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Effects of lateral osteotomy on surgically assisted rapid maxillary expansion

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Abstract. This study aimed to assess the potential effects of two different osteotomy designs of the maxillary lateral wall on dental and skeletal changes after surgically assisted rapid maxillary expansion (SARME). Thirty adult patients were divided into two groups according to the lateral osteotomy design: group 1 ($n = 16$) underwent lateral osteotomy performed in a horizontal straight fashion, and group 2 ($n = 14$) underwent lateral osteotomy performed in parallel to the occlusal plane with a step at the zygomatic buttress. Cone beam computed tomography scans were obtained preoperatively (T1), immediately after expansion (T2), and 6 months after expansion (T3). Mixed analysis of variance (ANOVA) was used for the statistical analysis. The results showed no significant interaction effect between groups and time points. Therefore, maxillary expansion was effective in both groups. Statistically significant increases in all dental and skeletal measurements were observed immediately after expansion ($P < 0.001$). Relapse of the nasal floor width, tipping of the supporting teeth, and an increase in root distance in molars occurred at T3 ($P < 0.05$). In summary, the maxillary lateral osteotomy design did not influence the results of SARME, which occurred mainly through the inclination of maxillary segments.

Key words: palatal expansion technique; maxillary osteotomy; cone beam computed tomography.

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Maxillary transverse deficiency commonly affects orthodontic patients. Clinical features of this deficiency include a narrow palate, unilateral or bilateral posterior crossbite, dental crowding, and difficulty in nasal breathing.[1] Treatment depends on the degree of maxillary transverse deficiency, as well as on the patient's skeletal maturation stage.[2] Orthopaedic rapid maxillary expansion is indicated for the treatment of maxillary transverse deficiency in children and young patients.[3] Surgically assisted rapid maxillary expansion (SARME) is recommended for adult patients because it lowers suture strength during expansion.[3–6]

Achieving uniform maxillary expansion without inclination of the teeth and maxillary segments constitutes one of the main challenges of SARME therapy.[3,6] Since the early 20th century, SARME techniques have been developed in which different osteotomies are performed.[7–13] Osteotomies of the zygomatic buttress, separation of the pterygomaxillary suture, opening of the midpalatal suture, or a combination of these procedures represent the most common techniques, as they involve structures that strongly resist expansion.[4,7]

Despite the effectiveness of SARME as a treatment for maxillary transverse deficiency, the literature provides no consensus regarding the minimum amount of osteotomies required for effective expansion.[5,14,15] Nevertheless, most authors agree about the need for a zygomatic buttress osteotomy to reduce resistance to expansion.[7,8,10–13] Even this osteotomy, however, may involve different techniques with potentially distinct outcomes.[7,8,12,13,16] The most common lateral osteotomy is performed in a horizontal straight fashion, from the piriform aperture to the pterygomaxillary suture.[8] In a variation proposed by Betts et al., this procedure is performed in parallel to the occlusal plane with a vertical osteotomy (step) at the zygomatic buttress to avoid buttress interference and resistance during expansion.[12]

Several authors have evaluated the dental and skeletal changes that may occur after SARME using different approaches, such as lateral and postero-anterior radiographs,[17–19] study casts,[5,18] finite element analysis,[16,20] computed tomography,[3,15] and cone beam computed tomography (CBCT).[21,22] Three-dimensional images including CBCT allow for the evaluation of facial structures with minimal distortion and low radiation doses.[23]

This study used CBCT to assess the effects of two different maxillary lateral osteotomy designs on dental and skeletal transverse changes in patients who underwent SARME.

