Original Article

Asymmetric rapid maxillary expansion in true unilateral crossbite malocclusion: *A prospective controlled clinical study*

Zehra Ileri[a]; Faruk Ayhan Basciftci[b]

ABSTRACT

Objective: To investigate the short-term effects of the asymmetric rapid maxillary (ARME) appliance on the vertical, sagittal, and transverse planes in patients with true unilateral posterior crossbite.

Materials and Methods: Subjects were divided into two groups. The treatment group was comprised of 21 patients with unilateral posterior crossbite (mean age = 13.3 ± 2.1 years). Members of this group were treated with the ARME appliance. The control group was comprised of 17 patients with Angle Class I who were kept under observation (mean age = 12.3 ± 0.8 years). Lateral and frontal cephalograms were taken before the expansion (T1), immediately after expansion (T2), and at postexpansion retention (T3) in the treatment group and at preobservation (T1) and postobservation (T2) in the control group. A total of 34 measurements were assessed on cephalograms. For statistical analysis, the Wilcoxon test and analysis of covariance were used.

Results: The ARME appliance produced significant increases in nasal, maxillary base, upper arch, and lower arch dimensions ($P < .01$) and a clockwise rotation of the occlusal plane ($P = .001$).

Conclusion: The ARME appliance created asymmetric increments in the transversal dimensions of the nose, maxilla, and upper arch in the short term. Asymmetric expansion therapy for subjects with unilateral maxillary deficiency may provide satisfactory outcomes in adolescents, with the exception of mandibular arch expansion. The triangular pattern of expansion caused clockwise rotation of the mandible and the occlusal plane and produced significant alterations in the vertical facial dimensions, whereas it created no displacement in maxilla in the sagittal plane. (*Angle Orthod.* 2015;85:245–252.)

KEY WORDS: Rapid maxillary expansion; Dentoalveolar; Skeletal; Soft tissue

INTRODUCTION

True unilateral posterior crossbite is a challenging malocclusion to treat, and conventional expansion methods have some shortcomings (unilateral head and face). In true unilateral posterior crossbite, it is suggested that appliances and biomechanics that primarily exert a unilateral effect should be selected, otherwise buccal nonocclusion may occur on the noncrossbite side.[1,2]

[a] Assistant Professor, Department of Orthodontics, Faculty of Dentistry, Selçuk University, Konya, Turkey.

[b] Professor, Department of Orthodontics, Faculty of Dentistry, Selçuk University, Konya, Turkey.

Corresponding author: Dr Zehra Ileri, Department of Orthodontics, Faculty of Dentistry, Selçuk University, Konya, 42079, Turkey
(e-mail: zehra.ileri@gmail.com)

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Since Angell first put forward the idea of expansion by opening the midpalatal suture in 1860, the rapid maxillary expansion (RME) procedure has been used effectively in children and adolescents, and its effects on craniofacial and dentoalveolar structures are well documented in the literature.[3–7] However, use of the RME procedure to produce asymmetric orthopedic expansion for the treatment of patients with true unilateral crossbite has not been questioned. Previous studies have described some methods and appliances to solve this problem. These appliances, however, produced orthodontic expansion or an undesirable bilateral expansion effect or revealed a need for asymmetric relapse after bilateral widening rather than orthopedic expansion.[2,8,9] To avoid these restrictions and undesirable effects, Marshall et al.[2] recommended a bonded RME appliance that attempts to resist lateral movement on the normal side by incorporating an occlusal index into the acrylic.

The hypothesis in our study was that a modified acrylic bonded appliance, which is a splint type of tooth- and tissue-borne appliance with a locked

Figure 1. Asymmetric rapid maxillary expander.

mechanism on the noncrossbite side, may provide unilateral orthopedic and orthodontic effects in patients with true unilateral posterior crossbite. Therefore, to test this hypothesis, an asymmetric rapid maxillary ARME appliance (Figure 1) was designed. We aimed to use it to perform asymmetric orthopedic expansion and evaluate its short-term effects on the vertical, sagittal, and transverse planes in patients with true unilateral posterior crossbite.

MATERIALS AND METHODS

This prospective controlled study was approved by the Regional Ethical Committee on Research of Selçuk University (decision number 76). According to this approval, the parents and patients were informed and their approvals were obtained.

