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Three-dimensional evaluation of surgically assisted asymmetric rapid maxillary expansion

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Introduction: Unilateral posterior crossbite is classified as true unilateral posterior crossbite (TUPC) or functional posterior crossbite (FPC). The differential diagnosis between TUPC and FPC is of utmost importance for the decision of expansion protocol because conventional expansion methods have some shortcomings for TUPC. The aim of this retrospective study was to 3-dimensionally evaluate the effects of asymmetric rapid maxillary expansion combined with unilateral osteotomy. **Methods:** This study sample comprised 16 patients (mean age 18.38 ± 1.45) with TUPC. A Hyrax acrylic cap included the maxillary premolars and molars on the constricted side, and all teeth up to the central incisor were included on the other side to increase anchorage. Unilateral surgically assisted rapid maxillary expansion was performed and included anterior (aperture piriformis), lateral (zygomatic buttress), and posterior (pterygomaxillary junction) osteotomies on the constricted side and separation of the midpalatal suture. Cone-beam computed tomographic scans taken just before the operation and after 6 months of retention were used to assess skeletal, dental, and periodontal changes. **Results:** Expansion was seen on both sides; however, the amount of expansion and tipping was higher on the osteotomy+ side. Because the canines were not included in the acrylic cap on the osteotomy+ side, they did not present the same amount of tipping as the ipsilateral posterior teeth. More teeth were affected periodontally on the osteotomy− side; however, there were no clinically significant differences between the osteotomy+ and osteotomy− sides (mean differences range +0.54 to −0.57 mm). The aperture piriformis width increased significantly on the osteotomy+ side. **Conclusions:** The treatment mechanics had no clinically detrimental effects on the supporting alveolar bone of the maxilla on either side, and it was thought to be effective in cases with TUPC; however, case selection is crucial. (Am J Orthod Dentofacial Orthop 2019;155:620-31)

Posterior crossbite is a prevalent malocclusion that occurs in the presence of maxillary transverse deficiency. Its etiology is multifactorial. Etiologic factors include nasal airway obstructions (enlarged tonsils and adenoids),[1] long-term pressure on the palatal area (sucking habits),[2] abnormal swallowing habits,[3] occlusal interferences that lead to a mandibular shift, cleft lip and palate, malformations in the head and neck area, juvenile rheumatoid arthritis, unilateral condylar abnormalities, long-term use of a pacifier, a decrease in muscular tonus, and mouth breathing.[4]

Posterior crossbite can be classified as skeletal, dental, or functional. It can also be either unilateral or bilateral.[5] Unilateral posterior crossbite can be divided into 2 groups as true unilateral posterior crossbite (TUPC) and functional posterior crossbite (FPC),[6] which have different characteristics and treatment modalities.[6,7] From 67% to 79% of unilateral posterior crossbites are functional, and they occur as a result of bilateral maxillary constriction and occlusal interferences, which lead the mandible to shift for maximum intercuspidation.[8-10] During intercuspidation, upper and lower midlines do not coincide, whereas with the open-mouth position upper and lower midline coincidence is observed.[8,11] Bilateral maxillary expansion is recommended for the treatment. Untreated FPC may morphologically change into TUPC

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over time,[12] which presents deformed and collapsed arch shape on the constricted side and no change in the midline coincidence during the opening and closing of the mouth.[13-16] This situation, which is hereafter a skeletal problem, can result in an asymmetry to different degrees in the face. In addition, some TUPC cases might be caused by the condylar hyperplasia, condylar hypoplasia, or condylar resorption in one side which leads to mandibular asymmetry. Moreover, an asymmetric maxillary arch form might be a reason for TUPC.[8,11,12] Therefore, cases with an asymmetric maxillary arch form with or without a mild mandibular asymmetry might require asymmetric maxillary expansion to prevent nonocclusion on the noncrossbite side. These features should be determined carefully during the clinical examination to decide on a precise treatment plan.

Several methods and asymmetric expansion appliances are reported in the literature for asymmetric maxillary expansion. Options include the following: leaving the crossbite as it is[16]; using cross-elastics on the noncrossbite side with or without conventional (bilateral) rapid maxillary expansion (RME)[6,13,17-19]; using a removable expansion appliance[6,18,20] that is divided asymmetrically or combined with acrylic extensions to resist lateral movement on the noncrossbite side (such as a Nord[13] appliance); applying an asymmetric rapid maxillary expansion appliance[21] or a quad-helix appliance with a vertically extending stopper on the crossbite side (known as asymmetric bihelical expansion)[22]; and asymmetric maxillary expansion.[16] However, none of these methods alone are sufficient to solve TUPC in adults. Forces during RME are directed to the maxillary bone through the teeth.[23] If the sutural opening does not occur as a result of the resistance created by circummaxillary structures and midpalatal suture fusion, some unwanted side-effects (such as buccal tipping, root resorption, decrease in buccal alveolar bone thickness, or marginal bone loss) might be seen because of high forces.[24-26] Clinicians can overcome all of these side-effects and limitations in adults with the assistance of surgically assisted rapid maxillary expansion (SARME). Some researchers have performed different types of osteotomies on the constricted sides, combined with different types of expansion appliances in adults with TUPC, and reported successful results.[19,20,27-32] The effects of these methods have been 2-dimensionally analyzed[33] with the help of posteroanterior cephalograms,[16,19,34] study models,[16,20,31] and lateral cephalograms.[19,34]

To the best of our knowledge, no previous study has evaluated the skeletal, dental, and periodontal effects of unilateral SARME with the use of cone-beam computed tomography (CBCT). The aim of the present study was to evaluate the effectiveness of asymmetrically designed hyrax appliance combined with unilateral osteotomy on the constricted side in adults with TUPC.