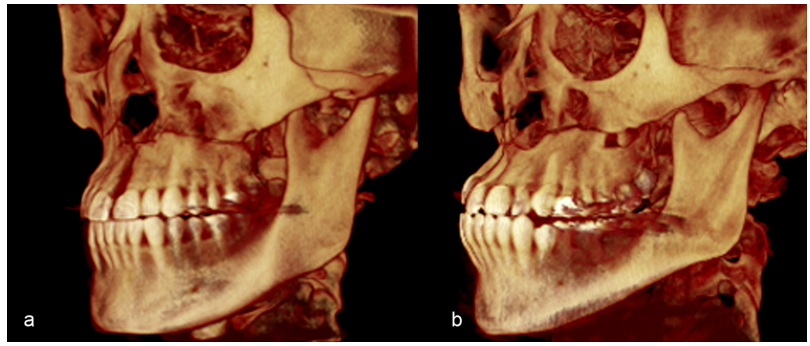

Fig. 1. Volumetric rendering from CBCT scans of patients who underwent SARME. (a) Straight osteotomy from piriform rim to pterygomaxillary suture; (b) osteotomy performed in parallel to the occlusal plane with a step at the zygomatic buttress.

Materials and methods

This retrospective study assessed the CBCT records of 30 adult patients (19 females and 11 males) who underwent SARME. The inclusion criteria were patients with a maxillary transverse deficiency of 5 mm or greater, the presence of a posterior crossbite, and SARME performed with osteotomies of the maxillary lateral walls, midpalatal suture, and separation of the pterygomaxillary suture. The exclusion criteria comprised patients with previous orthodontic treatment, cleft lip and palate, or congenital craniofacial syndromes. Surgeries were performed by two surgeons (group 1 by V.A.P.-F. and group 2 by E.S.G.) in a hospital environment under general anaesthesia, between the years of 2010 and 2012. This study was performed with ethics committee approval.

The sample was divided into two groups according to the lateral osteotomy design: group 1 included 16 patients with a mean age of 30.4 years (range 18.7–39.7 years), who underwent SARME with pterygomaxillary disjunction, midpalatal suture osteotomy, and lateral osteotomy performed in a horizontal straight fashion (Fig. 1a). Patients in this group were treated with a Hyrax type appliance and at an activation rate of one-quarter turn (0.2 mm) three times a day until the crossbite was corrected. Group 2 included 14 patients with mean age of 24.2 years (range 19.3–33.2 years), who underwent SARME with pterygomaxillary disjunction, midpalatal suture osteotomy, and lateral osteotomy performed in parallel to the occlusal plane with a step at the zygomatic buttress (Fig. 1b). In this group, patients were treated with Hyrax ($n = 8$) or Hass ($n = 6$) appliances. An initial activation of 1 mm was carried out, followed by a one-quarter turn twice a day for the first week, and after this, a one-quarter turn every day until the crossbite was corrected. In both groups, appliance activation was initiated 7 days postoperatively. After expansion, appliances were blocked and left in place for 4 months. After this period, appliances were replaced with a transpalatal arch.

CBCT scans were acquired before surgery (T1), immediately after expansion (T2), and at 6 months after expansion (T3) for each patient, using an i-CAT scanner (Imaging Sciences International, Hatfield, PA, USA) with settings of 120 kVp, 36 mA, 0.3-mm voxels, and a field of view (FOV) of 17 cm × 23 cm. CBCT images were evaluated randomly by a calibrated examiner using Dolphin 3D software (Dolphin Imaging, Chatsworth, CA, USA). The orientation of each dataset was standardized according to three reference planes using volume rendering and multiplanar views (Fig. 2). Linear and angular measurements were performed on the coronal slices at the level of the upper first molars and upper premolars to determine nasal floor width, maxillary width, distance between the