The study involved 38 patients (22 girls and 16 boys) who applied to be treated at the Department of Orthodontics at Selçuk University. Subjects were divided into two groups: a control group and a treatment group. The control group had a mean age of 12.3 ± 0.8 years and consisted of patients with Angle Class I malocclusion, a straight profile, and minimum crowding in the anterior mandibular region. To assess incisor crowding in the control group, the irregularity index[10] was used. None of the patients in the control group had had any previous orthodontic treatment or orthodontic intervention.

The treatment group consisted of 21 patients with skeletal unilateral posterior crossbite. Patients who fulfilled the following inclusion criteria were selected for the treatment group:

- Angle Class I malocclusion.
- Age between 11 and 17 years with permanent dentition.
- Unilateral insufficiency of the upper apical base.
- Absence of mandibular lateral shift in the transverse dimension.
- Absence of cleft lip and palate.

Patients with serious medical conditions, craniofacial abnormality, psychosocial impairment, or skeletal openbite were excluded from the study.

In the treatment group, a modified acrylic bonded appliance—a splint-type tooth- and tissue-borne appliance[11,12] with a locked mechanism on the noncrossbite side (ARME) appliance—was used for asymmetric rapid palatal expansion (Figure 1). After the hyrax screw (G&H, Franklin, Ind) was placed in the second premolars' alignment and as near to the palate as possible, the upper and lower study casts were mounted on a fixator using a wax registration, which was recorded at 2–3 mm higher than the maximum intercuspation position in the range of freeway space. The acrylic part of the appliance extended over the occlusal and middle third of the vestibular surfaces of all teeth. On the noncrossbite side, a vertically extending acrylic locked mechanism was formed from the palatal surfaces of the maxillary posterior teeth to the lingual surfaces of the mandibular posterior teeth. Throughout the locked mechanism, the bites of the lower posterior teeth were formed, and this acrylic part was extended to the vestibular surfaces of the lower posterior teeth. Therefore, the lower posterior teeth were surrounded on the vestibular and lingual sides. After the necessary arrangements had been made in the patients' mouths, the appliance was cemented. Holes were opened for the escape of excess cement during bonding. Glass ionomer cement was used for cementation.

The appliance was activated with a quarter turn ($2 \times \frac{1}{4}$ turn $= 0.5$ mm) twice per day during the first week to overcome the resistance of the sutures and a quarter turn once per day after the midpalatal suture opened radiographically until 2–3 mm overexpansion (overcorrection) was obtained. Upon completion of the expansion, the appliance was placed in the mouth and the screw was not turned for a week. Next, the appliance was cleaned to remove cement residue, the acrylic of the locked mechanism was removed, and the appliance was reused as a removable retention appliance for 6 weeks.

Lateral and frontal cephalograms were taken before the expansion (T1), immediately after expansion (T2), and at postexpansion retention (T3) in the treatment group and at preobservation (T1) and postobservation in the control group. In total, 34 measurements, 20 on the lateral and 14 on frontal cephalometric radiographs, were assessed by one author (ZI) (Figures 2 and 3).

Statistical Analysis

Descriptive statistics, including means and standard deviations, were calculated for the data. Intragroup comparisons were evaluated using the Wilcoxon signed-rank test, and intergroup changes (T_3–T_1 changes in the treatment group vs T_2–T_1 changes in the control group) were analyzed with the analysis of covariance. The analyses were performed using the