MATERIAL AND METHODS

CBCT images used in this retrospective study were collected from the archives of the Department of Orthodontics, Marmara University, Faculty of Dentistry, Istanbul, Turkey. This study was approved by the Ethical Committee of the Faculty of Dentistry, Marmara University. Ten patients were required for a power of 95% reliability. To increase the power of the study, 16 patients (8 female, 8 male; mean age 18.38 ± 1.45 years) participated, with the following inclusion criteria: older than 17 years, absence of mandibular shift laterally, TUPC with asymmetric maxillary arch form, treated with unilateral SARME, absence of craniofacial abnormalities and serious medical conditions, and presence of all records from before and 6 months after expansion (intraoral and extraoral photographs and CBCTs).

The routine protocol of our clinic in TUPC was to apply the asymmetrically designed hyrax appliance that covered all teeth through the upper midline on the noncrossbite side to strengthen the anchorage, whereas premolars and molars were included on the constricted side with the purpose of asymmetrical expansion (Fig 1). In addition, unilateral SARME, which included anterior (aperture piriformis), lateral (zygomatic buttress), and posterior (pterygomaxillary junction) osteotomies on the constricted side and separation of midpalatal suture, were performed for more efficient expansion (Fig 2). The surgical technique used in our patients followed the protocol described by Mossaz et al.[28] After a 5-day latency period, the expansion was performed twice daily (0.5 mm/d). The amount of expansion achieved varies between patients and was performed according to each individual's need for correcting the existing maxillary deficiency. The appliance was kept for 6 months for retention purpose.

CBCT images taken initially (T0) and 6 months after expansion (T1) were used for the assessment. CBCT images were obtained in the natural head position (x-ray tube 120 kV, scanning time 40 seconds maximum and 7.8 seconds minimum, field of view 14.2 × 21.1 cm, voxel size 0.0936 mm) with the Iluma Imtec Imaging machine (3M, Ardmore, Okla). MIMICs version 19.0 software (Materialise Europe, Leuven, Belgium) was used to perform 3-dimensional analysis, and 3 reference planes were constructed for the measurements (Fig 3). The Frankfort horizontal plane (FHP) was created between the right porion, the left porion, and the right orbitale.

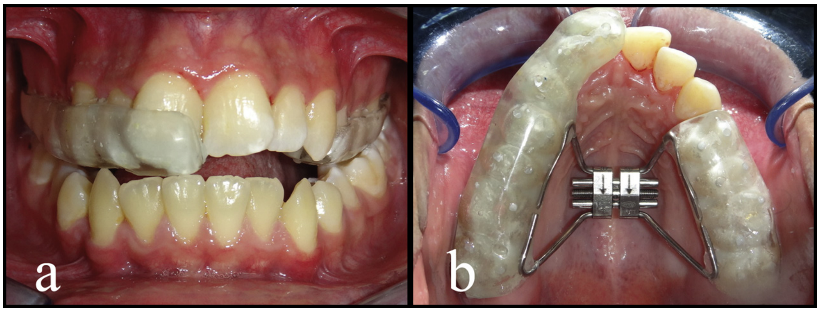

Fig 1. Asymmetrically designed hyrax appliance.

Fig 2. Anterior, lateral, posteriorm and midpalatal suture osteotomies.

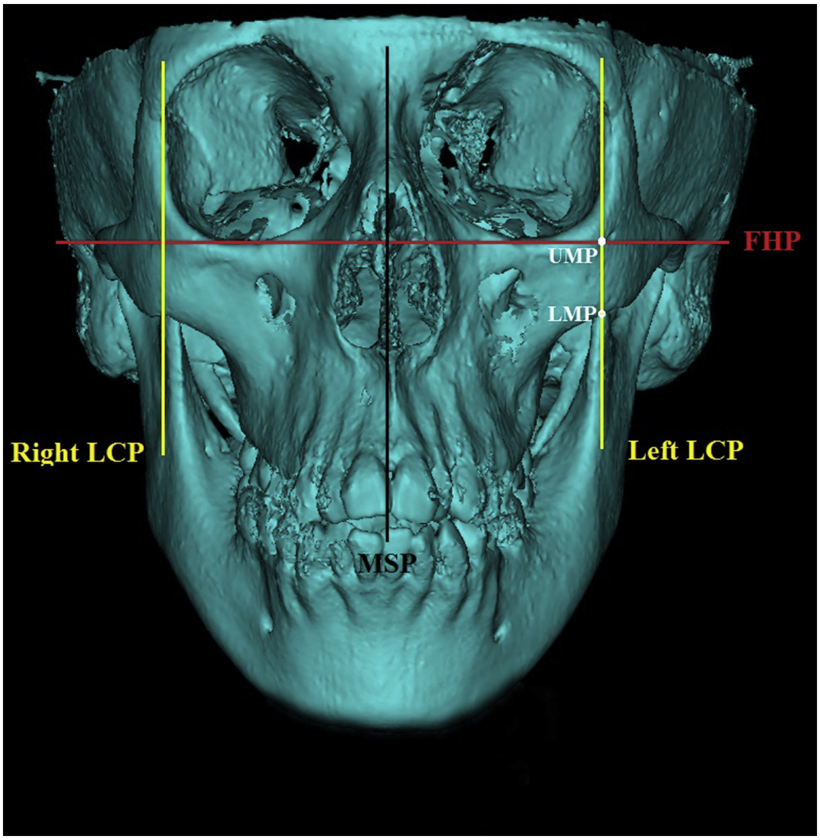

Fig 3. Planes used for the measurements.

