Original Article

Transverse dentoalveolar response of mandibular arch after rapid maxillary expansion (RME) with tooth-borne and bone-borne appliances: *A CBCT retrospective study*

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ABSTRACT

Objectives: To assess and compare spontaneous expansion of mandibular posterior teeth between tooth-borne (TB) and bone-borne (BB) rapid maxillary expansion (RME).

Materials and Methods: This study included 36 adolescents with bilateral maxillary crossbite receiving tooth-borne (average age: 14.4 ± 1.3 years) or bone-borne (average age: 14.7 ± 1.4 years) maxillary expansion. Cone beam computed tomography was acquired before expansion (T1) and after 6 months' retention (T2). Specific linear and angular measurements were performed in the coronal view to assess buccal inclinations and widths of mandibular posterior units. All data were statistically analyzed.

Results: In both groups there was a significant increase in buccal-lingual inclination of mandibular posterior teeth ranging from 1.67° to 2.30° in the TB group and from 1.46° to 2.11° in BB group. Mandibular posterior widths showed an increase ranging from 0.80 mm to 1.33 mm in TB group and from 0.64 mm to 0.96 mm in the BB group. No differences between groups were found for linear or angular measurements.

Conclusions: A clinically significant gain of space in the mandibular arch should not be expected after RME. (*Angle Orthod.* 2020;90:680–687.)

KEY WORDS: RME; Tooth-borne RME; Bone-borne RME; Arch expansion; Dentoalveolar effects

INTRODUCTION

Skeletal and dentoalveolar effects of rapid maxillary expansion (RME) have been widely investigated and confirmed by the highest levels of scientific evidence.[1–3] However, little is known about the potential dentoalveolar effects of RME in the mandibular arch. The assumption has been that expansion of the maxillary dental arch could induce functional uprighting of mandibular posterior teeth.[4–7] This may have clinical relevance concerning the indication for mandibular dental arch expansion.

Some studies[8,9] have confirmed, while others have refuted,[10,11] the spontaneous increase in lower intermolar and intercanine widths after expansion of the maxillary arch, and no definitive consensus was reached.[12] Previous investigations[8–11] were performed using conventional dental casts without the evaluation of the buccal-lingual inclination of the roots or were biased since quantitative data were obtained after completion of fixed orthodontic therapy.[12] Only one previous study[13] was conducted using cone beam computed tomography and showed that maxillary and

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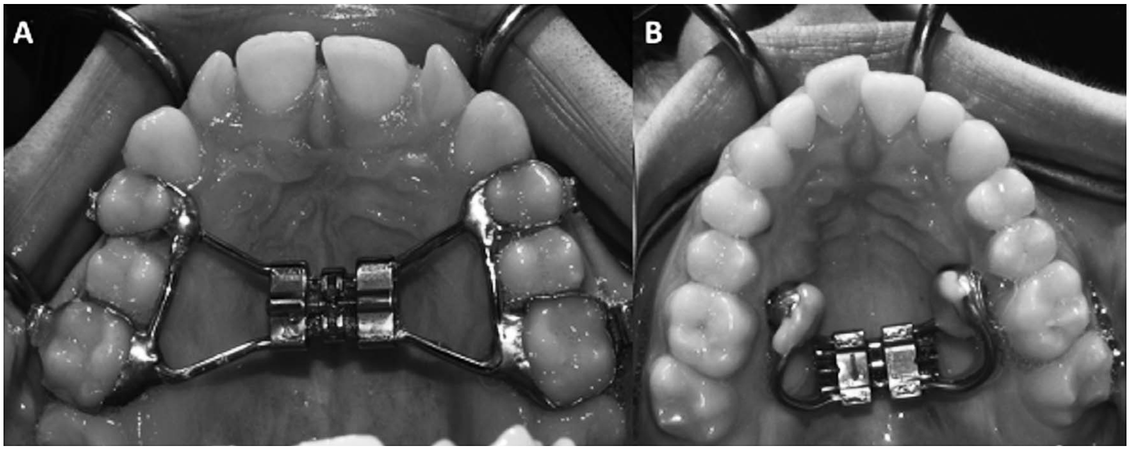

Figure 1. Tooth-borne (A) and Bone-borne (B) palatal expander used in this study.

mandibular posterior dental units tipped buccally immediately after RME, with slight relapse in the upper arch and further expansion in the lower arch during the follow-up period.[13]

Previous evidence confirmed that skeletal anchorage can increase the skeletal effect of RME, extending the benefits of this therapy to late adolescence and adulthood.[14–16] Also, it appeared that bone-borne RME limited the tipping of maxillary posterior teeth.[14,17] However, no studies have assessed the potential effects of bone-borne RME on the mandibular arch compared to conventional tooth-borne RME.

