Journal of the World Federation of Orthodontists 4 (2015) 2–7

Contents lists available at ScienceDirect

Journal of the World Federation of Orthodontists

journal homepage: www.jwfo.org

Research

Rapid maxillary expansion on the permanent teeth versus the deciduous teeth: Comparison of skeletal and dentoalveolar effects by volumetric tomography

Lombardo Luca*, Albertini Enrico, Arreghini Angela, D'Alessandro Angela Chiara, Siciliani Giuseppe

Department of Orthodontics, Postgraduate School of Orthodontics of Ferrara, University of Ferrara, Ferrara, Italy

ARTICLE INFO

Article history:
Received 24 November 2012
Received in revised form
16 September 2014
Accepted 28 October 2014
Available online 4 February 2015

Keywords:
Cone beam computed tomography
Maxillary expansion

ABSTRACT

Background: The aim of this study was to evaluate skeletal and dentoalveolar effects of rapid maxillary expansion (RME) on the permanent and deciduous teeth by means of volumetric tomography.
Methods: The sample included 12 patients with transverse maxillary hypoplasia (6 treated with RME on the permanent first molars, 6 treated with RME on the deciduous second molars) in the mixed-dentition phase. Beginning and postexpansion cone beam computed tomography images were compared for analysis of the skeletal and dentoalveolar effects of the two devices.
Results: RME treatment significantly increased the palatal volume in both groups (by 10.78% with RME on the permanent teeth vs. by 9.89% with RME on the deciduous teeth). Intermolar width increased for both skeletal and dental measurements. First upper molar tipping was greater on the first permanent molars when RME was anchored on the deciduous teeth than when anchored on the permanent teeth (4.02° vs 2.13°). Decompensation of the lower molars was greater in patients treated with RME on the permanent teeth than on the deciduous teeth (4.58° vs. 1.71°).
Conclusions: RME treatment significantly increased palatal volume. RME anchored on the permanent teeth determined greater dental intermolar width variation and a significant difference in decompensation of the lower molars. RME anchored on the deciduous teeth was more effective in increasing skeletal intermolar width and inclination of the first molars.

1. Introduction

Rapid maxillary expansion (RME) is the most common treatment employed for the correction of transverse maxillary hypoplasia. Orthopedic maxillary expansion is the result of skeletal (sutural openings), dental (tipping), and alveolar (bending and remodeling) changes. Many researchers have demonstrated its benefits in terms of posterior crossbite resolution [1], breathing improvement [2], and prognosis amendment of permanent teeth retention [3]. Side effects of maxillary expansion include dental extrusion and tipping [4], opening of the bite, and gingival recessions [5–7].

Many studies have shown the effectiveness of maxillary expansion on both skeletal and dental structures. Prior research [8–12] utilized dental casts and two-dimensional lateral and posteroanterior cephalography. Although those studies were able to highlight changes with two-dimensional measures, a three-dimensional evaluation of the dentoskeletal changes is now requested.

The diffusion of cone beam computed tomography (CBCT) has allowed for the study of the variations in oropharyngeal airway volume [13], suture opening [14], radicular resorption [15], and variation of palatal volume [16].

The aim of this study was to assess the dentoalveolar and skeletal effects of RME anchored on either the permanent or the deciduous teeth by means of CBCT.

2. Methods and materials

A sample of 53 patients actively treated at the School of Specialization in Orthodontics (University of Ferrara, Ferrara, Italy) for the correction of transverse maxillary hypoplasia was submitted to the following inclusion criteria: unique treatment with RME,

* Corresponding author: Postgraduate School of Orthodontics of Ferrara, via Montebello, 31, Ferrara 44100, Italy.
E-mail address: lulombardo@tiscali.it (L. Luca).