Table I. Explanations of some points and measurements

Abbreviation	*Explanation*
UMP	The most anterior bone point of the intersection of FHP and LCP
LMP	The most inferior and anterior bone point of the maxilla on LCP
J	The point of intersection of a horizontal line passing through the floor of the nose and zygomatic process on the coronal slice that passes through the furcation of the upper first molar
LPP	The most posterior point of the lateral pterygoid plate on axial slice
C1	The most inferior palatine margin of the alveolar process of the maxilla on the coronal slice of the upper first molar furcation
C2	The deepest point of the palatine process on the coronal slice in which the upper first molar furcation was seen
Piri	The most lateroinferior points of aperture
Furcation (f)	For single-rooted teeth (second premolars and canines), furcation point was determined on the axial slice when the furcation of the first molars were seen
UMP-MSP	Distance between upper malar point (UMP) and MSP
LMP-MSP	Distance between lower malar point (LMP) and MSP
J-MSP	Distance between jugale point (J) and MSP
LPP-MSP	Distance between most posterior point of lateral pterygoid plate (LPP) and MSP
Piri-MSP	Distance from aperture piriformis (Piri) to MSP
Alveolar segment tilting	Outer angle between orbital reference line (between orbital points) and C line (between inferior palatine margin of alveolar process and palatine process of maxilla)
3,4,5,6-ORL	Angle between orbital reference line and axis of corresponding tooth
a-MSP	Distance between apex of corresponding tooth and MSP
c-MSP	Distance between cusp tip of corresponding tooth and MSP
f-MSP	Distance between furcation of corresponding tooth and MSP
4c, 6c (R-L)	Distance between cusp tips of right and left first premolars or molars
4f, 6f (R-L)	Distance between furcation of right and left first premolars or molars
BABT	Buccal alveolar bone thickness: distance between furcation of each teeth and outer border of bone on axial slice
Cusp-ABM	Distance between cusp tip of each tooth and alveolar bone margins at the coronal slice where the furcation of related tooth is seen

The midsagittal plane (MSP) was defined as being passing through the nasion and basion, perpendicular to the FHP. The right and left lateral canthal planes (LCPs) were created through the right and left lateral canthus points, parallel to the MSP and perpendicular to the FHP. Ten skeletal, 2 dentoalveolar, 36 dental, and 16 periodontal measurements were performed (Table I). The osteotomy side (osteotomy+; crossbite side) and the side that did not undergo osteotomy (osteotomy−; noncrossbite side) were assessed separately. The distances of skeletal and dental points to the MSP (Figs 4 and 5), alveolar segment tilting (Fig 6), and tooth tipping (Fig 7) were measured separately for each side. For periodontal evaluation, buccal alveolar bone thickness (BABT) and the distance between the cusp tip and alveolar bone margin (Cusp-ABM) for buccal alveolar bone height (BABH) were measured for each tooth (Fig 8). All measurements were performed by the same examiner, who was blinded to the osteotomy± sides.

Statistical analysis

IBM SPSS Statistics 22 software was used for statistical analysis. During the assessment of the study data, conformity of the parameters to the normal distribution was assessed by means of the Shapiro-Wilk test. The Student *t* test was used for the intergroup (osteotomy+, osteotomy−) comparisons of parameters with normal distribution, and the Mann-Whitney *U* test was used for the intergroup comparisons of parameters without normal distribution. The paired-samples *t* test was used for the in-group comparisons of parameters with normal distribution. For the in-group comparisons of parameters without normal distribution, the Wilcoxon signed rank test was used. In the analysis of reliability regarding parameter measurements, the intraclass correlation coefficient (ICC) was calculated. Significance was evaluated at a level of $P < 0.05$. Intraobserver reliability was determined by reevaluating the 8 patients (half of the sample) 1 week after the original investigation.

RESULTS

Clinically, maxillary expansion was recorded in all patients. The mean amounts of transverse arch width increase were 8.11 ± 1.67 mm between the first premolars and 7.63 ± 1.58 mm between the first molars (Table II). The improvement in one of the patients is shown in Figures 9 and 10. Regarding skeletal and dentoalveolar measurements, the alveolar segment tilting angle showed statistically significant decreases on both osteotomy− and osteotomy+ sides. However, a significant increase was seen in the distance from the piriformis to the MSP on the osteotomy+ side, unlike on the osteotomy− side (Table III). When the osteotomy+ and osteotomy− sides were compared, changes in the alveolar-segment tilting angle and the distance from