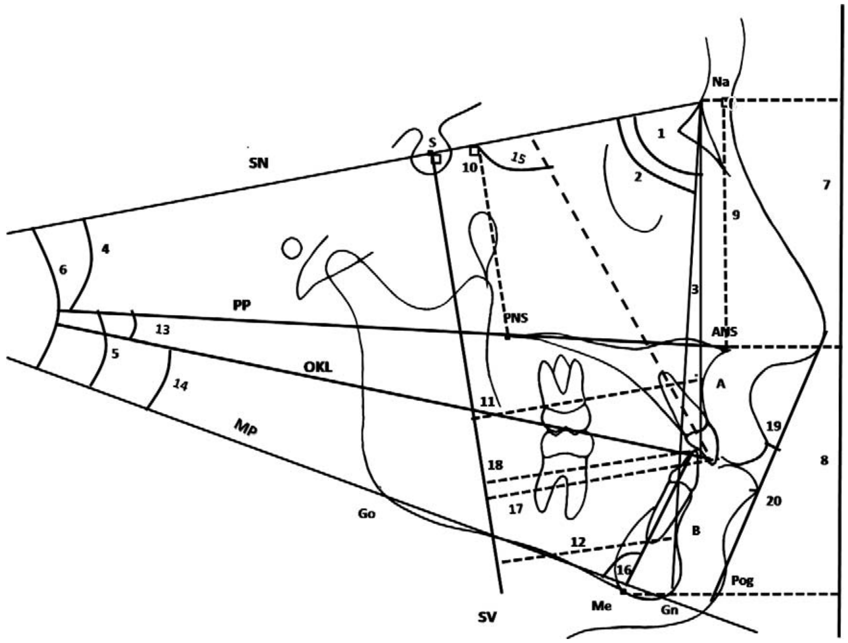

Figure 2. Lateral cephalometric measurements used in this study. 1: SNA°, angle formed by the planes of sella-nasion and nasion-point A; 2: SNB°, angle formed by the planes of sella-nasion and nasion-point B; 3: ANB°, angle formed by the planes of nasion-point A and nasion-point B; 4: SN-PP°, angle formed by the sella-nasion plane and the palatal plane [anterior nasal spine (ANS) – posterior nasal spine (PNS)]; 5: MP-PP°, angle formed by the mandibular plane (gonion- gnathion) and the palatal plane; 6: SN-MP°, angle formed by the sella-nasion plane and the mandibular plane; 7: N-ANS (mm), the distance between nasion and ANS; 8: ANS-Me (mm), the distance between ANS and menton; 9: SN⊥ANS (mm), the perpendicular distance of ANS to the sellanasion plane; 10: SN⊥PNS (mm), the perpendicular distance of PNS to the sella-nasion plane; 11: SV⊥A (mm), the perpendicular distance of point A to the sella vertical plane (SV) was constructed through the sella, perpendicular to the sella-nasion plane; 12: SV⊥B (mm), the perpendicular distance of point B to the sella vertical plane constructed through the sella, perpendicular to the sella-nasion plane; 13: PP-OKL°, angle formed by the planes of the platal plane and the occlusal plane; 14: MP-OKL°, angle formed by the planes of the mandibular plane and the occlusal plane; 15: U1P-SN°, angle formed between the sella-nasion plane and U1 plane, a plane from the superior central incisor's incisal edge through its root; 16: L1P-MP°, angle formed between the mandibular plane and L1 plane, a plane from the inferior central incisor's incisal edge through its root; 17: SV⊥U1 (mm), the perpendicular distance of the incisal edge of superior central incisor to sella vertical plane; 18: SV⊥L1(mm), the perpendicular distance of incisal edge of the inferior central incisor to sella vertical plane; 19: E-Ls (mm), the perpendicular distance of the most anterior point on the convexity of the superior lip to E plane that extends from the tip of the nose and the chin; 20: E-Li (mm), the perpendicular distance of the most anterior point on the convexity of the inferior lip to the E plane.

Statistical Package for Social Sciences (version 13.0, SPSS Inc, Chicago, Ill). When the P value was $<.05$, the statistical test was determined to be significant.

Method Error

The method error was determined with 13 records from each group, selected randomly and traced and remeasured approximately 6 weeks after the first measurements were made by the same operator (ZI). Intraexaminer measurement error was calculated with a Bland and Altman plot analysis. The smallest measurement error was 0.27 mm for Jn-MS and the largest 0.93 mm at SV⊥U1.

RESULTS

A power analysis was established by the G*Power version 3.1.2 software (Franz Faul, Universität Kiel, Kiel, Germany) based on a 1:1 ratio between the groups and found that a total sample size of 34 patients (17 patients in each group) would give more than 75% power (actual power = 0.7945812, two groups, three repeated measurements) to detect significant differences with 0.40 effect size and at a .05 significance level.

Demographic variables, treatment, and retention periods for the treatment group are presented in Table 1. The treatment group had a mean age of 13.3 ± 2.1 years and a mean treatment time of 89 ± 15 days. The observation period for the control group was 91 ± 5 days. The average irregularity index value of the samples was 1.8 (range = 0.9–2.8).

The average cephalometric measurements at pre-treatment, after expansion, and after retention and the comparison of the phases in the treatment group are presented in Table 2. The ARME appliance produced a triangular pattern of expansion by the significant asymmetric increments in nasal, jugular ($P < .01$), and maxillary arch ($P < .001$) measurements with a greater increase on the narrower side. In this instance, our results failed to reject the null hypothesis.