2212-4438/$ – see front matter © 2015 World Federation of Orthodontists.
http://dx.doi.org/10.1016/j.ejwf.2014.10.003

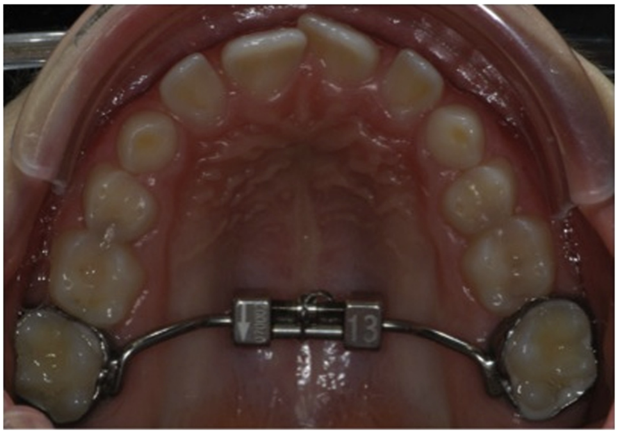

Fig. 1. “New REP” anchored on upper first permanent molars.

mixed-dentition phase, and the availability of pretreatment (T_0) CBCT.

The final sample was made up of 12 patients, 6 treated with RME on the deciduous second molars (9 female, 4 male; mean age, 9 years and 4 months) and 6 treated with RME on the permanent first molars (3 female, 1 male; mean age, 10 years and 1 month).

CBCT was repeated after an interval of 10 months (T_1), 1 month of active phase and 9 months of retention.

The Hyrax type “new REP” [17] was cemented either on the upper deciduous second molars or on the permanent first molars, depending on the availability of root support (Fig. 1).

The expansion protocol included one activation per day (0.2 mm) until the achievement of a slight hypercorrection, with the upper palatal cusps in contact with the lower buccal cusps.

A NewTom 3G VGI (QR S.r.l., Verona, Italy) was employed to obtain a scan using an effective dose (50.2 mL) of sievert [18,19]. The settings were the following: field of view, 12 in; 110 kV (AP-LL); 2.00 mA (AP) and 1.00 mA (LL); exposure time, 5.4 seconds; and section thickness, 0.50 mm. The Osirix version 3.9.1 software (Pixmeo, Geneva, Switzerland) was used to perform linear and bidimensional measures and volumetric reconstruction.

All measures were classified as volumetric, skeletal, or dental.

2.1. Volumetric measures

2.1.1. Palatal volume

Areas were created on consecutive coronal slices, using the cementoenamel junction (CEJ) as the vertical reference and the posterior nasal spine (PNS) as the posterior one. All of the areas were summed to obtain palatal volume by means of Osirix (Fig. 2).

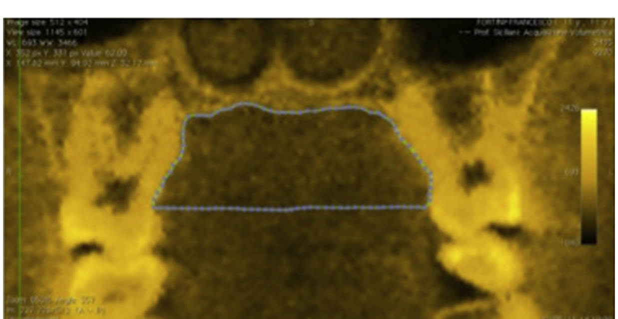

Fig. 2. Area traced on a coronal slice for palatal volume reconstruction.

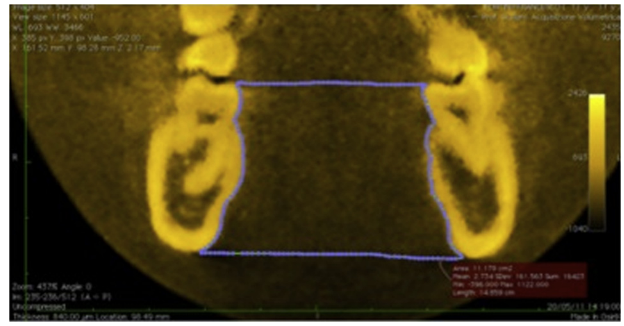

Fig. 3. Area traced on a coronal slice for space volume between lower first permanent molars reconstruction.

2.1.2. Space volume between lower first molars (volumetric evaluation of inferior molar decompensation)

Areas were created on five consecutive slices between the lower first molars, using lingual dental surfaces and mandibular inner cortical bone as references. All of the areas were summed to obtain palatal volume by means of Osirix (Fig. 3).

2.2. Skeletal measures

Transverse upper skeletal diameter was measured on axial slices at the canine (apex) and the first molar (mesiovestibular root apex) levels to the end of the buccal cortical bone (Fig. 4).

