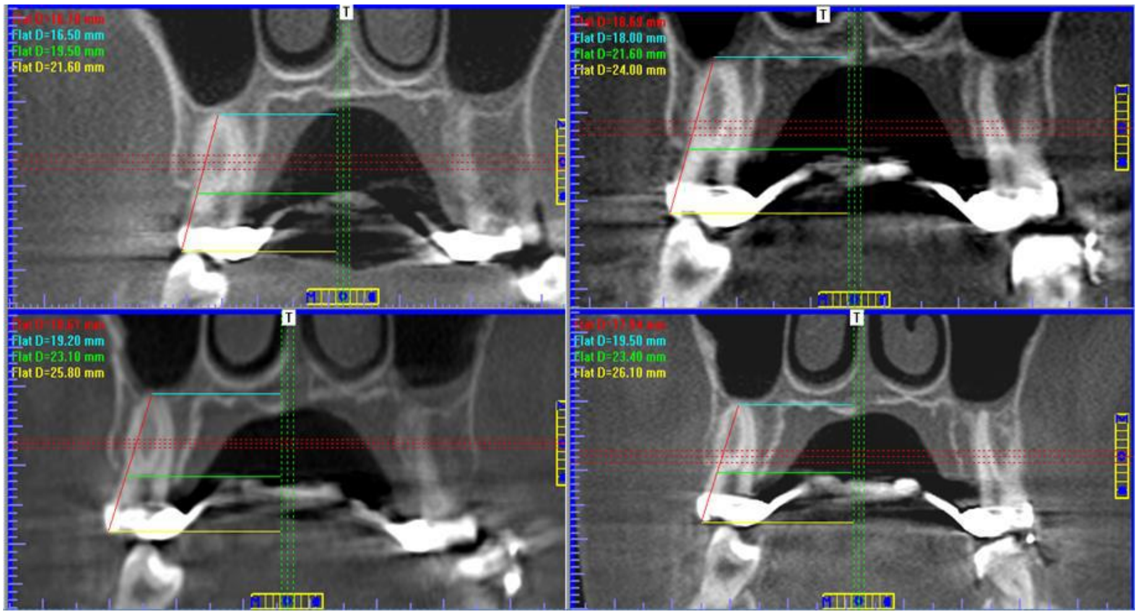
Posterior teeth and abutment teeth tipping was evaluated using the same positions standardized for the images described above; after that, a line was drawn using the DISTANCE tool from the buccal cusp to the tooth apex (long axis); perpendicular to this line, measurements were made from the apical (Apical), cervical (Cervical) and coronal (Coronal) regions of the tooth under analysis to the green line that crossed the incisive foramen and the nasal septum (fixed/standardized position) (Figure 1). Figures 2 and 3 show the sequence of distances from the roots to the cortical bone and the amount of tooth tipping at the different time points (preoperative, PO15, PO60 and PO180).

Figure 2 - Buccal and lingual bone of 2nd M in one patient: (a) Preoperative; (b) PO15; (c) PO60; (d) PO180



Source: Authors.

Figure 3 - Tooth tipping of 2nd M in one patient: (a) Preoperative; (b) PO15; (c) PO60; (d) PO180;



Source: Authors.

After data collection, values were recorded, compared between the study time points and analyzed statistically using paired analysis of variance (paired ANOVA), the Tukey test, systematic error analysis (paired t test) and random error analysis (Houston, 1983).

3. Results

Fourteen patients (9 women), whose mean age was 25.3 years (SD = 5.71 years) and who had tooth-borne (8) or tooth-tissue-borne (6) appliances, underwent preoperative CBCT, SARME and postoperative CBCT at a mean 14.9 (SD = 2) (PO15), 65.4 (SD = 9.7) (PO60) and 192 (SD = 16) (PO180) days after operation.

A total of 26 right molars (1st M = 12; 2nd M = 14), 27 right premolars (1st PM = 14; 2nd PM = 13) (Table 1), 26 left molars (1st M = 12; 2nd M = 14) and 28 left premolars (1st PM = 14; 2nd PM = 14) (Table 2) were measured. Overall, there was a reduction in buccal cortical bone thickness and an increase in lingual cortical bone thickness. However, statistical analysis revealed that reductions and increases were not significant in some specific regions.

Table 1 - Mean (mm) thickness of buccal and lingual bone at the level of roots of molars and premolars in the right side of the maxilla at the four time points under evaluation. Significance (S) p <0.05; *NS = not significant (standard deviation).