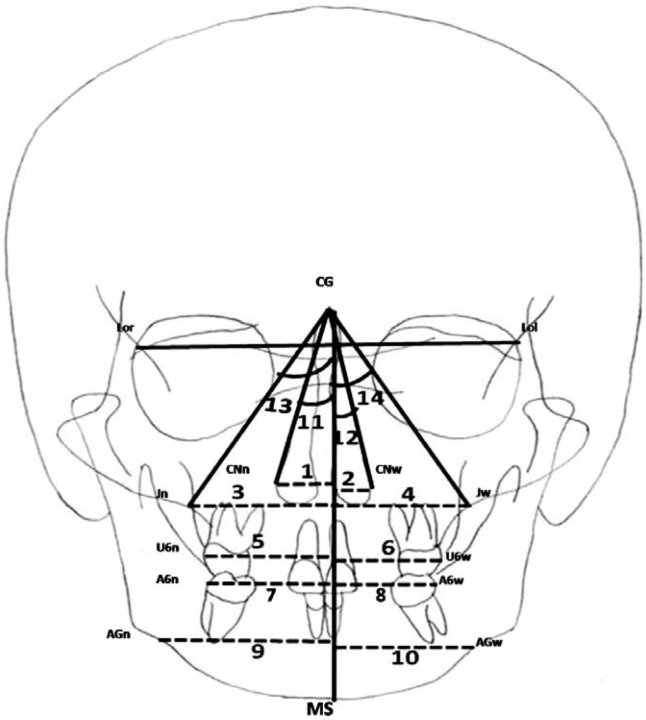

Figure 3. Frontal cephalometric landmarks and measurements used in this study. L plane: the horizontal reference plane was constructed through the points Lor and Lol; MS (midsagittal plane): the vertical reference plane was constructed through Crista Galli (CG), perpendicular to L plane; 1: CNn-MS (mm), the distance between piriform rim of narrower side and MS; 2: CNw-MS (mm), the distance between piriform rim of wider side and MS; 3: Jn-MS (mm), the distance between jugale point of narrower side and MS; 4: Jw-MS (mm), the distance between jugale point of wider side and MS; 5: U6n-MS (mm), the distance between the buccal surface of upper first molar in the narrower side and MS; 6: U6w-MS (mm), the distance between the buccal surface of upper first molar in the wider side and MS; 7: A6n-MS (mm), the distance between the buccal surface of lower first molar in the narrower side and MS; 8: A6w-MS (mm), the distance between the buccal surface of lower first molar in the wider side and MS; 9: AGn-MS (mm), the distance between antegonial notch point of the narrower side and MS; 10: AGw-MS (mm), the distance between antegonial notch point of the wider side and MS; 11: NASn°, angle formed by the nasal plane of the narrower side (CG-CNn) and MS; 12: NASw°, angle formed by the nasal plane of the wider side (CG-CNw) and MS; 13: MAXn°, angle formed by the maxillary plane of the narrower side (CG-Jn) and MS; 14: MAXw°, angle formed by the maxillary plane of the wider side (CG-Jw) and MS.

The treatment changes with the ARM expander produced clockwise rotations of the mandible ($P < .05$) and the occlusal plane ($P < .01$) with significant alterations in the vertical facial dimensions ($P < .05$) but created no displacement in the maxilla in the sagittal plane ($P > .05$) (Table 2).

The average cephalometric measurements at the beginning and end of the observation periods and a comparison of the phases in the control group are presented in Table 3. The only significant change was in the CNw-MS distance ($P < .05$).

A comparison of the differences between the treatment group (T1–T3 changes) and the control group (T1–T2 changes) is presented in Table 4. Significant increments were seen in nasal ($P < .01$), maxillary arch, and jugular ($P < .05$) measurements in the treatment group when compared with the control group.

DISCUSSION

This study showed that asymmetric orthopedic expansion can be produced with a rapid maxillary expansion procedure without creating buccal nonocclusion on the noncrossbite side in patients with true unilateral posterior crossbite.

Unilateral transverse insufficiency of maxilla continues to be a highly challenging problem to treat. Studies related to the usage of bonded RME appliances in patients with unilateral posterior crossbite are not sufficient. In such cases the clinician wishes to produce a unilateral effect of expansion. Unfortunately, conventional expanders always produce a bilateral effect.[13] To solve this problem, Marshall et al.[2] recommended using removable expansion plates or a bonded RME appliance with an occlusal index into the acrylic. In this study, to overcome the unnecessary contralateral expansion, an ARME appliance, which was constructed by adding a locked mechanism to a bonded RME,[11,12] was used. Therefore, more expansion occurred on the crossbite side than on the clinically normal side. However, some expansion was also observed on the normal side, which relapsed quickly after removal of the expander.