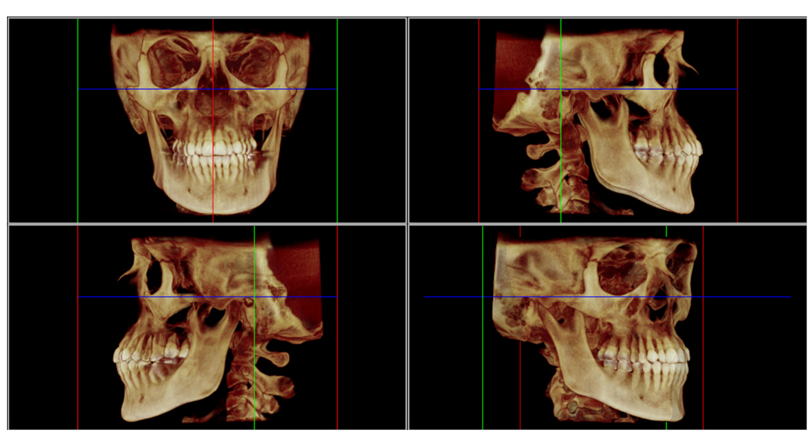

Fig. 2. Orientation and reference planes: axial plane (blue) defined by right and left orbitale and right porion landmarks; coronal plane (green) defined by right and left porions, perpendicular to the axial plane; sagittal plane (red) defined as the plane orthogonal to axial and coronal planes passing through the nasion landmark. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

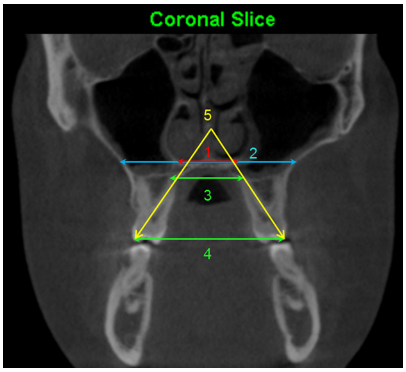

Fig. 3. Distances measured at the level of the upper first molars. (1) Nasal floor width: measured at the most inferior level of the nasal floor. (2) Maxillary width: distance between maxillary lateral walls at the level of the nasal floor. (3) Interradicular width: distance between the apex of the palatal roots of the right and left molars. (4) Intermolar width: the distance between the mesiobuccal cusps of the right and left molars. (5) Intermolar angle: angle between the lines passing through mesiobuccal cusp and palatal root apex of the right and left molars.

palatal root apices, and distance between the buccal cusps and tooth tipping (Figs 3 and 4).

Eighteen CBCT images were chosen at random and assessed twice by the same calibrated examiner, with an interval of at least 30 days. Reliability was confirmed by the intra-class correlation coefficient (ICC), which ranged from 0.984 to 0.998.

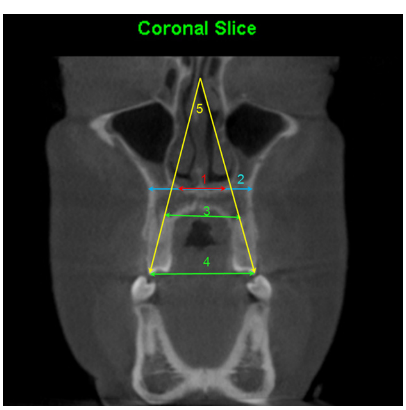

Fig. 4. Distances measured at the level of the first premolars. (1) Nasal floor width: measured at the most inferior level of the nasal floor. (2) Maxillary width: distance between maxillary lateral walls at the level of the nasal floor. (3) Interradicular width: distance between the apex of the palatal roots of the right and left premolars. (4) Interpremolar width: distance between the buccal cusps of the right and left premolars. (5) Interpremolar angle: angle between the lines passing through the buccal cusp and root apex of the right and left premolars.

The Shapiro-Wilk and Levene tests were used to investigate assumptions of normality and equality of variances between groups. Once these assumptions were confirmed, the Student's *t*-test was used to compare the amount of expansion between groups 1 and 2, the differences in expander appliances used in group 2, and differences between the anterior and posterior maxillary regions. The non-parametric Mann–Whitney test was used for the data that did not fit normality.

Longitudinal changes between time points for both groups were evaluated using a mixed analysis of variance (ANOVA) for repeated measures, with Greenhouse–Geisser adjustment for violation of sphericity. In the case of statistically significant results, the Bonferroni multiple comparison test was used to assess differences between groups and time points. The association between expander opening and dentoskeletal changes was investigated using the Pearson correlation coefficient. The data analysis was performed using SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA) with a significance level of 5% ($\alpha = 0.05$).