Mandibular alveolar bone thickness was measured both at the apex and furcation height as the distance between the external cortical bone and the inner one (Fig. 5).

Anterior nasal spine (ANS)-PNS was the distance between the ANS and the PNS, as measured on the sagittal slices. Palatal vault height was measured on the sagittal slices using as a reference a line passing at the central incisor CEJ and parallel to the bispinal plane (Fig. 6).

2.3. Dental measures

Dental measures included the inclination of the first upper molars with respect to the nasal base horizontal plane (inner angle) and of the first lower molars with respect to the nasal base horizontal plane (inner angle) (Fig. 7). The intercanine distance was measured on the axial slices at the apex and crown tip height (Fig. 8). Intermolar distance was measured on the axial slices at the palatal root apex and crown height (center of palatal surface) (Fig. 9). The right upper central incisor–PNS (projection) was

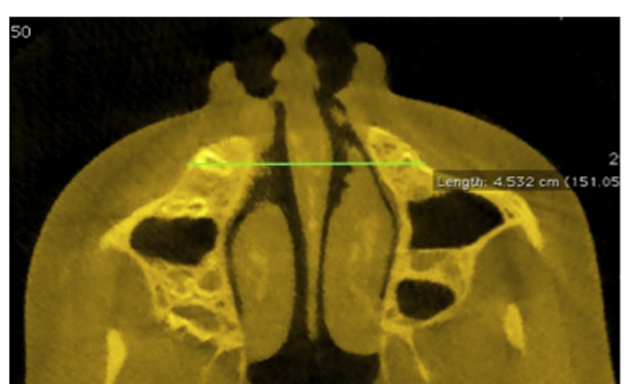

Fig. 4. Transverse upper skeletal diameter measured on axial slices at canine (apex).

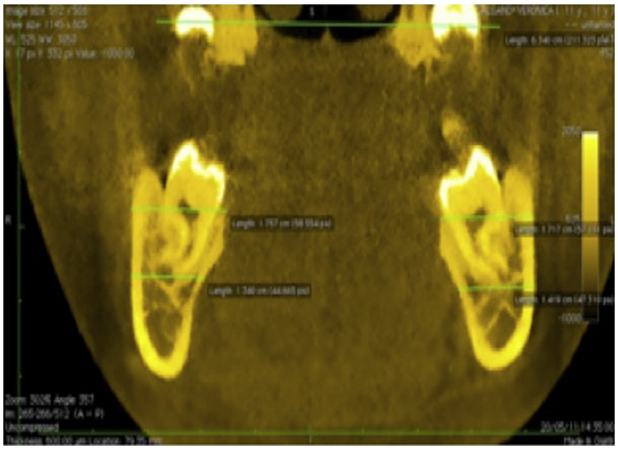

Fig. 5. Mandibular alveolar bone thickness, measured both at apex and furcation height.

measured on the sagittal slices at the apex, CEJ, and margin height (Fig. 10). The right upper molar–PNS (projection) was measured on the sagittal slices at the distovestibular root apex, CEJ, and distal cusp height (Fig. 11).

2.4. Statistical analysis

Data were examined with SPSS version 18.0 software (SPSS Inc., Chicago, IL). Statistical analysis was carried out with the Mann-Whitney *U* test for comparisons of the two unrelated groups. The Student's *t* test for paired data was used for the comparison of pre- and post-treatment values. The significance level was set at 0.05.

3. Results and discussion

All of the results are reported in Tables 1–4. Group I refers to patients with RME anchored on the permanent first molars; group II refers to patients with RME anchored on the deciduous second molars.

3.1. Volumetric measures

Palatal volume increased between T_0 and T_1 by about 10.78% ($P = .004$) in group I and by about 9.89% in group II. Space volume between the lower first molars perceived a 17.19% reduction in group I and a 27.71% ($P < .0001$) reduction in group II.