In the short term, evaluation of the active treatment effects after use of the ARME appliance showed significant increments in the nasal, jugular, and maxillary dimensions in both sides of that transverse plane relative to the control group. The increments on the narrower side were greater than on the noncrossbite side in the measurements related to the transversal dimensions of nasal, jugular, and maxillary arch in the treatment group. The findings indicated that the

Table 1. Age Distribution of Patients and Expansion and Retention Time for the Treatment Group

	Age, Year	Expansion Time, Day	Retention Time, Day	Total Time, Day
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Girls	13.4 ± 2.2	43 ± 14	47 ± 7.3	89 ± 15
Boys	13 ± 1.9	42 ± 18	47 ± 3.6	89 ± 16
Total	13.3 ± 2.1	43 ± 15	47 ± 7.3	89 ± 15

Table 2. Average Cephalometric Measurements Before Treatment, After Expansion, and After Retention and Comparison of the Phases in the Treatment Group (N = 21)

	Before Treatment (T1)	After Expansion (T2)	After Retention (T3)	Intragroup Test* *P* Value		
	Mean ± SD	Mean ± SD	Mean ± SD	T1–T2	T2–T3	T1–T3
Lateral cephalogram						
SNA°	78.60 ± 3.88	79.17 ± 4.49	78.83 ± 4.08	NS	NS	NS
SNB°	77.40 ± 4.57	77.33 ± 4.44	77.24 ± 4.19	NS	NS	NS
ANB°	1.19 ± 2.23	1.83 ± 2.29	1.60 ± 2.27	.034	NS	NS
SN-PP°	8.83 ± 4.58	9.05 ± 3.72	8.60 ± 3.75	NS	NS	NS
MP-PP°	28.81 ± 5.35	29.67 ± 5.67	29.83 ± 5.89	.041	NS	.011
SN-MP°	37.55 ± 4.71	38.12 ± 4.68	38.05 ± 4.54	.037	NS	NS
N-ANS°	53.57 ± 3.94	54.12 ± 3.99	54.19 ± 3.73	NS	NS	.027
ANS-Me (mm)	67.74 ± 4.79	68.81 ± 5.81	68.67 ± 5.43	.013	NS	.016
SN⊥ANS (mm)	52.93 ± 3.11	54.29 ± 3.18	53.57 ± 3.25	.027	.014	NS
SN⊥PNS (mm)	46.14 ± 3.27	47.43 ± 3.16	46.93 ± 3.01	.026	NS	NS
SV⊥A (mm)	58.60 ± 4.29	58.90 ± 4.35	58.57 ± 4.42	NS	NS	NS
SV⊥B (mm)	47.64 ± 7.83	46.98 ± 7.53	47.00 ± 7.65	NS	NS	.025
PP-OKL°	12.88 ± 4.30	15.62 ± 4.67	15.38 ± 4.23	.001	NS	.000
MP-OKL°	15.95 ± 4.10	13.93 ± 3.78	14.40 ± 3.97	.000	NS	.000
U1P-SN°	100.4 ± 7.33	99.48 ± 7.12	99.79 ± 6.04	NS	NS	NS
L1P-MP°	85.14 ± 6.64	85.86 ± 6.99	85.98 ± 7.27	NS	NS	NS
SV⊥U1 (mm)	57.64 ± 6.02	57.76 ± 5.93	57.43 ± 5.79	NS	NS	NS
SV⊥L1 (mm)	55.52 ± 5.75	54.90 ± 5.87	55.38 ± 5.78	NS	NS	NS
E-Ls (mm)	−5.38 ± 2.49	−4.81 ± 2.23	−4.83 ± 2.23	NS	NS	.014
E-Li (mm)	−2.17 ± 3.06	−1.40 ± 2.96	−1.71 ± 2.96	.017	NS	.025
Frontal cephalogram						
CNn[a]-MS (mm)	16.55 ± 2.4	17.45 ± 2.26	17.71 ± 2.28	.003	NS	.003
CNw[b]-MS (mm)	16.76 ± 1.93	17.88 ± 2.28	17.57 ± 2.26	.000	NS	.004
Jn-MS (mm)	33.00 ± 3.1	34.48 ± 2.81	34.67 ± 2.42	.001	NS	.001
Jw-MS (mm)	33.86 ± 2.66	34.88 ± 2.45	34.60 ± 3.02	.001	NS	NS
U6n-MS (mm)	27.98 ± 2.65	30.21 ± 2.74	30.07 ± 3.01	.000	NS	.000
U6w-MS (mm)	27.81 ± 2.45	30.48 ± 2.41	29.83 ± 2.44	.000	.011	.000
A6n-MS (mm)	30.60 ± 2.91	29.52 ± 2.82	30.48 ± 3.04	.005	.021	NS
A6w-MS (mm)	27.50 ± 1.99	29.43 ± 2.24	29.33 ± 2.73	.000	NS	.000
AGn-MS (mm)	44.43 ± 3.85	43.36 ± 3.22	44.33 ± 2.77	.018	NS	NS
AGw-MS (mm)	42.98 ± 3.06	44.40 ± 3.36	44.00 ± 3.27	.004	NS	.034
NASn°	16.86 ± 2.27	17.50 ± 2.39	17.57 ± 2.28	NS	NS	NS
NASw°	16.83 ± 2.27	17.48 ± 2.43	17.55 ± 2.44	.027	NS	.013
MAXn°	28.10 ± 2.47	28.76 ± 2.17	28.95 ± 2.22	NS	NS	NS
MAXw°	28.71 ± 2.31	29.05 ± 2.13	28.83 ± 2.64	NS	NS	NS