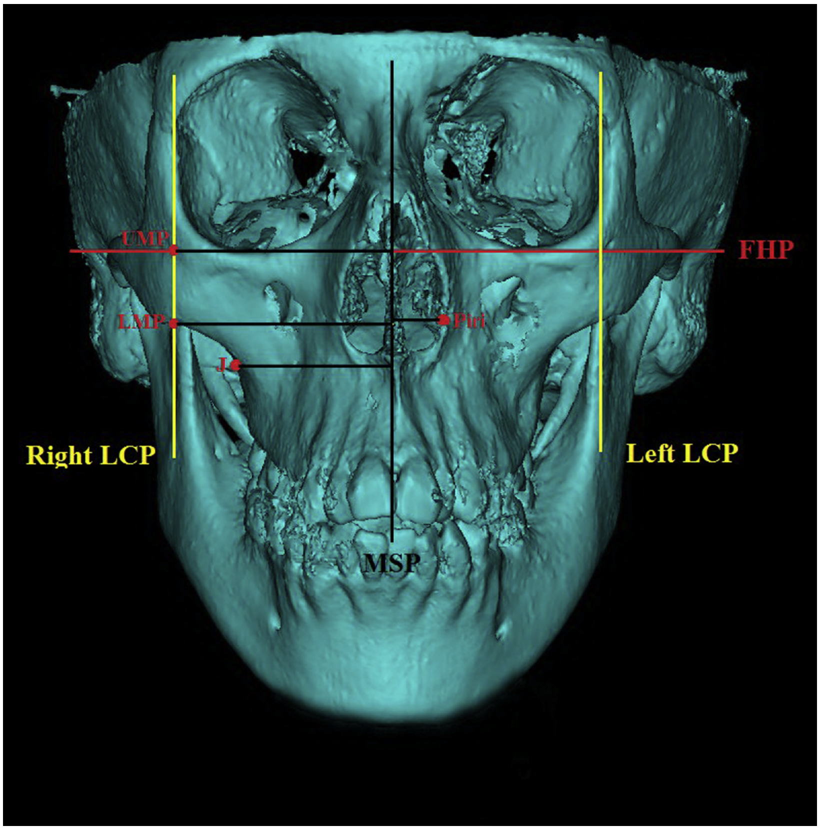

Fig 4. Distances between MSP and some reference points.

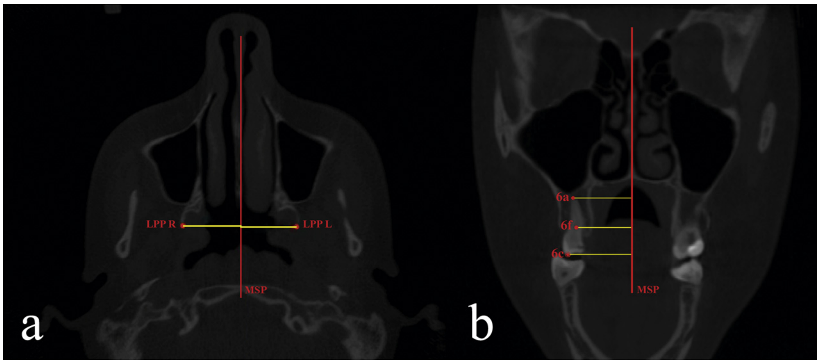

Fig 5. A, Distances between MSP and lateral pterygoid points; **B,** distances between MSP and tooth apex, furcation, and cusp.

piriformis to the MSP were significantly higher on the osteotomy+ side (Table IV).

The distances from the teeth to the MSP and dental tipping changes are presented in Table V. According to these measurements, there were significant changes for all parameters on both sides, except for the distance from the upper second premolar apex to the MSP. When the osteotomy+ and osteotomy− sides were compared, changes after expansion were significantly higher on the osteotomy+ side, except for the 3-ORL angle, which was statistically insignificant between the sides (Table VI).

Regarding periodontal changes, the buccal alveolar bone thickness of premolars and first molar showed a statistically significant decrease on the osteotomy− side, whereas only the first premolar presented a

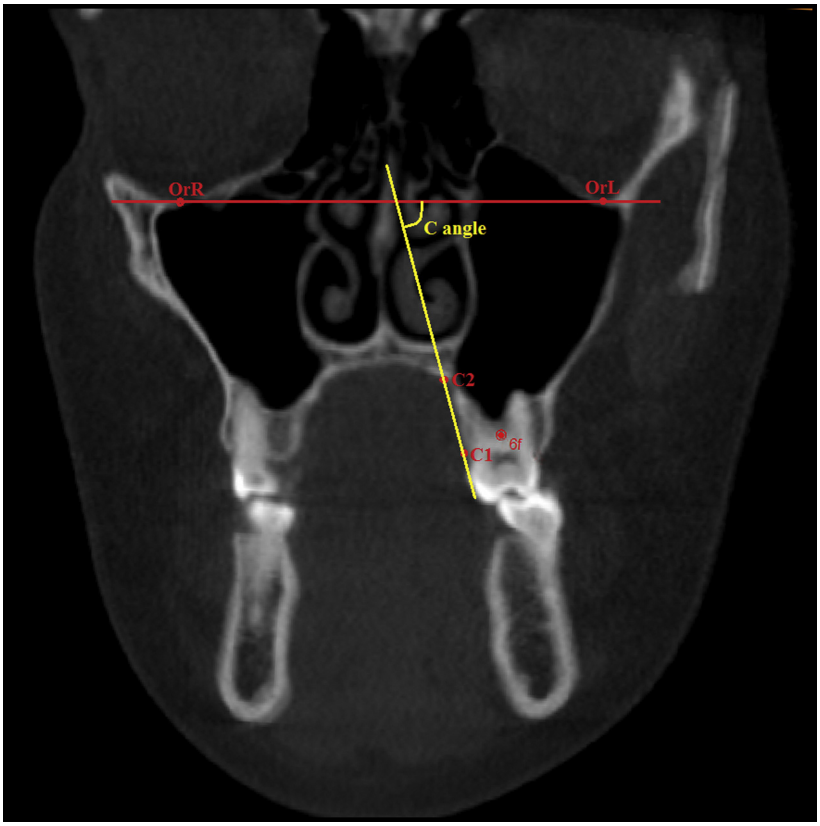

Fig 6. Alveolar segment tilting (C angle).

significant increase in the distance of Cusp-ABM on the osteotomy− side (Table VII). However, in the osteotomy+ side only the first molar presented a statistically significant decrease of alveolar bone thickness and a statistically significant increase in the distance Cusp-ABM.