Results

The average expansion in group 1 was 8.00 mm (standard deviation (SD) 1.64 mm) and in group 2 was 8.16 mm (SD 1.24 mm), with no significant difference between them ($P = 0.764$). No statistically significant differences were found between time points with the Hass and Hyrax appliances used in group 2 (Table 1), thus the entire group 2 ($n = 14$) was used as a single sample for the analyses.

Mixed-design ANOVA revealed no significant interaction effects between groups over time points for any dental or skeletal measurements in this study ($P > 0.05$). There were no differences between groups regarding the expansion of dental and skeletal measurements ($P > 0.05$). However, changes over time points were significant for all measures ($P < 0.001$), as shown in Table 2.

The lack of interaction effects indicated comparable patterns of change for the two groups. Thus, both groups were pooled for pairwise comparisons, which revealed a significant increase in all measures assessed post-expansion (T2–T1, $P < 0.001$). Significant differences between time points T2 and T3 were found for the distance between the palatal root apices in molars, intermolar angle, nasal floor width at the level of premolars, and interpremolar angle (Table 3).

Skeletal expansion measured by the nasal floor width and maxillary width at the level of the upper molars and premolars showed significant differences between T1 and T2 ($P < 0.001$). However, a decrease in nasal floor width (0.29 mm) was observed between T2 and T3 ($P = 0.017$) when assessed at the premolar level, which represented an average relapse of 4.8% in this measure. Dental expansion measured at the level of the palatal root apices and buccal cusps showed significant differences post-expansion for molars and premolars ($P < 0.001$). The distance of root apices of first molars increased by 1.28 mm in the retention period ($P < 0.001$), whereas no significant change was observed in the distance of buccal cusps for these teeth ($P = 0.409$). Increases in tooth tipping were observed after expansion for molars (11.42°) and premolars (10.44°) as a result of SARME. However, a decrease in these angles was observed between T2 and T3 ($P < 0.05$) (Table 3).

The difference in post-expansion maxillary width (T2–T1) was greater at the first premolar level (2.87 mm, SD 1.82) than at the first molar level (0.97 mm, SD 0.80) ($t = 5.26$; df = 39.7; $P < 0.001$). However, the expansion measured in the nasal floor was not significantly different between the two regions ($P = 0.103$). The amount of expansion in the cusps of first molars (7.47 mm, SD 2.02) was similar to that obtained in the cusps of first premolars (7.71 mm, SD 2.00) ($t = 0.481$; df = 58; $P = 0.632$). This result indicates that parallel expansion occurred when assessed at the coronal level of appliance-supporting teeth. Similar results were found for measurements at the level of the palatal root apex ($P = 0.315$).

The results revealed greater expansion in the most inferior region of the maxilla, where dental expansion corresponded to 90% of expander opening in the first molars and 96% in the first premolars. At the level of the root apex these expansions corresponded to 43% and 51%, while in the maxillary width they only accounted for 11% and 34%, and in the nasal floor width for 17% and 23% of the appliance opening in the molar and premolar regions, respectively. Overall, these results translate into maxillary segment tilting (Fig. 5).

Correlations were observed only between the amount of expander opening and dental changes. The distance between the cusps of molars and premolars after expansion showed high correlations with expander opening. Moderate

Table 1. Comparison of dentoskeletal changes at the level of the first molars and first premolars using Haas and Hyrax appliances.