The aim of the present study was to assess the transverse changes (buccal-lingual inclinations and transverse widths) of mandibular posterior dental units after RME and to make comparative analyses between two groups of subjects treated with tooth- and bone-borne maxillary expanders. The null hypothesis was that there would be no differences in post-treatment changes in the lower arch between tooth-borne (TB) and bone-borne (BB) groups.

MATERIALS AND METHODS

The present study was approved by the Institutional Review Board of Indiana University–Purdue University (IRB protocol number: 1708606623) and included a retrospective sample of adolescents with a diagnosis of skeletal transverse deficiency treated with tooth-borne (TB group) or bone-borne (BB group) RME as part of their comprehensive orthodontic therapy (Figure 1). Inclusion criteria for the present study were as follows: (1) age between 11 and 16 years, (2) full permanent dentition (except for third molars), (3) posterior crossbite without mandibular functional shift in centric occlusion, (4) CBCT scans of good quality taken prior to the placement of the maxillary expander (T1) and after its removal (6 months) (T2), (5) no caries, dental restorations, or endodontic therapy of the upper and lower posterior dental units (first premolar, second premolar, first molar), (6) no artifacts, (7) no temporomandibular joint disorder, (8) no previous orthodontic treatment, (9) no craniofacial anomalies or systemic diseases. Eighteen subjects in the TB group (10 females, eight males; mean age: 14.4 $\pm$ 1.3 years) and 18 subjects in the BB group (12 females, six males; mean age: 14.7 $\pm$ 1.4 years) were included in the study.

In the TB group, subjects received a Hyrax expander with bands on the permanent first molars and first premolars. In the BB group, two miniscrews were inserted in the palate between the permanent first molar and the second premolar (length: 12 mm; diameter: 1.5 mm; Straumann GBR System, Andover, MA) and connected with the expander (Palex II Extra-Mini Expander, Summit Orthodontic Services, Munroe Falls, OH; Figure 1B). In both groups, the activation rate of the jackscrew was 0.25 mm/turn and the RME protocol included two turns per day, for a total of 0.5 mm/d. Activations were stopped once overexpansion was achieved, ie, when the mesiopalatal cusps of the maxillary first molars were in contact with the buccal cusps of the mandibular first molars. The appliance was kept in place for 6 months as retention and, during this period, patients did not receive other orthodontic appliances either in the upper or lower arch.

Cone beam computed tomography (CBCT) was performed on all subjects before expansion (T1) and after the 6 months of retention (T2). Patients were scanned with the same iCAT CBCT Unit (Imaging Sciences International, Hartfield, PA). The setting protocol included 0.3 mm voxel, 8.9 seconds, and large field of view at 120 kV and 20 mA. The distance between 2 slices was 0.3 mm, which provided accuracy in anatomic registration.

Buccal-lingual inclinations of maxillary and mandibular posterior teeth were assessed at T1 and T2 by