Comparison of the osteotomy+ and osteotomy− sides revealed no significant differences regarding buccal alveolar bone height and thickness, except for the distance of Cusp-ABM of the first premolars, which presented a significant increase on the osteotomy− side (Table VIII).

DISCUSSION

Conventional expansion appliances always have a double-sided effect.[35] Therefore, many different appliances have been designed to achieve expansion only on the constricted side.[13,16,21,22] However, these appliances are insufficient alone to solve TUPC in adults. Therefore, some researchers have attempted to expand with the help of the osteotomy on the constricted side in adults, as in the present study. In this regard, there are some case reports in the literature[19,20,28,31] in which different types of appliances were used for expansion purposes, and the results were analyzed 2-dimensionally.[19,20,31] CBCT images for skeletal, dental, and periodontal changes were used in only 2 studies,[21,34] in which asymmetric expansion appliances were used but osteotomies were not performed. However, the use of 2-dimensional methods is inadequate when measuring 3-dimensional changes. Therefore, CBCT images were used for more precise and comprehensive evaluation of the effects of asymmetric expansion protocol in the present study.

In the literature, at least 3 months' retention to obtain mineralization of the midpalatal suture is recommended for long-term stability.[36,37] In the present study, the records of the patients whose appliances were kept in their mouths for 6 months were used. Therefore, this period seemed to be adequate for adaptation of both hard and soft tissues after expansion.

Because no previous study had evaluated the skeletal, dental, or periodontal effects of unilateral SARME with the use of CBCT images and the results of case reports on this topic could not be statistically evaluated, the results of our study will be compared with the results of bilateral SARME procedures and conventional asymmetric RME studies.

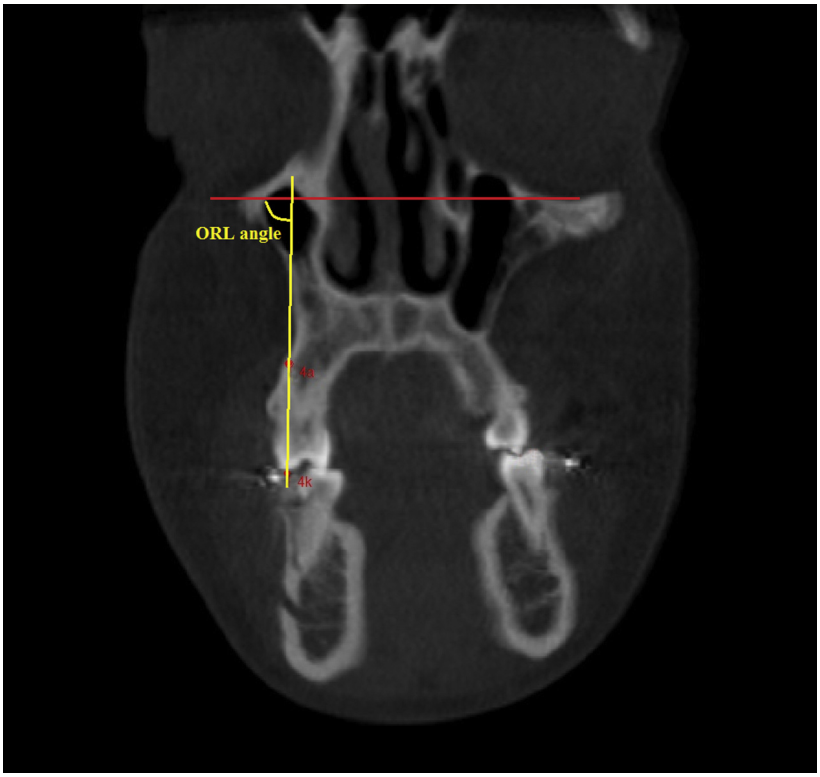

Fig 7. Tooth tipping.

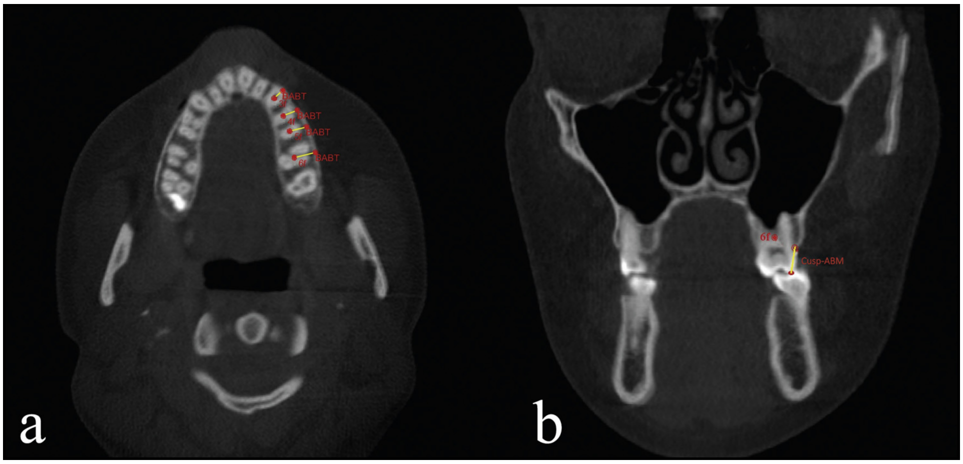

Fig 8. A, Buccal alveolar bone thickness; **B,** Buccal alveolar bone height for left first molar.