[a] n indicates narrower side of the maxillary arch.
[b] w, wider side of the maxillary arch; NS, not statistically significant; * $P > .05$, Wilcoxon signed rank test.

triangular pattern of expansion in the transverse plane, with the greatest increase in maxillary arch width, was followed by the maxillary width and the nasal width. Previous studies reported a similar pattern in the expansion of the skeletal structures after the RME.[5,7,14–19] In this instance, our results failed to reject the null hypothesis.

The increase in mandibular width (the increase of 1.83 mm in A6w-MS and the reduction of 0.12 mm in A6n-MS) from T1 to T3 might be due to the acrylic part of the locked mechanism, which may upright the mandibular molars.

In the sagittal plane, our data clearly showed that there was no statistically significant displacement of the maxilla with the ARM expander. This finding was in agreement with previous reports.[12,16,20] However, our data disagreed with the findings of Basciftci and Karaman,[11] Sari et al.,[21] and Chung and Font,[22] who showed significant forward displacement of the maxilla. The different conclusions may be explained by the differences in the locations of the center of rotation of the maxillary halves in the horizontal plane.

In the present study, we found significant cephalometric alterations in the A-P position of the mandible. In the treatment group, a statistically significant decrease was found in the SV⊥B distance. The changes in the position of the mandible observed in our study also observed in the previous studies.[12,22,23] Mandibular rotation has a direct effect in the A-P position of point B. In the vertical plane, MP-PP angle

Table 3. Average Cephalometric Measurements at the Beginning and End of the Observation Period and Comparison of the Phases in the Control Group (N = 17)

	Before Observation	After Observation	Intragroup Test*
	Mean ± SD	Mean ± SD	*P* Value
Lateral cephalogram			
SNA°	80.80 ± 2.89	80.85 ± 3.03	NS
SNB°	78.26 ± 3.49	78.43 ± 3.54	NS
ANB°	2.54 ± 1.73	2.42 ± 1.60	NS
SN-PP°	7.78 ± 3.12	7.32 ± 2.95	NS
MP-PP°	27.44 ± 4.86	27.75 ± 4.56	NS
SN-MP°	34.99 ± 5.67	35.29 ± 6.10	NS
N-ANS°	48.91 ± 3.42	49.37 ± 3.96	NS
ANS-Me (mm)	60.72 ± 5.83	61.44 ± 5.56	NS
SN⊥ANS (mm)	54 ± 1.08	53.86 ± 0.85	NS
SN⊥PNS (mm)	45 ± 1.41	45.04 ± 1.63	NS
SV⊥A (mm)	56.41 ± 3.87	56.62 ± 4.05	NS
SV⊥B (mm)	46.31 ± 6.44	46.59 ± 6.47	NS
PP-OKL°	12.09 ± 3.56	12.00 ± 3.91	NS
MP-OKL°	15.35 ± 2.89	15.75 ± 2.41	NS
U1P-SN°	15.35 ± 2.89	15.75 ± 2.41	NS
L1P-MP°	90.79 ± 4.50	90.49 ± 4.52	NS
SV⊥U1 (mm)	57.05 ± 4.80	57.38 ± 5.11	NS
SV⊥L1 (mm)	54.57 ± 4.98	54.78 ± 5.12	NS
E-Ls (mm)	−2.43 ± 2.40	−2.12 ± 2.47	NS
E-Li (mm)	−1.15 ± 2.44	−0.92 ± 2.66	NS
Frontal cephalogram			
CNn[a]-MS (mm)	16.32 ± 2.03	16.17 ± 2.25	NS
CNw[b]-MS (mm)	17.09 ± 1.69	16.71 ± 1.51	.026
Jn-MS (mm)	34.32 ± 2.94	34.08 ± 3.32	NS
Jw-MS (mm)	34.72 ± 2.51	34.37 ± 3.29	NS
U6n-MS (mm)	28.51 ± 2.75	28.56 ± 3.02	NS
U6w-MS (mm)	29.44 ± 2.74	29.13 ± 2.60	NS
A6n-MS (mm)	27.96 ± 2.71	27.41 ± 2.87	NS
A6w-MS (mm)	28.95 ± 2.90	28.36 ± 2.57	NS
AGn-MS (mm)	41.93 ± 3.45	41.55 ± 3.85	NS
AGw-MS (mm)	43.11 ± 3.74	42.23 ± 3.53	NS
NASn°	16.29 ± 2.11	16.71 ± 2.81	NS
NASw°	17.00 ± 1.79	17.29 ± 2.04	NS
MAXn°	28.68 ± 2.47	28.21 ± 2.40	NS
MAXw°	29.12 ± 2.53	28.53 ± 2.40	NS