Tooth	Region	Preoperative	PO15	PO60	PO180	Significance
2nd M	**DB root**	2 (0.8)	1.93 (0.9)	1.56 (1)	1.47 (0.8)	**S**
	MB root	2.02 (0.7)	1.8 (0.9)	0.93 (0.9)	1.16 (0.7)	**S**
	B cortical bone	1.19 (0.2)	1.21 (0.3)	1.04 (0.4)	1.15 (0.4)	NS
	L root	1.35 (0.6)	1.3 (0.7)	1.68 (1)	1.61 (1.1)	NS
	L cortical bone	1.19 (0.3)	1.23 (0.3)	1.25 (0.3)	1.18 (0.4)	NS
1st M	**DB root**	1.37 (1.1)	1.17 (1.1)	0.67 (0.9)	0.27 (0.4)	**S**
	MB root	0.87 (0.7)	0.47 (0.6)	0.35 (0.6)	0.08 (0.2)	**S**
	B cortical bone	1.21 (0.5)	0.92 (0.5)	1 (0.5)	0.66 (0.6)	**S**
	L root	0.73 (0.7)	0.85 (0.7)	1.3 (1.1)	1.54 (1.1)	**S**
	L cortical bone	1.3 (0.3)	1.49 (0.4)	1.4 (0.1)	1.3 (0.3)	NS
2nd PM	**B root**	1.48 (1)	1.4 (1)	1.23 (1)	0.81 (0.9)	**S**
	B cortical bone	1.14 (0.6)	1.1 (0.7)	0.85 (0.7)	0.77 (0.6)	NS
	L root	1.9 (0.8)	2.11 (0.6)	2.32 (1)	2.51 (1.2)	NS
	L cortical bone	1.47 (0.5)	1.43 (0.4)	1.68 (0.6)	1.28 (0.6)	NS
1st PM	**B root**	0.78 (0.7)	0.7 (0.9)	0.2 (0.4)	0.37 (0)	**S**
	B cortical bone	0.68 (0.6)	0.74 (0.7)	0.17 (0.3)	0 (0)	**S**
	L root	2.2 (0.5)	2.46 (0.9)	3.19 (0.9)	2.89 (1.5)	**S**
	L cortical bone	1.59 (0.4)	1.68 (0.6)	1.99 (0.6)	1.57 (0.7)	NS

DB – distobuccal; MB – mesiobuccal; B – buccal; L – lingual; PO15 – 15 days after operation; PO60 – 60 days after operation; PO180 – 180 days after operation. Source: Authors.

Table 2 - Mean (mm) thickness of buccal and lingual bone at the level of roots of molars and premolars in the left side at the four time points under evaluation. Significance (S) p <0.05; *NS = not significant (standard deviation).

Tooth	Region	Preoperative	PO15	PO60	PO180	Significance
2nd M	**DB root**	2.04 (1.3)	1.95 (1.3)	1.74 (1.1)	1.74 (1)	NS
	MB root	1.83 (1.2)	1.73 (1.1)	1.37 (1.4)	1.62 (1.2)	NS
	B cortical bone	1.22 (0.3)	1.18 (0.2)	1.08 (0.4)	1.2 (0.2)	NS
	L root	1.41 (0.9)	1.7 (0.9)	1.84 (0.9)	1.89 (1.2)	NS
	L cortical bone	1.33 (0.4)	1.25 (0.4)	1.59 (0.5)	1.32 (0.5)	NS
1st M	**DB root**	0.95 (0.9)	0.81 (1.1)	0.39 (0.7)	0.29 (0.7)	**S**
	MB root	0.77 (1)	0.6 (0.8)	0.31 (0.6)	0.2 (0.5)	**S**
	B cortical bone	1.17 (0.4)	1.12 (0.3)	0.85 (0.6)	0.91 (0.5)	NS
	L root	0.91 (0.8)	1.13 (1)	1.59 (1.1)	2.07 (0.8)	**S**
	L cortical bone	1.44 (0.4)	1.46 (0.4)	1.44 (0.5)	1.48 (0.5)	NS
2nd PM	**B root**	1.36 (1.1)	1.29 (1)	1.15 (1.4)	1.04 (1.4)	NS
	B cortical bone	0.98 (0.7)	0.97 (0.6)	0.56 (0.6)	0.56 (0.6)	**S**
	L root	1.86 (0.7)	2.19 (0.7)	2.71 (1.5)	2.53 (0.8)	NS
	L cortical bone	1.34 (0.4)	1.49 (0.7)	1.55 (0.5)	1.57 (0.4)	NS
1st PM	**B root**	0.49 (0.7)	0.36 (0.7)	0 (0)	0 (0)	**S**
	B cortical bone	0.55 (0.6)	0.57 (0.6)	0.26 (0.5)	0.24 (0.5)	NS
	L root	1.9 (0.8)	2.58 (1)	3.49 (1.4)	3.07 (1.4)	**S**
	L cortical bone	1.32 (0.5)	1.56 (0.4)	1.62 (0.5)	1.53 (0.5)	NS