In this study, intragroup and intergroup comparisons showed no significant skeletal changes except for the aperture piriformis, which presented a statistically significant increase on the osteotomy+ side. Some studies reported significant increases in the aperture piriformis width after bilateral SARME[38,39] and asymmetric expansion without osteotomy,[34] which were in agreement with our study. The expansion amount for the constricted side[34] (1.17 ± 1.50 mm) was almost similar to our findings (1.1 ± 0.87 mm). Regarding the distance between jugale point and midsagittal plane, they reported statistically significant increases more on the crossbite side (1.67 ± 1.65 mm), unlike our results. There was only one CBCT study evaluating jugale distances after asymmetric expansion and it showed a significant increase on the constricted side.[40] However,

Table II. Transverse expansion amounts (mean ± SD) between cusp tips and furcation of teeth

	(T0 − T1)	P
4c (R-L) (mm)	8.11 ± 1.67	0.001*
6c (R-L) (mm)	7.63 ± 1.58	0.001*
4f (R-L) (mm)	5.2 ± 1.24	0.001*
6f (R-L) (mm)	5.03 ± 0.71	0.001*

*$P < 0.001$ (paired-samples t test).

Fig 9. Treatment process of a patient: **A,** initial; **B,** after expansion; **C,** debonding of the appliance after 6 months of retention; **D,** final.

Fig 10. Treatment process of a patient: **A,** initial occlusal view; **B,** after expansion; **C,** final.

the patients evaluated in those studies were still growing, whereas ours were adult.

It is commonly supposed that pterygomaxillary disjunction leads to a bigger posterior expansion because of the released posterior stresses. However, there are quite different findings because posterior expansion have been described differently in various studies. Dental or dentoalveolar points which were affected by buccal alveolar bending were generally used to measure posterior expansion. However, these measurements do not mean skeletal posterior expansion. Therefore, accurate distinction between dental

Table III. Evaluation of the skeletal and dentoalveolar measurements (mean ± SD), in-group comparison

Measurement	*T0*	*T1*	P
Osteotomy−			
UMP-MSP (mm)	48.01 ± 2.66	47.94 ± 2.77	0.611
LMP-MSP (mm)	48 ± 2.62	47.97 ± 2.71	0.838
J-MSP (mm)	32.17 ± 2.47	32.42 ± 2.58	0.283
LPP-MSP (mm)	27.35 ± 2.76	27.22 ± 2.48	0.516
Piri-MSP (mm)	10.86 ± 1.17	11.05 ± 1.44	0.313
Alveolar segment tilting (°)	70.3 ± 8.72	67.01 ± 9.8	0.016*
Osteotomy+			
UMP-MSP (mm)	47.86 ± 2.88	48.15 ± 2.5	0.122
LMP-MSP (mm)	47.86 ± 2.92	48.2 ± 2.55	0.085
J-MSP (mm)	31.67 ± 1.87	31.54 ± 1.86	0.759
LPP-MSP (mm)	27.03 ± 2.9	27.36 ± 2.88	0.289
Piri-MSP (mm)	10.17 ± 1.37	11.27 ± 1.6	0.001*
Alveolar segment tilting (°)	72.19 ± 6.4	58.85 ± 8.88	0.001*

*P <0.05 (paired-samples t test).

Table IV. Comparison of skeletal and dentoalveolar changes (mean ± SD) between osteotomy− and osteotomy+ sides

Measurement (T0 − T1)	*Osteotomy−*	*Osteotomy+*	P
UMP-MSP (mm)	−0.07 ± 0.57	0.29 ± 0.71	0.120
LMP-MSP (mm)	−0.03 ± 0.64	0.34 ± 0.73	0.137
J-MSP (mm)	0.24 ± 0.88	−0.13 ± 1.6	0.425
LPP-MSP (mm)	−014 ± 0.83	0.32 ± 1.18	0.210
Piri-MSP (mm)	0.19 ± 0.72	1.1 ± 0.87	0.003*
Alveolar segment tilting (°)	−3.29 ± 4.88	−13.33 ± 4.7	0.001*

*P <0.05 (Student t test).