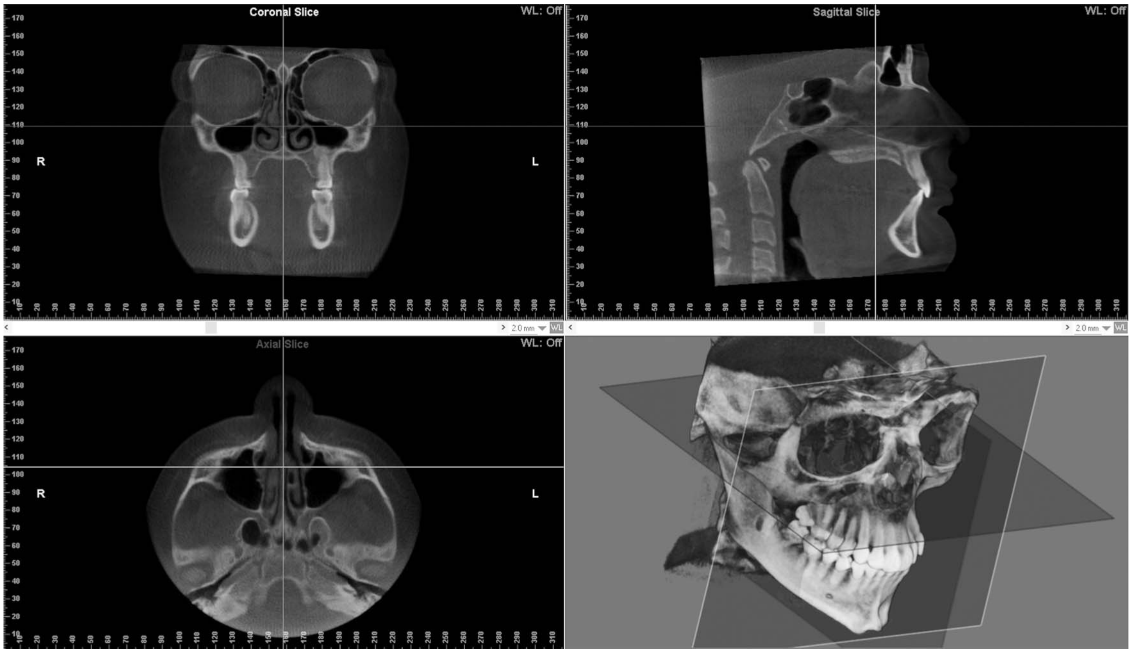

Figure 2. Head re-orientation on axial, sagittal and coronal plane of CBCT scans. The 3D image shows the head orientation in 3D space. Lines represent the reference axes.

using the CWRU's transverse analysis method.[18] Although this method was reported for measuring the inclinations of first molars and canines, application was extended for this study to the measurements of first and second premolars. Upper and lower canines were excluded from the examination since most of the included subjects presented ectopic displacement of these teeth. After head orientation (Figure 2),[9] a reference line was drawn tangent to the nasal floor and the buccal-lingual inclinations of maxillary teeth were calculated by measuring the angle between this line and the palatal long axis of each tooth (Figure 3). For mandibular measurements, a reference line was drawn tangent to the inferior border of the mandible and the buccal-lingual inclinations of mandibular teeth were calculated by measuring the angle between this line and the long axis of each tooth (Figure 4). Internal widths of maxillary and mandibular posterior units were also evaluated at T1 and T2 by choosing the most occlusal reference points of the right and left palatal cusps (mesiopalatal cusps for the lower first molars) (Figures 3 and 4).

The entire measurement workflow was performed by a single expert examiner (A.L.G.) who processed only 2 CBCT scans each day to avoid fatigue and who was blinded regarding the type of appliance used. CBCT records of 10 subjects were randomly selected to calculate intra-observer variability and the method error. The entire process was repeated 4 weeks later by the same researcher, with no knowledge of the first measurements.

Statistics

Sample size calculation was performed using data from a previous study.[13] The analysis showed that 18 subjects were required for each treatment group to detect a mean difference of 0.68° in the angular measurement of mandibular first molars between T1 and T2, with a power of 80% and a significance level of 0.05.

The normal distribution and equality of variance of the data was performed with Shapiro-Wilk Normality Test and Levene's test. When data showed normal distribution and equality of variance, the following parametric tests were used: Paired Student's *t*-test for intra-group comparison between T1 and T2 measurements, Independent Student's *t*-test for between-groups comparison of the T1-T2 differences. When data did not show a normal distribution, the following non-parametric tests were used: Wilcoxon signed-rank test for intra-group comparison between T1 and T2 measurements, and Mann-Whitney *U*-test for between-group comparisons of the T1-T2 differences. Linear regression was performed to investigate a cause-effect relationship between expansion of the maxillary posterior units (independent variable) and expansion of the mandibular posterior units (dependent variable).