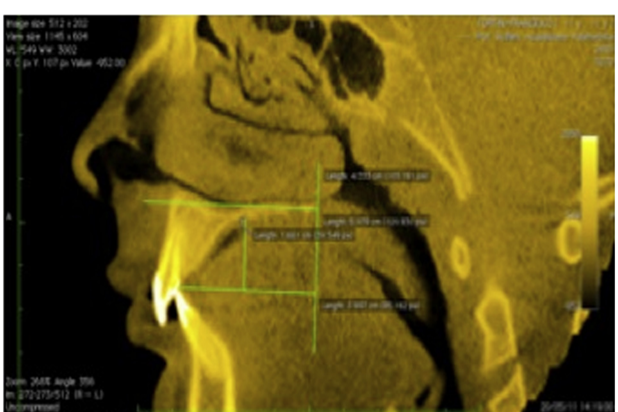

Fig. 6. Palatal vault height.

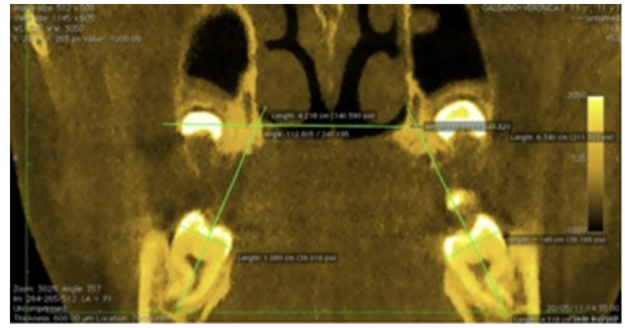

Fig. 7. First lower molars inclination with respect to the nasal base horizontal plane.

3.2. Skeletal measures

Transverse skeletal diameter at the canine increased from 3.593 to 3.662 cm in group I and from 3.823 to 3.867 cm in group II. Transverse skeletal diameter at the first molar increased from 5.769 to 5.804 cm in group I and from 5.167 to 5.730 cm ($P = .028$) in group II.

Regarding mandibular alveolar bone thickness, decreases were recorded: −1.0%, on average, in group I and −1.0%, on average, in group II.

Measures on the sagittal slices revealed increases in ANS-PNS of 0.085 cm in group I ($P = .056$) and 0.174 cm in group II. Palatal vault height increased by 0.071 cm in group I and by 0.090 cm in group II.

3.3. Dental measures

Inclination of the upper first molars increased to extents of 2.13°, on average, in group I and 4.02°, on average, in group II.

The lower first molars showed reductions of 4.58°, on average, with reference to group I, and 1.77°, on average, with respect to group II.

Intercanine distance regarding apex measures showed increases equal to 0.127 cm in group I and 0.103 cm in group II. At tip, variations were 0.364 cm in group I ($P = .011$) and 0.073 cm in group II.

Intermolar distances, regarding apex measures, were increased by 0.395 cm in group I ($P = .007$) and by 0.090 cm in group II.

Sagittally, the distance between the right upper central incisor and PNS showed variations of +0.050, +0.002, and −0.026 cm at the apex, CEJ, and crown, respectively, in group I and +0.163, +0.311 ($P = .021$), and +0.429 cm in group II ($P = .001$).

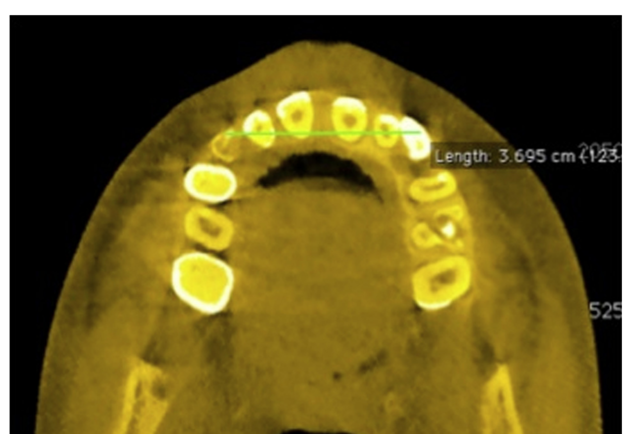

Fig. 8. Intercanine distance measured at crown tip height.