	T1			T2–T1		
	Haas ($n = 6$) Mean (SD)	Hyrax ($n = 8$) Mean (SD)	*P*-value	Haas Mean (SD)	Hyrax Mean (SD)	*P*-value
First molars						
Nasal floor width (mm)	22.80 (4.05)	22.98 (2.65)	0.918	0.97 (2.00)	1.51 (0.68)	0.484
Maxillary width (mm)	64.30 (8.78)	59.51 (5.69)	0.239	0.67 (0.35)	1.07 (0.72)	0.230
Interradicular width (mm)	31.93 (6.40)	32.21 (5.93)	0.934	3.18 (2.18)	4.08 (1.85)	0.418
Intermolar width (mm)	46.51 (4.33)	46.09 (3.91)	0.849	8.48 (2.54)	6.74 (1.41)	0.125
Intermolar angle (°)	47.83 (4.86)	41.07 (15.40)	0.422	12.85 (5.02)	7.85 (4.62)	0.126[a]
First premolars						
Nasal floor width (mm)	17.81 (1.79)	18.81 (2.14)	0.376	1.38 (0.73)	2.00 (1.08)	0.255
Maxillary width (mm)	37.63 (4.11)	34.77 (5.26)	0.293	2.06 (1.30)	3.10 (1.22)	0.154
Interradicular width (mm)	33.02 (3.83)	29.52 (4.09)	0.302[a]	3.10 (2.99)	4.70 (2.77)	0.322
Interpremolar width (mm)	36.95 (3.51)	37.95 (4.01)	0.636	8.90 (2.16)	6.73 (2.34)	0.101
Interpremolar angle (°)	17.30 (4.23)	25.11 (14.23)	0.318	11.87 (4.41)	7.22 (4.65)	0.129

T1, before surgery; T2, immediately after expansion; SD, standard deviation.
[a] Mann–Whitney non-parametric test.

correlations were found for tooth tipping changes, while the distance of root apices showed low correlation for the first molars and no correlation between the distance of root apices of the premolar and the appliance opening. No correlations were found between maxillary expansion measurements and the amount of expander appliance opening (Table 4).

Discussion

SARME is a safe, effective, and stable procedure for the treatment of maxillary transverse deficiency.[11,18,19] However, one of the main challenges of SARME therapy is the achievement of uniform maxillary expansion without inclination of the teeth and maxillary segments.[3,6] Several types of maxillary osteotomy have been performed in association with SARME to promote greater maxillary release and a reduction in tipping.[3] In this study, the influence of maxillary lateral osteotomy design on dental and skeletal changes after SARME was assessed.

Assessments made immediately and 6 months after expansion did not show any osteotomy-design-dependent differences in SARME outcome. Both osteotomies

Table 2. Dentoskeletal variables at the level of the first molars and first premolars before surgery (T1), immediately after expansion (T2), and 6 months after expansion (T3). Results of mixed ANOVA for comparison between groups and time points.

	Group[a]	Time points[b]			ANOVA (*P*-values)		
		T1	T2	T3	Time	Group	Group × time
First molar							
Nasal floor width (mm)	G1	22.77 (4.05)	24.21 (4.61)	24.09 (4.64)	<0.001[c]	0.966	0.807
	G2	22.91 (3.18)	24.19 (2.84)	24.16 (2.93)			
Maxillary width (mm)	G1	61.54 (4.99)	62.58 (4.78)	62.40 (4.69)	<0.001[c]	0.972	0.793
	G2	61.56 (7.29)	62.46 (7.01)	62.26 (6.99)			
Interradicular width (mm)	G1	32.98 (3.55)	36.30 (3.33)	37.51 (3.61)	<0.001[c]	0.710	0.608
	G2	32.09 (5.89)	35.79 (5.04)	37.14 (4.55)			
Intermolar width (mm)	G1	49.56 (4.99)	57.01 (5.77)	56.20 (5.36)	<0.001[c]	0.096	0.409
	G2	46.27 (3.94)	53.76 (4.29)	53.73 (4.47)			
Intermolar angle (°)	G1	47.74 (11.63)	61.06 (13.92)	55.48 (13.90)	<0.001[c]	0.214	0.176
	G2	43.32 (12.97)	52.84 (13.63)	49.53 (12.11)			
First premolar							
Nasal floor width (mm)	G1	16.83 (3.52)	19.00 (3.66)	18.58 (3.77)	<0.001[c]	0.219	0.527
	G2	18.39 (1.99)	20.12 (2.00)	19.95 (2.20)			
Maxillary width (mm)	G1	37.08 (5.19)	40.17 (5.14)	39.84 (4.93)	<0.001[c]	0.464	0.675
	G2	36.00 (4.85)	38.66 (4.96)	38.44 (4.84)			
Interradicular width (mm)	G1	31.51 (3.22)	35.55 (3.15)	35.51 (3.38)	<0.001[c]	0.804	0.662
	G2	31.02 (4.23)	35.04 (4.86)	35.49 (4.38)			
Interpremolar width (mm)	G1	38.01 (3.25)	45.78 (4.08)	45.21 (3.33)	<0.001[c]	0.721	0.756
	G2	37.52 (3.70)	45.18 (3.05)	45.01 (3.01)			
Interpremolar angle (°)	G1	19.28 (10.85)	31.40 (11.11)	28.51 (10.92)	<0.001[c]	0.792	0.208
	G2	22.50 (14.25)	31.28 (12.88)	28.85 (13.16)			