Intra-examiner reliability was assessed using intraclass correlation coefficient (ICC) while analysis of the method error was performed using Dahlberg's formula.[20] Data sets were analyzed using SPSS version 24

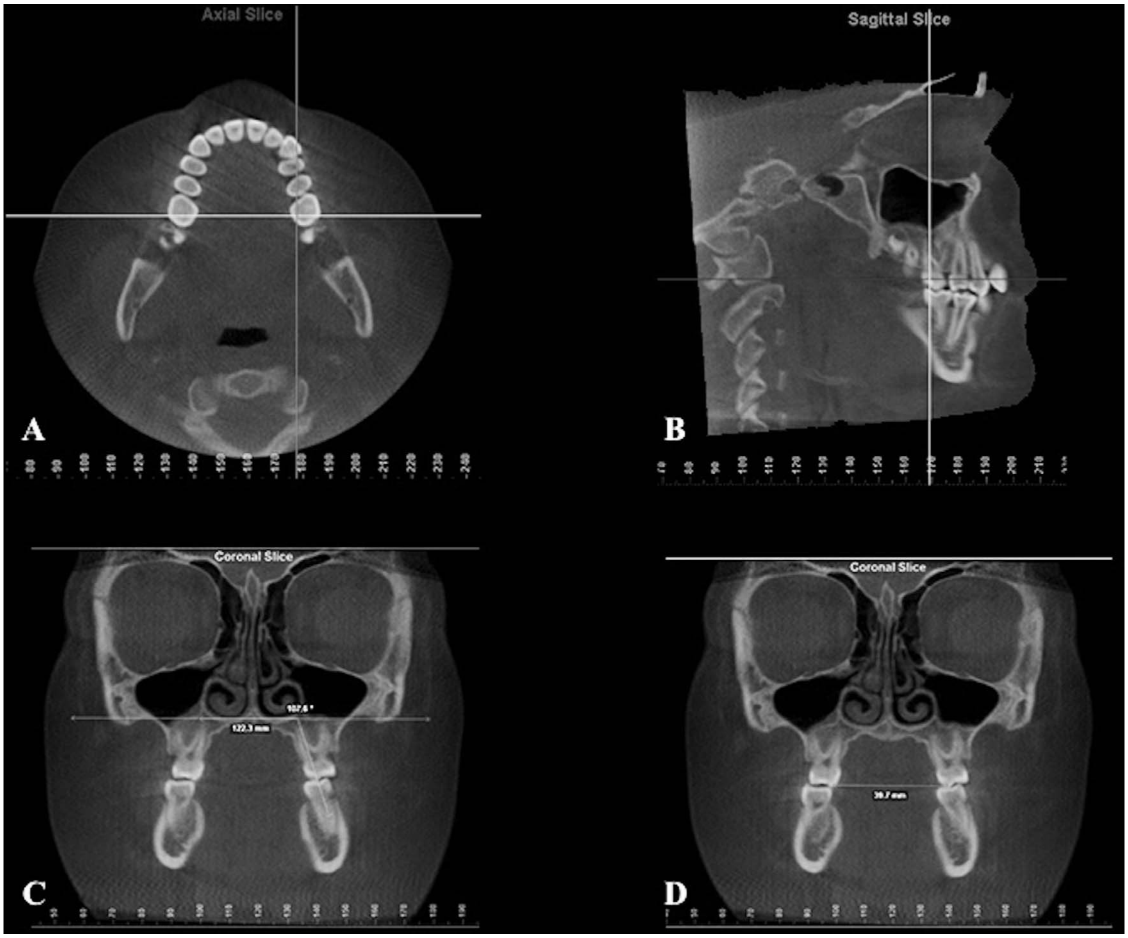

Figure 3. Example of measurement procedure for the maxillary first molars.

Statistics software (IBM Corporation, Armonk, New York, USA).

RESULTS

TB and BB groups showed a statistically significant increase of buccal-lingual inclinations of upper and lower posterior teeth ($P < .001$) (Tables 1 and 2). In the maxillary arch, these increases were significantly greater in the TB group for each tooth investigated (P values $\leq .001$) (Table 1). In the mandibular arch, the increases did not differ between the two groups, except for the right and left first premolars ($P < 005$) (Table 2).

Similarly, TB and BB groups showed a statistically significant increase in all posterior widths (linear measurements) examined in the maxilla ($P < .001$) and in the mandible ($P < .001$). There were no differences in amount of expansion between the two groups, except for the measurements made between the mandibular first premolars ($P < .05$) (Table 3).

Table 4 shows the linear regression values between the increase in mandibular linear measurements and the increase in maxillary linear measurements (predictor variable). In both the TB and BB groups, the increase in mandibular intermolar widths showed strong (0.826) and good (0.716) correlations, respectively, with maxillary expansion (increase in maxillary intermolar width).

Finally, the ICC values showed excellent correlations between the two readings for angular measurements (0.871 to 0.992) and for linear measurements (0.925 to 0.995). The random error ranged from 0.05° to 0.14° for angular measurements and from 0.06 mm to 0.10 mm for linear measurements (Dahlberg's formula).