Table V. Evaluation of the dental measurements (mean ± SD), in-group comparison

Measurement	*T0*	*T1*	P
Osteotomy−			
3-ORL angle (°)	82.19 ± 4.77	78.99 ± 6.18	0.001*
3a-MSP (mm)	12.34 ± 1.86	12.96 ± 1.63	0.014*
3f-MSP (mm)	13.01 ± 1.92	14.13 ± 1.77	0.001*
3c-MSP (mm)	15.54 ± 2.14	17.28 ± 2.27	0.001*
4-ORL angle (°)	82.49 ± 5.77	80.22 ± 5.28	0.002*
4a-MSP(mm)	17.73 ± 1.49	18.52 ± 1.64	0.001*
4f-MSP (mm)	16.5 ± 1.42	17.86 ± 1.3	0.001*
4c-MSP (mm)	18.84 ± 1.64	20.79 ± 1.57	0.001*
5-ORL angle (°)	82.82 ± 4.87	78.79 ± 4.93	0.001*
5a-MSP (mm)	19.05 ± 1.61	19.57 ± 1.69	0.058
5f-MSP (mm)	18.62 ± 1.15	19.74 ± 1.25	0.001*
5c-MSP (mm)	21.54 ± 1.59	23.41 ± 1.83	0.001*
6-ORL angle (°)	87.7 ± 2.42	83.48 ± 4.38	0.001*
6a-MSP (mm)	23.82 ± 1.68	24.38 ± 2.03	0.023*
6f-MSP (mm)	20.95 ± 1.68	22.06 ± 1.78	0.001*
6c-MSP (mm)	24.06 ± 1.64	26.14 ± 1.85	0.001*
Osteotomy+			
3-ORL angle (°)	81.56 ± 3.7	78.45 ± 5.43	0.006*
3a-MSP (mm)	11.86 ± 1.86	14.17 ± 2	0.001*
3f-MSP (mm)	12.52 ± 1.84	15.49 ± 2.19	0.001*
3c-MSP (mm)	14.87 ± 3.83	18.64 ± 3.39	0.001*
4-ORL angle (°)	81.12 ± 5.5	72.17 ± 5.34	0.001*
4a-MSP (mm)	16.39 ± 1.42	19.1 ± 1.6	0.001*
4f-MSP (mm)	15.43 ± 1.15	19.27 ± 1.81	0.001*
4c-MSP (mm)	18.17 ± 1.17	24.33 ± 1.8	0.001*
5-ORL angle (°)	82.42 ± 5.35	72.81 ± 6.57	0.001*
5a-MSP (mm)	17.63 ± 1.85	20.78 ± 1.92	0.001*
5f-MSP (mm)	17.34 ± 1.12	21.37 ± 1.39	0.001*
5c-MSP (mm)	20.33 ± 1.57	26.79 ± 1.59	0.001*
6-ORL angle (°)	87.04 ± 2.09	78.49 ± 3.92	0.001*
6a-MSP (mm)	22.47 ± 1.21	25.17 ± 1.65	0.001*
6f-MSP (mm)	19.91 ± 1.67	23.83 ± 1.7	0.001*
6c-MSP (mm)	23.44 ± 1.62	29 ± 1.97	0.001*

*P <0.05 (paired-samples t test).

and skeletal posterior expansion should be done carefully when comparing the results of the studies. Sygouros et al[38] defined posterior expansion between lateral pterygoid plates as in our study and compared the changes in SARME patients with (PD+) and without (PD−) pterygomaxillary disjunction. They reported insignificant posterior expansion (0.93 ± 1.68 mm in PD+ group, 0.75 ± 1.19 mm in PD− group), and no significant differences could be seen between the groups. Although the amounts of those changes were bilateral, the results were in accordance with our findings when they are considered as unilateral. Insignificant changes in this region might be related to the use of the furthest reference point to the force of expansion, because expansion amounts generally decrease from anterior to posterior owing to the V-shaped expansion pattern. To our knowledge, there no other study measured posterior skeletal expansion by using the points of lateral pterygoid plates. When we checked the expansion amount from the furcation points of teeth (which was least affected by dental tipping, so it might be assumed as dentoalveolar expansion), the increase was statistically significant. The total expansion amounts were 5.2 ± 1.24 mm and 5.03 ± 0.71 mm for the upper first premolar and first molar regions, respectively (Table II).

In the present study, the measurements for segment tilting of the alveolar bone showed statistically significant increases on both sides (−3.29 ± 4.88° on the osteotomy− side, −13.33 ± 4.7° on the osteotomy+ side; P <0.05), and it was more on the osteotomy+ side, as was also reported in a case report of unilateral SARME.[28]

When we checked T0 distances between teeth and MSP (Table V), values on the constricted side showed lesser amounts, indicating the asymmetry in the maxilla. On the other hand, at the end of the expansion (T1) the

Table VI. Comparison of dental changes (mean ± SD) between osteotomy− and osteotomy+ sides

Measurement (T0 − T1)	*Osteotomy−*	*Osteotomy+*	P
3-ORL angle (°)	−3.2 ± 2.51	-3.11 ± 3.91	0.937
3a-MSP (mm)	0.62 ± 0.88	2.3 ± 1.25	0.001*
3f-MSP (mm)	1.12 ± 0.59	2.97 ± 1.23	0.001*
3c-MSP (mm)	1.74 ± 0.87	3.77 ± 1.31	0.001*
4-ORL angle (°)	−2.27 ± 2.48	−8.95 ± 3.34	0.001*
4a-MSP (mm)	0.79 ± 0.75	2.71 ± 1.55	0.001*
4f-MSP (mm)	1.36 ± 0.65	3.84 ± 1.28	0.001*
4c-MSP (mm)	1.96 ± 0.81	6.16 ± 1.66	0.001*
5-ORL angle (°)	−4.04 ± 2.86	−9.61 ± 4.93	0.001*
5a-MSP (mm)	0.52 ± 1.01	3.16 ± 1.3	0.001*
5f-MSP (mm)	1.12 ± 0.32	4.03 ± 1.14	0.001*
5c-MSP (mm)	1.87 ± 0.96	6.47 ± 1.5	0.001*
6-ORL angle (°)	−4.22 ± 3.14	−8.55 ± 4.37	0.003*
6a-MSP (mm)	0.56 ± 0.88	2.7 ± 1.12	0.001*
6f-MSP (mm)	1.11 ± 0.5	3.92 ± 0.78	0.001*
6c-MSP (mm)	2.07 ± 0.94	5.56 ± 1.68	0.001*

*P <0.05 (Student t test).