ANOVA, analysis of variance.
[a] G1 and G2: lateral osteotomy design groups. G1 (group 1), lateral osteotomy without step at the zygomatic buttress; G2 (group 2), lateral osteotomy with a step at the zygomatic buttress.
[b] Time point numbers represent means and standard deviations. T1, before surgery; T2, immediately after expansion; T3, 6 months after expansion.
[c] Values are significant at $P < 0.05$.

Table 3. Results of Bonferroni multiple comparison tests applied between time points (pooled groups).

	Time point comparison	Mean difference	SE	*P*-value	95% CI	
					Lower	Upper
First molar						
Nasal floor width (mm)	T2–T1	1.36	0.25	<0.001[a]	0.73	1.99
	T3–T2	–0.07	0.08	1.000	–0.27	0.13
	T3–T1	1.29	0.22	<0.001[a]	0.74	1.84
Maxillary width (mm)	T2–T1	0.97	0.15	<0.001[a]	0.59	1.35
	T3–T2	–0.19	0.11	0.271	–0.48	0.09
	T3–T1	0.78	0.14	<0.001[a]	0.42	1.13
Interradicular width (mm)	T2–T1	3.50	0.30	<0.001[a]	2.73	4.28
	T3–T2	1.28	0.20	<0.001[a]	0.77	1.79
	T3–T1	4.79	0.32	<0.001[a]	3.97	5.60
Intermolar width (mm)	T2–T1	7.47	0.38	<0.001[a]	6.51	8.43
	T3–T2	−0.42	0.27	0.409	−1.12	0.28
	T3–T1	7.05	0.37	<0.001[a]	6.10	7.99
Intermolar angle (°)	T2–T1	11.42	1.13	<0.001[a]	8.51	14.32
	T3–T2	–4.44	0.91	<0.001[a]	–6.75	–2.13
	T3–T1	6.98	0.97	<0.001[a]	4.48	9.47
First premolar						
Nasal floor width (mm)	T2–T1	1.95	0.27	<0.001[a]	1.25	2.65
	T3–T2	–0.29	0.10	0.017[a]	–0.54	–0.04
	T3–T1	1.66	0.25	<0.001[a]	1.02	2.30
Maxillary width (mm)	T2–T1	2.87	0.34	<0.001[a]	2.01	3.73
	T3–T2	–0.28	0.17	0.368	–0.72	0.17
	T3–T1	2.60	0.35	<0.001[a]	1.70	3.50
Interradicular width (mm)	T2–T1	4.03	0.43	<0.001[a]	2.91	5.14
	T3–T2	0.21	0.20	0.969	–0.32	0.73
	T3–T1	4.23	0.43	<0.001[a]	3.15	5.31
Interpremolar width (mm)	T2–T1	7.71	0.37	<0.001[a]	6.76	8.66
	T3–T2	–0.37	0.22	0.302	–0.92	0.18
	T3–T1	7.34	0.34	<0.001[a]	6.47	8.22
Interpremolar angle (°)	T2–T1	10.44	1.05	<0.001[a]	7.75	13.14
	T3–T2	–2.66	1.01	0.042[a]	–5.23	–0.08
	T3–T1	7.89	0.96	<0.001[a]	5.33	10.24