DISCUSSION

The present CBCT study was the first that assessed changes of buccal-lingual inclinations and changes of transverse widths of mandibular posterior dental units in two groups of subjects treated with tooth-borne and bone-borne palatal expanders.

Before discussing the data obtained in the mandibular arch, a brief summary of the changes recorded in the maxillary arch is necessary. Both groups showed

Figure 4. Example of measurement procedure for the mandibular first molars.

an increase of buccal-lingual inclinations of maxillary posterior teeth, with subjects in the TB group showing greater changes compared to the BB group. This was in agreement with previous findings reporting greater tipping of posterior teeth with tooth-borne expanders.[21] The intermolar and interpremolar widths also increased after RME, with subjects in the TB group showing slightly greater increases compared to the BB group, though the difference between groups was not significant. All of the subjects included in this study experienced successful correction of their cross-bite either with tooth-borne or bone-borne expanders. Previously published data from the same study sample[22] showed greater skeletal opening of the midpalatal suture using the bone-borne expander; the small differences in the dento-alveolar expansion found between the two groups would compensate for the differences in the skeletal changes.[14]

Table 1. Maxillary Angular Measurements Before (T1) and After Rapid Maxillary Expansion (T2) for Each Investigated Tooth: Intra-Group Comparisons and Inter-Group Comparisons (Mean Differences)[a]

	Intra-Group Comparisons												Inter-Groups Comparisons (Mean Differences)				
	TB Group						BB Group										
		T1		T2				T1		T2			TB Group		BB Group		
Maxillary Angular Measurements (°)	N	Mean	SD	Mean	SD	Significance	N	Mean	SD	Mean	SD	Significance	Mean	SD	Mean	SD	Significance
16	18	96.42	1.99	99.07	2.31	$P < .001$*	18	98.10	3.60	98.70	4.12	$P < .001$**	2.66	0.58	0.60	0.58	
15	18	93.48	2.06	94.67	2.07	$P < .001$*	18	92.26	2.39	92.79	2.80	$P < .001$*	1.19	0.27	0.53	0.49	$P < .001$^^
14	18	89.47	0.93	92.97	1.12	$P < .001$*	18	93.11	1.90	93.35	2.10	$P < .001$**	3.51	0.50	0.24	0.27	$P < .001$^^
26	18	98.84	2.69	101.06	3.10	$P < .001$**	18	99.83	4.38	100.62	4.73	$P < .001$**	2.22	0.85	0.78	0.62	$P < .001$^
25	18	91.81	1.52	92.79	1.61	$P < .001$**	18	91.57	3.13	92.22	2.80	$P < .001$**	0.98	0.35	0.64	0.52	$P < .001$^^
24	18	90.41	1.36	94.44	2.60	$P < .001$*	18	92.03	1.80	92.36	1.90	$P < .001$**	4.03	1.44	0.33	0.29	$P < .001$^^

[a] TB indicates tooth-borne group; BB, bone-borne group; N, sample size; SD, standard deviation.

* Significance set on $P < .05$, according to the paired Student's *t*-test; ** Significance set on $P < .05$, according to the Wilcoxon signed-rank test; ^ Significance set at $P < .05$, according to the Independent Student's *t*-test; ^^ Significance set at $P < .05$, according to the Mann-Whitney *U* test.

Table 2. Mandibular Angular Measurements Before (T1) and After Rapid Maxillary Expansion (T2) for Each Investigated Tooth: Intra-Group Comparisons and Inter-Groups Comparisons (Mean Differences)[a]

Maxillary Angular Measurements (°)	Intra-Group Comparisons												Inter-Groups Comparisons (Mean Differences)				
	TB Group						BB Group						TB Group		BB Group		
		T1		T2				T1		T2							
	N	Mean	SD	Mean	SD	Significance	N	Mean	SD	Mean	SD	Significance	Mean	SD	Mean	SD	Significance
46	18	75.87	2.09	77.76	2.07	$P < .001$**	18	76.47	1.80	78.36	2.17	$P < .001$*	1.88	0.55	1.89	0.90	NS
45	18	77.48	2.00	79.28	2.14	$P < .001$**	18	76.20	3.11	77.83	2.88	$P < .001$**	1.81	0.57	1.63	0.85	NS
44	18	83.47	1.32	85.77	1.44	$P < .001$*	18	79.77	0.91	81.23	1.13	$P < .001$*	2.30	0.55	1.46	0.73	$P < 0.05$^^
36	18	74.45	1.24	76.38	1.66	$P < .001$*	18	77.21	2.35	79.33	1.99	$P < .001$**	1.93	0.88	2.11	0.92	NS
35	18	80.46	1.96	82.13	2.17	$P < .001$*	18	78.80	1.51	80.23	1.57	$P < .001$*	1.67	0.94	1.43	0.73	NS
34	18	85.98	1.17	88.00	1.36	$P < .001$*	18	81.30	1.34	82.60	0.86	$P < .001$*	2.02	0.69	1.30	0.71	$P < 0.05$^