DB – distobuccal; MB – mesiobuccal; B – buccal; L – lingual; PO15 – 15 days after operation; PO60 – 60 days after operation; PO180 – 180 days after operation. Source: Authors.

The evaluation of tooth tipping in both sides revealed that tipping of abutment teeth, as well as of other teeth, was associated with expansion. In the right side, M and 1st PM had significant increases in Apical, Cervical and Coronal variables, and 2nd PM, in Cervical and Coronal values (Table 3), whereas in the left side, 2nd M had significant increases in Apical, Cervical and Coronal values, and 1st M, in all variables (Table 4).

Table 3 - Mean (mm) values indicating tooth tipping in molars and premolars in the right side at the four time points under evaluation. Significance (S) p <0.05; *NS = not significant (standard deviation).

Tooth	Region	Preoperative	PO15	PO60	PO180	Significance
2nd M	Long axis	19 (2.6)	19.8 (2.4)	19.6 (2.4)	19.2 (3)	NS
	Apical	17.4 (3.2)	17.5 (3.1)	18.1 (2.9)	18.8 (3.6)	S
	Cervical	22.5 (2.3)	23.2 (2.1)	24.1 (2.3)	24.6 (2.1)	S
	Coronal	26.6 (2.1)	28 (2)	29.8 (2.3)	29.8 (2)	S
1st M	Long axis	20.8 (3.1)	20.4 (2.6)	20.5 (2.7)	20.9 (2.3)	NS
	Apical	15.4 (4.2)	16 (4.1)	17.3 (3.5)	16.2 (6.1)	S
	Cervical	20.4 (2.3)	21.5 (2)	23.1 (1.5)	23.8 (2.2)	S
	Coronal	24 (2.2)	25.5 (2.1)	27.7 (1.8)	28.4 (1.6)	S
2nd PM	Long axis	18.2 (5.2)	19.9 (3.1)	19.8 (2.7)	19.5 (2.7)	NS
	Apical	16.8 (2)	17.1 (1.7)	17.7 (1.7)	18.2 (2.4)	NS
	Cervical	19.1 (1.5)	20.2 (1.4)	21.8 (1.4)	21.8 (1.8)	S
	Coronal	20.4 (1.8)	21.7 (2.7)	24.1 (1.5)	23.9 (2)	S
1st PM	Long axis	18.4 (3.6)	19.5 (3.6)	19.1 (3.3)	18.8 (2.5)	NS
	Apical	13.4 (2.2)	14.4 (2)	15.6 (1.9)	16.3 (2.9)	S
	Cervical	16.5 (1.6)	18 (1.5)	20.1 (1.5)	19.6 (2.2)	S
	Coronal	20.4 (3)	20.5 (2.1)	22.8 (1.7)	21.9 (1.9)	S

PO15 – 15 days after operation; PO60 – 60 days after operation; PO180 – 180 days after operation. Source: Authors.

Table 4 - Mean (mm) values indicating tooth tipping in molars and premolars in the left side at the four time points under evaluation. Significance (S) p <0.05; *NS = not significant (standard deviation).