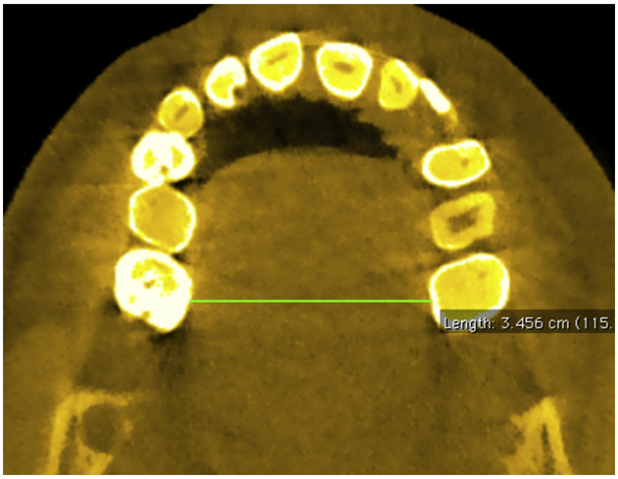

Fig. 9. Intermolar distance measured at crown height.

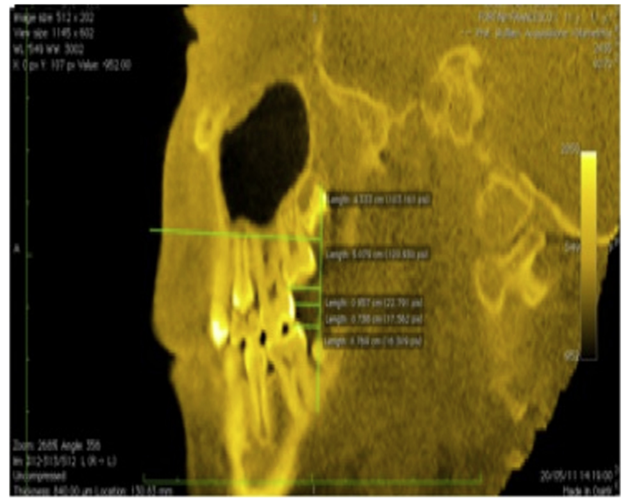

Fig. 11. Right upper molar-PNS (projection), measured at distovestibular root apex, CEJ and distal cusp height.

Sagittally, the distances between the right upper molar and PNS were increased by 0.111, 0.153, and 0.064 cm at the distovestibular root apex, CEJ, and distal cusp tip, respectively, in group I and by 0.216 ($P = .004$), 0.403 ($P = .021$), and 0.404 cm ($P = .012$) in group II.

The aim of this research was to evaluate and compare the three-dimensional effects of RME when used on the permanent and deciduous teeth.

The accuracy of linear and volumetric measurements obtained by CBCT has been demonstrated by many authors [20,21].

Because stable reference planes for the comparison CBCT measurements do not exist, the bispinal plane and hard palate base were chosen for sagittal and coronal values, respectively.

The second CBCT was repeated 10 months after the insertion of the two appliances; this interval was chosen estimating 1 month for the activation of RME and 9 months for the stabilization of RME. Intermediate lapse resulted in greater treatment duration (12.7 months, on average) considering that some patients started the treatment a few months after the first volumetric tomography. Some variations should be imputed to the growth during this period, although the extent is assessable as nonsignificant [22,23].

The type of expander employed was a Veltri “new REP” [17], without palatal arms to allow for the examination of the skeletal effects and to avoid distortions determined by tipping action on the adjacent teeth.

In the considered interval, a significant palatal volume increase was achieved in both groups. The amount was increased when RME was anchored on the permanent teeth (by 10.78% vs. 9.89%, on average).

Enhancements were less in both groups compared with that obtained by Gohl et al. [16] (21.7%), but that research examined a younger group of patients.

Inferior decompensation volume was reduced in both groups, probably as a consequence of the mesial first molar migration during trade-tooth. Inferior decompensation was greater when RME was anchored to the permanent teeth. This result can be ascribed to the greater amount of expansion relative to the upper first molars when they are used as anchorage elements.

Tipping movement of the upper first molars was increased in both groups. This outcome was not only an orthopedic but also a dentoalveolar RME effect. According to the study of McNamara et al., buccal tipping of the upper first molars after RME expresses in a range between 0° and 24° [24]. Recently, Kartalian et al. [25] noticed that dentoalveolar buccal tipping after RME treatment was principally determined by an alveolar bending. In our study, in agreement with Kartalian, it is possible to conclude that the greater tipping found in both groups is referable to the alveolar bending created by RME action [26].