[a] TB indicates tooth-borne group; BB, bone-borne group; N, sample size; SD, standard deviation.
* Significance set on $P < .05$, according to the paired Student's *t*-test; ** Significance set on $P < .05$, according to the Wilcoxon signed-rank test; ^ Significance set at $P < .05$, according to the Independent Student's *t*-test; ^^ Significance set at $P < .05$, according to the Mann-Whitney *U* test.

The buccal-lingual inclinations of the mandibular posterior teeth increased slightly after RME, with the lower molars almost reaching an increase of 2° in the TB and BB groups. Similarly, the intermolar and interpremolar widths showed a small increase after RME that ranged from 0.80 mm for the second premolars to 1.33 mm for the first premolars in the TB group, and from 0.71 mm for second premolars to 0.96 mm for first premolars in the BB group. All these findings were in agreement with previous evidence obtained from a sample of subjects treated with tooth-borne expanders.[13] No differences were found in the angular and linear changes of mandibular first molars and second premolars between the two groups, suggesting that the different pattern of expansion of the upper arch between tooth-borne and bone-borne appliances (skeletal sutural opening, dental tipping, bending of the alveolar processes), still to be completely clarified,[14] did not affect the spontaneous response of mandibular arch. However, a small significant difference between the two groups was found in the measurements of the lower first premolars, with post-treatment tipping and expansion greater in the TB group. These findings could be attributed to the design of the Hyrax expander that was anchored also to the upper first premolars, causing greater tipping of these teeth (see notably greater values compared to the upper second premolars) and, as a consequence, similar effects on the antagonist lower first premolars due to potential occlusal interferences occurring during the expansion.

The hypothesis that expansion of the maxillary arch could modify the equilibrium of forces between the tongue and cheeks could explain the present findings as well as previous evidence.[12] In particular, maxillary expansion could cause buccinator muscles to move away from the lower arch (lip bumper-like effect), favoring tongue forces that would be responsible for uprighting of the lower posterior teeth, as found in the present study.[4,5] Baysal et al.[13] found that mandibular transverse widths increased immediately after RME but also after the retention period, supporting that there was an initial, spontaneous decompensation of the lower arch following RME and a subsequent, slower uprighting during the retention period caused by the lip-bumper-like effect. In the present study, CBCT scans

Table 3. Maxillary and Mandibular Linear Measurements Before (T1) and After Rapid Maxillary Expansion (T2) for Each Investigated Tooth: Intra-Group Comparisons and Inter-Groups Comparisons (Mean Differences)

	Linear Measurements (mm)	Intra-Group Comparisons												Inter-Groups Comparisons (Mean Differences)				
		TB Group						BB Group						TB Group		BB Group		
			T1		T2				T1		T2							
		N	Mean	SD	Mean	SD	Significance	N	Mean	SD	Mean	SD	Significance	Mean	SD	Mean	SD	Significance
Maxilla	16–26 width	18	36.40	3.48	40.60	3.35	$P < .001$*	18	35.34	2.90	38.36	4.28	$P < .001$*	4.20	1.39	3.02	1.48	NS
	15–25 width	18	33.24	2.42	36.35	2.84	$P < .001$*	18	32.37	3.16	35.17	2.75	$P < .001$*	3.12	1.19	2.80	0.75	NS
	14–24 width	18	26.61	1.79	30.56	1.96	$P < .001$*	18	24.71	2.09	27.82	1.80	$P < .001$*	3.94	1.18	3.11	1.12	NS
Mandible	36–46 width	18	31.98	2.70	33.06	3.12	$P < .001$*	18	33.13	3.43	34.09	3.60	$P < .001$*	1.08	0.69	0.96	0.60	NS
	35–45 width	18	28.39	2.25	29.19	2.53	$P < .001$*	18	31.39	1.89	32.10	2.26	$P < .001$*	0.80	0.54	0.71	0.91	NS
	34–44 width	18	22.89	3.32	24.22	2.67	$P < .001$*	18	24.17	2.19	24.81	2.52	$P < .001$*	1.33	0.74	0.64	0.47	$P < 0.05$^