SE, standard error; CI, confidence interval; T1, before surgery; T2, immediately after expansion; T3, 6 months after expansion.
[a] Values are significant at $P < 0.05$.

were effective in dental and skeletal expansion, although tipping movements of the maxillary segments occurred. Tilting patterns after maxillary expansion were similar to those reported by Daif, who found greater expansion in the anterior and lower maxillary regions.[3]

According to de Assis et al., the step in the zygomatic buttress and the pterygomaxillary suture release decrease the harmful stress dissipation during SARME.[16] The authors used finite element analysis to simulate 1 mm of appliance activation. Therefore, they could only assess the stresses produced at the beginning of SARME, but not clinical situations, which require further expansion.

Skeletal changes resulting from SARME included increases in maxillary width and nasal floor width at the level of the first molars and first premolars. Several authors have reported maxillary expansion, albeit with great variation in the amount of expansion.[6,17–19,21,22,24] In this study, an average maxillary expansion at the level of the first molars and premolars of 0.97 and 2.87 mm, respectively, was found. Byloff and Mossaz observed 1.31 mm of expansion[19] and Gurgel et al. reported an increase of 4.25 mm in maxillary width,[17] while Magnusson et al. found 2.63 mm.[22] These inconsistencies in measures can be explained by great individual variability, by the use of different methodologies including radiographic methods[17–19] and CBCT,[6,21,22,24] and by the maxillary region assessed in each method. The tipping of maxillary segments generates smaller changes in maxillary width in the upper regions of the maxilla, below the lateral osteotomy. In this study, the lower region of the nasal floor was used as a reference for measurements of maxillary width, explaining the lower values found.

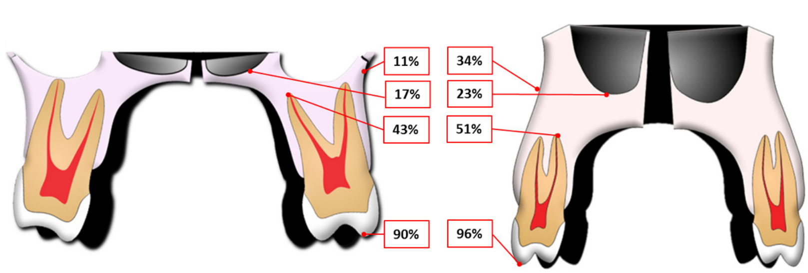

Fig. 5. Schematic drawing representing the lateral rotation of the maxillary segments at the level of the first molars and first premolars.

Skeletal changes were stable in the short term after the removal of the expander appliance, except for the nasal floor width in the premolar region, which decreased significantly between T2 and T3

Table 4. Pearson's correlation coefficient (r) between expander appliance opening and variable changes observed after expansion (T2–T1).

Variable	r	P-value
First molars		
Nasal floor width (mm)	0.146	0.449
Maxillary width (mm)	0.052	0.787
Interradicular width (mm)	0.382	0.041[a]
Intermolar width (mm)	0.852	<0.001[a]
Intermolar angle (°)	0.569	<0.001[a]
First premolars		
Nasal floor width (mm)	0.185	0.356
Maxillary width (mm)	0.321	0.090
Interradicular width (mm)	0.215	0.262
Interpremolar width (mm)	0.701	<0.001[a]
Interpremolar angle (°)	0.457	0.013[a]

T1, before surgery; T2, immediately after expansion.
[a] Values are significant at $P < 0.05$.

(−0.29 mm, SD 0.54; $P = 0.017$). The standard deviation reflects a wide individual variation in the amount of relapse observed: 23% of the sample had more than 0.5 mm of relapse, whereas 7% showed an increase in nasal floor width greater than 0.5 mm. Among patients, 70% had changes of less than 0.5 mm, which bear no clinical consequence. Chamberland and Proffit reported similar results,[18] whereas Gurgel et al. did not observe changes in nasal floor width at any time during their study.[17]

The transverse movement of maxillary segments at the lateral osteotomy level displayed individual variation. Expansion movements were observed, as well as inward movements of the maxillary segment, regardless of the osteotomy design (Fig. 6). These movements may reflect an inward sliding of the maxillary wall during expansion, as reported by Chamberland and Proffit.[18] Despite the inward sliding movement observed, the final expansion was not affected.