Table VII. Evaluation of the periodontal measurements (mean ± SD), in-group comparison

Measurement	*T0*	*T1*	P
Osteotomy−			
3 BABT (mm)	3.6 ± 0.74	3.6 ± 0.72	1.000
4 BABT (mm)	4.21 ± 0.9	3.78 ± 0.86	0.001*
5 BABT (mm)	4.66 ± 0.99	4.19 ± 1.08	0.008*
6 BABT (mm)	6.48 ± 0.82	5.91 ± 0.71	0.001*
3 Cusp-ABM (mm)	11.67 ± 1.35	11.86 ± 1.03	0.389
4 Cusp-ABM (mm)	10.07 ± 1.02	10.62 ± 1.17	0.013*
5 Cusp-ABM (mm)	9.4 ± 0.9	9.69 ± 0.92	0.066
6 Cusp-ABM (mm)	10.08 ± 0.71	10.23 ± 1.15	0.524
Osteotomy+			
3 BABT (mm)	6.84 ± 4.08	6.92 ± 4	0.430
4 BABT (mm)	6.98 ± 3.94	6.79 ± 4.11	0.110
5 BABT (mm)	7.37 ± 3.67	7.11 ± 3.88	0.119
6 BABT (mm)	8.45 ± 2.81	7.88 ± 3.25	0.008*
3 Cusp-ABM (mm)	11.75 ± 1.37	11.79 ± 1.33	0.757
4 Cusp-ABM (mm)	10.74 ± 1.28	10.78 ± 1.14	0.802
5 Cusp-ABM (mm)	10.2 ± 1.56	10.36 ± 1.39	0.237
6 Cusp-ABM (mm)	10.59 ± 1.38	10.97 ± 1.12	0.030*

*P <0.05 (paired-samples t test).

values were higher on the constricted side in contrast to T0, because overexpansion is performed in all expansion cases against the possibility of relapse. Therefore, higher amounts on the constricted side at T1 are not surprising because the dental relapse has not taken place yet owing to the retention appliance. It would be better if we were able to measure the same parameters 3-dimensionally after fixed orthodontic treatment.

Regarding dental changes in this study, there were statistically significant increases in dental tipping amounts and the distances from teeth to the MSP on

Table VIII. Comparison of periodontal changes (mean ± SD) between osteotomy− and osteotomy+ sides

Measurement (T0 − T1)	*Osteotomy−*	*Osteotomy+*	P
3 BABT (mm)	0 ± 0.59	0.08 ± 0.4	0.652
4 BABT (mm)	−0.44 ± 0.42	−0.19 ± 0.45	0.124
5 BABT (mm)	−0.47 ± 0.61	−0.26 ± 0.64	0.357
6 BABT (mm)	−0.57 ± 0.48	−0.56 ± 0.74	0.975
3 Cusp-ABM (mm)	0.19 ± 0.85	0.04 ± 0.47	0.537
4 Cusp-ABM (mm)	0.54 ± 0.77	0.03 ± 0.5	0.034*
5 Cusp-ABM (mm)	0.3 ± 0.6	0.15 ± 0.5	0.470
6 Cusp-ABM (mm)	0.15 ± 0.92	0.39 ± 0.64	0.406

*P <0.05 (Student t test).

both sides. When sides were compared, the amount of dental tipping for all teeth except the canines was significantly higher on the osteotomy+ side than on the osteotomy− side. This insignificant difference might be because the canines were not covered with acrylic on the osteotomy+ side; therefore, the ipsilateral canine was less affected. According to the limited results of the unilateral osteotomy studies[19,28] and the conventional asymmetric RME studies,[16,21,34,40] more dental movements were reported on the constricted sides. However, in our study, the amounts of tipping were higher than the amounts reported by Baka et al[40] and Toroglu et al.[16] Performing osteotomy, including adult patients, and differences in appliance design are the distinctive features between the present study and the other studies, which might cause different results among the studies.

Owing to the heavy forces during RME, some side-effects on the dentoalveolar supporting tissues, such as root resorption and decrease in alveolar bone thickness and height, might be observed. In the evaluation of the BABT, statistically significant decreases were found in the first molar and first and second premolars on the osteotomy− side, whereas there was a significant decrease only in the first molar on the osteotomy+ side. Because of higher resistance against the expansion force on the osteotomy− side, more teeth might have been affected on that side. Conversely, the reason for the significant decrease in BABT of the first molar on the osteotomy+ side might be higher resistance because of the more complex neighboring structures in the posterior region, despite surgical relief. However, there was no statistically significant difference between the 2 sides. Akın et al[21] reported that the BABT of canine, first premolar, and first molar decreased statistically significantly on the crossbite side, whereas there was no significant change in any of the teeth on the noncrossbite side. They did not perform any osteotomy, because the subjects in their study were young.

Therefore they reported different results from the present study.

The amount of periodontal changes in either alveolar bone height or thickness was limited to 0-0.5 mm, which was not clinically significant, although some of them were statistically significant. Consequently, there was no adverse effect noted on the supporting alveolar bone though teeth covered by acrylic appliance tipped more on the osteotomy+ side. On the other hand, Akın et al[21] reported a decrease in alveolar bone height on the crossbite side, but no change was found on the noncrossbite side.

Although short-term results were promising, further studies with a larger sample size and posttreatment follow-up records should be evaluated for long-term stability.

CONCLUSIONS

1. The teeth and alveolar segment (except the canine, which was not covered with acrylic) expanded and tipped more on the osteotomy+ side.
2. The aperture piriformis width was increased on the osteotomy+ side.
3. The treatment mechanics did not have clinically detrimental effects on the supporting alveolar bone of the maxilla on either side.
4. The method might be considered to be successful in the treatment of true unilateral crossbite in adults.

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