[a] TB indicates tooth-borne group; BB, bone-borne group; N, sample size; SD, standard deviation; NS, not significant.
* Significance set on $P < .05$, according to the Wilcoxon signed-rank test; ^ Significance set at $P < .05$, according to the Mann-Whitney *U* test.

Table 4. Linear Regression Tests Model Using Maxillary Width Measurements as Independent Variables (Predictor) and Mandibular Width Measurements as Dependent Variables

Groups	Dependent Variables	Predictor Variables	R	R Squared	Coefficients Beta	Coefficients Standard Error	95% Interval Coefficient (B) Lower Limit	95% Interval Coefficient (B) Upper Limit
TB	36–46 width	16–26 width	0.826	0.628	0.826	0.070	0.261	0.558
	35–45 width	15–25 width	0.570	0.325	0.570	0.093	0.061	0.455
	34–44 width	14–24 width	0.562	0.316	0.562	0.130	0.078	0.631
BB	36–46 width	16–26 width	0.716	0.513	0.716	0.071	0.141	0.442
	35–45 width	15–25 width	0.415	0.172	0.415	0.276	0.082	1.087
	34–44 width	14–24 width	0.528	0.279	0.528	0.088	0.033	0.408

were taken after removal of the palatal expander (six months after RME) and both described hypotheses could have contributed to the findings.

To test the cause-effect relationship between changes in the upper and lower arches, a regression analysis was performed using the increase in maxillary width as a predictor variable. The results of linear regression tests indicated a significant correlation only between the upper and lower first molars in both the TB and BB groups. These findings may be interpreted considering that the first molars were the teeth most involved in the cross-bite relationship. When two opposing teeth are in a cross-bite relationship, greater occlusal interferences can be generated during maxillary expansion, which may have resulted in greater expansion of the antagonist lower teeth.[23] In this regard, bonded expander appliances were recommended in those cases in which decompensation of the lower arch was not required, since the acrylic plane eliminated these interferences.[24] With this notion in mind, it could be postulated that, during maxillary expansion, when first molars are in a cross-bite relationship, the two buccal cusps may generate greater interferences at the lower molar fossa and along the sloped lingual aspect of the buccal cusps, favoring buccal movement of the antagonist lower first molars. This assumption may explain previous evidence of the immediate response of the mandibular molars after maxillary expansion,[13] however rejecting the hypothesis of "spontaneous" mandibular uprighting. Taking this assumption with caution, well-designed prospective clinical trials, involving different areas of cross-bite as recruitment variables, even using non-invasive methods such as measurements performed on digital dental casts, could provide useful information.

Aside from analysis of the present findings, appraisal of their clinical implications is important. In this respect, as assessed by intermolar and interpremolar linear measurements, the amount of expansion in the lower arch after RME was about 1 mm in both the TB and BB groups. Accordingly, clinicians should not expect to obtain significant clinical gains of space in the mandibular arch in subjects treated with an RME protocol. If expansion of the mandibular dentition is needed, it must be done using specific biomechanic strategies within the lower arch.[12]

Limitations

The absence of a control group was the main limitation of the present study. Expansion by normal growth may have affected quantitative data in both treated groups. However, considering that data were obtained after short-term evaluation (6 months),[23] this limitation could be considered negligible.

The present findings did not consider subjects with different skeletal patterns. Several studies reported a relationship between vertical skeletal pattern and muscle activity or occlusal forces.[25–29] These differences may also affect the mandibular dentoalveolar response after RME due to different intensities of occlusal contacts.

CONCLUSIONS

- RME caused slight buccal inclination and a slight increase in the intra-arch widths between mandibular posterior teeth.
- Post-RME treatment changes in the lower arch did not differ between TB and BB groups. Thus, the null hypothesis of the present study was not rejected.
- From a clinical perspective, considering the small amount of post-treatment expansion in the mandible, clinicians should not expect to see a clinically significant gain of space in the lower arch after RME.

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