[a] n indicates right side.
[b] w, left side; NS, not statistically significant; * $P > .05$, Wilcoxon signed rank test.

Table 4. Comparison of the Differences Between the Treatment and Control Groups

	Treatment Group	Control Group	Intergroup Comparison*
	Mean ± SD	Mean ± SD	*P* Value
Lateral cephalogram			
SNA°	0.24 ± 0.98	0.05 ± 1.27	NS
SNB°	−0.17 ± 0.78	0.16 ± 1.25	NS
ANB°	0.40 ± 1.01	−0.12 ± 0.51	NS
SN-PP°	−0.24 ± 1.69	−0.46 ± 1.44	NS
MP-PP°	1.02 ± 1.60	0.31 ± 1.36	NS
SN-MP°	0.50 ± 1.44	0.31 ± 1.62	NS
N-ANS°	0.62 ± 1.13	0.65 ± 1.26	NS
ANS-Me (mm)	0.93 ± 1.57	0.71 ± 1.44	NS
SN⊥ANS (mm)	0.64 ± 1.14	−0.14 ± 0.24	NS
SN⊥PNS (mm)	0.79 ± 0.86	0.04 ± 0.24	.037
SV⊥A (mm)	−0.02 ± 1.05	0.22 ± 1.10	NS
SV⊥B (mm)	−0.64 ± 1.55	0.28 ± 2.13	NS
PP-OKL°	2.50 ± 2.14	−0.09 ± 1.26	.000
MP-OKL°	−1.55 ± 1.56	0.46 ± 1.21	.000
U1P-SN°	−0.62 ± 3.30	0.11 ± 2.54	NS
L1P-MP°	0.83 ± 1.91	−0.30 ± 2.86	NS
SV⊥U1 (mm)	−0.21 ± 1.45	0.34 ± 1.64	NS
SV⊥L1 (mm)	−0.14 ± 1.24	0.21 ± 1.82	NS
E-Ls (mm)	0.55 ± 0.92	0.25 ± 0.78	NS
E-Li (mm)	0.45 ± 1.19	0.22 ± 0.58	NS
Frontal cephalogram			
CNn-MS (mm)	1.17 ± 1.50	−0.16 ± 1.45	.006
CNw-MS (mm)	0.81 ± 1.03	−0.38 ± 1.18	.003
Jn-MS (mm)	1.67 ± 1.65	−0.24 ± 1.29	.001
Jw-MS (mm)	0.74 ± 1.65	−0.35 ± 1.32	.030
U6n-MS (mm)	2.10 ± 1.37	0.04 ± 1.46	.000
U6w-MS (mm)	2.02 ± 1.80	−0.31 ± 2.36	.010
A6n-MS (mm)	−0.12 ± 2.26	−0.55 ± 1.31	NS
A6w-MS (mm)	1.83 ± 2.15	−0.59 ± 2.08	.006
AGn-MS (mm)	−0.10 ± 2.18	−0.38 ± 1.88	NS
AGw-MS (mm)	1.02 ± 2.03	−0.88 ± 1.73	.004
NASn°	0.71 ± 2.00	0.41 ± 2.03	NS
NASw°	0.71 ± 1.62	0.29 ± 2.11	NS
MAXn°	0.86 ± 1.72	−0.47 ± 2.03	.049
MAXw°	0.12 ± 1.67	−0.59 ± 1.68	NS