Increased inter-tooth and interradicular distances for the appliance-supporting teeth between time points T1 and T2 was an expected effect, reported by other authors.[17,19,21] However, correction tendencies in root inclination of the first molars were observed after removal of the expander appliance. The distance between first molar palatal root apices increased, whereas no significant changes in crown position were observed for these teeth. The transpalatal bar probably prevented molar crown relapse. These combined effects contributed to correct first molar buccal tipping, corroborating previous findings.[19] The root and crown movement of first premolars, although not significant, may have led to the correction of the excessive buccal tipping of these teeth. Changes in dental tipping may have occurred due to muscle action, occlusal stabilization, or due to the beginning of fixed orthodontic treatment after expander removal, which could not be controlled given the retrospective nature of this study. These results contradict the findings of Gurgel et al., who reported no dental tipping during the retention period.[17] However, these authors performed the last assessment at 4 months post-expansion and the expander appliances were still in place.

Long-term relapse was not assessed in this study because all patients were still in orthodontic treatment at T3. Due to the lack of short-term differences between the lateral osteotomies, it is difficult to determine which one provides the best long-term results. However, long-term studies have shown that relapses continue to occur after orthodontic treatment, but that almost all of the relapse appears to be dental, not skeletal,[18] and it is most pronounced during the first 3 years post-treatment.[25]

The parallel tooth expansion observed for first molars and first premolars is in agreement with other studies,[18,26] and may have occurred due to the use of tooth-borne appliances. Dental expansion and dental tipping measurements correlated with the amount of expander opening; however, this opening did not correlate with the amount of skeletal expansion observed. Thus, there was no correlation between dental and skeletal expansion for the maxillary posterior region ($r = 0.016$, $P = 0.932$) or for the maxillary anterior region ($r = 0.282$, $P = 0.132$), confirming that SARME promotes maxillary tilting, with teeth expanding more than the basal bone. Similar results were reported by Goldenberg et al.[6] and Chamberland and Proffit.[18]

Assessing expander efficacy was not a central objective of this study, but no differences between the types of expander appliance used in group 2 were observed, which justified the inclusion of patients with either device in this group. Similar results regarding the two appliances have been reported previously.[27] The different activation rates could be construed as a study limitation, but in fact did not seem to affect expansion features. The literature is not clear about the optimal activation rate, which ranges from 0.25 to 1.0 mm per day.[4] According to Cureton and Cuenin, the activation rate should be customized to each patient and adjusted according to the symmetry of the bony fracture and the condition of the gingival attachment between the central incisors.[28]

This study showed no differences in dental and skeletal transverse changes related to lateral osteotomy design during SARME. Lateral osteotomies with and without a step at the zygomatic buttress are both effective for maxillary expansion, which mainly occurs by tilting of the two maxillary halves.

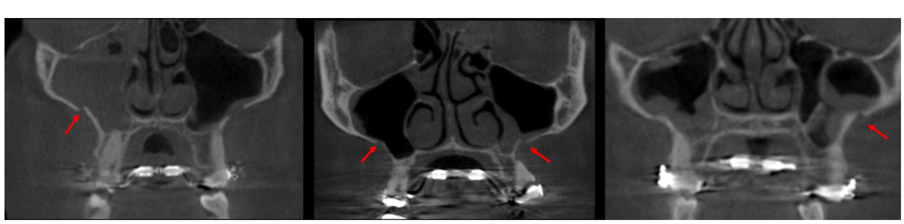

Fig. 6. CBCT images showing inward movement of the lateral wall of the maxilla after SARME.

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Competing interests

The authors have no conflicts of interest.

Ethical approval

Approved by the Ethics Committee of Araraquara School of Dentistry, under protocol number CAAE 14484713.1.0000.5416.

Patient consent

Not required.

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