Tooth	Region	Preoperative	PO15	PO60	PO180	Significance
2nd M	Long axis	19.5 (2.4)	19.72 (2.4)	19.63 (2.8)	19.7 (2.7)	NS
	Apical	18.7 (4.5)	19.18 (4.1)	19.77 (4.1)	20.1 (4.3)	S
	Cervical	23.3 (2.3)	24.25 (2.5)	25.11 (2.6)	23.35 (3.1)	S
	Coronal	26.8 (1.7)	28.62 (1.6)	29.87 (2.3)	29.6 (2.2)	S
1st M	Long axis	20.5 (1.9)	20.64 (1.7)	20.47 (1.8)	20.36 (1.7)	S
	Apical	15.8 (3.7)	15.82 (5)	18.52 (4)	19.08 (3.5)	S
	Cervical	20.9 (2.3)	22.58 (2.9)	24.1 (2.4)	23.97 (2.2)	S
	Coronal	24.1 (2.4)	26.44 (2.9)	27.9 (2.6)	27.51 (2.3)	S
2nd PM	Long axis	19 (2.9)	19.55 (2.5)	19.49 (2.5)	19.72 (2.8)	NS
	Apical	17.2 (1.7)	18.07 (1.7)	18.92 (2.1)	19.18 (2.1)	S
	Cervical	20.3 (2.1)	21.66 (2.1)	23.18 (2.3)	23.16 (2)	S
	Coronal	21.9 (2.6)	23.63 (2.9)	25.28 (2.9)	25.24 (2.4)	S
1st PM	Long axis	18.1 (2.8)	19.05 (2.6)	19.09 (2.5)	18.21 (3.1)	NS
	Apical	14.8 (2.5)	15.86 (2.9)	17.1 (2.5)	16.96 (2.5)	S
	Cervical	17.8 (2.1)	19.55 (2.3)	20.97 (2)	20.43 (2.2)	S
	Coronal	19.6 (2.5)	21.75 (2.7)	23.18 (2.6)	23.28 (4.5)	S

PO15 – 15 days after operation; PO60 – 60 days after operation; PO180 – 180 days after operation. Source: Authors.

The analysis of systematic error (paired t test) and random error (Dahlbert test) (Houston, 1983) did not reveal any statistically significant result for a level of significance of p<0.05.

4. Discussion

Several techniques and technical variations have been described for the treatment of transverse maxillary deficiencies in adults that undergo SARME (Basdra et al., 1995; Bell & Epker, 1976; Schwarz et al., 1985), and some (Betts et al., 1995; Woods et al., 1997) should avoid tooth tipping or movement because these movements reduce, at a greater degree, the resistance of the consolidated facial sutures, essential in the treatment of older patients (Anttila et al., 2004). However, Gonçales, 2011 demonstrated that stresses were dissipated despite the use of a subtotal Le Fort I osteotomy with a step in the zygomaticomaxillary buttress, pterygomaxillary disjunction and osteotomy of the midpalatal suture, and that teeth tipped and moved in the direction of the expansion.

As in the study conducted by Gauthier et al., 2011, who reported significant changes in cortical bone, our study also found buccal cortical bone changes associated or not with abutment teeth. These changes, identified on CBCT scans, were first confirmed at 60 days and consisted of reductions of the buccal cortical bone thickness at the level of the mesiobuccal and distobuccal roots resulting from tooth movement in the direction of expansion. Some teeth moved beyond the buccal bone limit and emerged from the bone in the buccal region.

Our results are also confirmed by Starnbach et al., 1966, who described tooth movement after SARME, and by Chung & Goldman, 2003 and Lima et al., 2011, who recorded the buccal movement of first premolars and first molars of individuals that underwent SARME.

Changes in bone layer thickness do not affect only buccal cortical bone. However, differently from Garib et al., 2006, we did not find any significant increases in lingual cortical bone thickness in any of the regions under analysis, but the distance from the lingual root to the corresponding cortical bone layer increased significantly in 50% of the specimens, which confirmed that tooth movement was associated with expansion.

Tooth movement in the cases under study here is characterized by rotations (Chung & Goldman, 2003) and tipping (Bretos et al., 2007; Chung & Goldman, 2003; Hino et al., 2008; Lima et al., 2011) resulting from the pattern of dissipation of forces applied to bones by the teeth used as abutment for the expander (Gonçales, 2011). In our study, movement was clearly demonstrated, as the values of tooth tipping (buccolingual distances) underwent significant changes, regardless of the type of appliance used (Gauthier et al., 2011; Loddi et al., 2008).

Cone beam computed tomography (CBCT) was used in our investigation because a recent study (Nada et al., 2012) has recommended it as an effective diagnostic test to follow-up the results of SARME. However, image reformatting standardization and the method to perform measurements still pose challenges to researchers. Despite that, the measurement method used in our study was reliable, as error analysis results were not significant. Therefore, CBCT was safe and useful for cases of SARME, which suggests that a reproducible method may be developed and that linear measurements may be standardized to obtain reliable results.

5. Conclusion

Although subtotal Le Fort I osteotomy, pterygomaxillary disjunction and midpalatal suture osteotomy were used, there was tooth movement in the direction of expansion, characterized by tooth tipping and buccal movement, which led to a reduction in buccal cortical bone thickness and an increase in the thickness of the lingual bone. Further studies with CT analysis are strongly recommended for more comprehensive results.

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