NS indicates not statistically significant; * $P > .05$, analysis of covariance.

and facial heights were significantly increased in the treatment group. These alterations indicate inferior and posterior rotation of the mandible. This could be due to the transverse cusp-to-cusp occlusion from overexpansion (clinically, the occlusal inclines on the palatine cusps of the upper molars occlude with the occlusal inclines of the buccal cusps of the lower molars),[20] the downward displacement of the maxilla,[20] and the disruption of occlusion caused by extrusion and tipping of the maxillary posterior teeth along with alveolar bending.[3]

In the lateral cephalometric film analysis, the SN⊥ANS and SN⊥PNS distances were significantly and almost equally increased in the treatment group between T1 and T2. These alterations showed inferior movement of the palatal plane without rotation. Haas[5] stated that the inferior movement of the palatal plane occurred as a result of the outward tilting of the alveolar processes. This finding was in agreement with previous reports.[5,22,24]

When the two groups were compared, the only statistically significant difference was found for SN⊥PNS, which indicates more inferior movement of PNS in the treatment group. Despite the fact that the difference between the two groups in the amount of inferior movement of PNS was as low as 0.75 mm, which is probably clinically insignificant, it might be taken into consideration in vertically growing patients. Reed et al.[23] stated that the inferior movement of the palatal plane was an undesirable side effect caused by RME, particularly in patients with open-bite tendency. Inferior movement of PNS may also play a role in the increase of posterior nasal space airway; however, the clinical significance of this requires further investigation.

Significant changes were found in the occlusal plane inclination with the ARME appliance in the T1–T2 and T1–T3 periods. These alterations were significantly different from those in the control group and indicated the clockwise rotation of the occlusal plane in the treatment group. Da Silva Filho et al.[20] stated that the downward and backward mandibular rotation induces an alteration in the occlusal plane inclination.

The present study showed an increase in the vertical dimensions of the face because of the maxillary downward displacement and mandibular downward and backward rotation, as is shown in the previous studies.[11,20]

The upper and lower lips were moved forward by the ARM expander in T1–T3. Küçükkeleş and Ceylanoğlu[25] stated that the lips adapted to the new positions of the dental arches within 3 months of the retention period. The positions of the lips were almost the same after the active treatment and the retention period in our study. It was indicated that the lips could not adapt because of the shorter retention period.

Previous studies have suggested a retention period of 2–6 months, a 2–3 mm overexpansion,[7,20] and insertion of a transpalatal arch between the first upper molars to maintain transversal dimensions after the expander is removed.[3] In our study, after adequate expansion was obtained, the appliance was placed in the mouth and the screw was not turned for a week before removal. The same appliance without a locked mechanism was worn during the retention period, which lasted 6 weeks. Then, a transpalatal arch was inserted and upper arch brackets were bonded. Nevertheless, some relapse in the form of a narrowing of the upper arch was observed.

Two-dimensional evaluation is one of the limitations of our study, in contrast to the three-dimensional imaging that has become very popular in recent years. Navarro et al.[26] stated that lateral cephalograms are reliable and valid for scientific research in both angular and linear measurements and have clinically acceptable differences when compared to three-dimensional cephalometric approaches. However, the use of CT scans for orthodontic diagnosis is not routine because of ethical sanctions, and in the current study, lateral and frontal cephalometric changes were evaluated together. The lack of evaluation of skeletal maturity is another limitation of the study. Further studies should be performed to evaluate the effects of the ARME appliance with respect to stages in skeletal maturation. A narrower age range should also be considered in future studies.

CONCLUSIONS

Based on the interpretation of the cephalometric alterations observed after asymmetric RME with an ARM expander during permanent denture, we may conclude the following:

- An ARME appliance creates asymmetric increments in the transversal dimensions of the nose, maxilla, and upper arch in the short term, and asymmetrical expansion therapy for subjects with unilateral maxillary deficiency may provide satisfactory outcomes in adolescents, with the exception of mandibular arch expansion.
- The ARME appliance produced a triangular pattern of expansion in the transversal plane. It caused clockwise rotation of the mandible and occlusal plane with significant alterations in the vertical facial dimensions, whereas it created no displacement in the maxilla in the sagittal plane.

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