Upper molar inclination increased more in group II (RME anchored on the deciduous teeth) compared with group I (RME anchored on the permanent teeth). Because in group I the first molars were not RME anchorage units, the increase registered must have been due to alveolar bending.

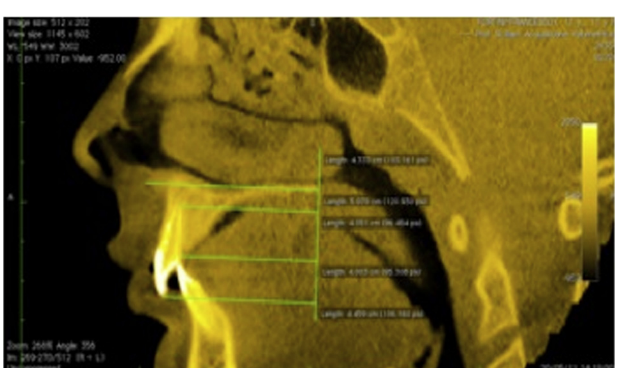

Fig. 10. Right upper central incisor-PNS (projection), measured at apex, CEJ and margin height.

Table 1
Volumetric results

Parameter	Group I: RME anchored on first permanent molars (n = 6)			Group II: RME anchored on second deciduous molars (n = 6)		
	Mean	SD	SE	Mean	SD	SE
Volume						
T_0	9.351	1.915	0.782	9.381	1.924	0.785
T_1	10.479	1.663	0.679	10.406	2.779	1.135
Variation	+1.128	0.563	0.230	+1.025	1.851	0.756
Lower molar space volume						
T_0	1.574	0.293	0.120	1.835	0.311	0.127
T_1	1.303	0.194	0.079	1.326	0.263	0.107
Variation	−0.271	0.324	0.132	−0.509	0.110	0.045

Values are cm^3. $P < .001$.

Table 2
Skeletal results

Parameter	Group I: RME anchored on first permanent molars (n = 6)			Group II: RME anchored on second deciduous molars (n = 6)		
	Mean	SD	SE	Mean	SD	SE
Transverse skeletal diameter						
At canine						
T_0	3.593	0.380	0.155	3.823	0.263	0.107
T_1	3.662	0.405	0.165	3.867	0.250	0.102
Variation	−0.069	0.204	0.083	−0.045	0.133	0.054
At molar						
T_0	5.769	0.145	0.059	5.167	0.463	0.189
T_1	5.804	0.259	0.106	5.730	0.343	0.140
Variation	−0.035	0.248	0.101	−0.563	0.448	0.183
Bone thickness at 36 forcation						
T_0	1.456	0.359	0.146	1.335	0.130	0.053
T_1	1.334	0.376	0.154	1.245	0.294	0.120
Variation	−0.122	0.102	0.042	−0.090	0.251	0.103
Bone thickness at 36 apex						
T_0	1.481	0.287	0.117	1.375	0.070	0.029
T_1	1.524	0.282	0.115	1.268	0.158	0.065
Variation	+0.043	0.096	0.039	−0.101	0.122	0.050
Bone thickness at 46 forcation						
T_0	1.385	0.373	0.152	1.276	0.203	0.083
T_1	1.287	0.374	0.153	1.344	0.329	0.134
Variation	−0.097	0.138	0.056	+0.068	0.250	0.102
Bone thickness at 36 apex						
T_0	1.499	0.262	0.107	1.339	0.081	0.033
T_1	1.473	0.309	0.126	1.277	0.155	0.063
Variation	−0.026	0.067	0.027	−0.062	0.199	0.081
ANS-PNS						
T_0	5.043	0.448	0.183	4.635	0.400	0.163
T_1	5.127	0.440	0.179	4.809	0.394	0.161
Variation	+0.085	0.084	0.034	+0.174	0.232	0.095
Palatal vault height						
T_0	1.403	0.208	0.085	1.821	0.365	0.149
T_1	1.473	0.235	0.096	1.911	0.333	0.136
Variation	+0.071	0.173	0.071	+0.090	0.126	0.052

Values are cm. $P < .001$.

Axial measurements evidenced a minimal transverse skeletal diameter increase at the canine (0.07 cm in group I and 0.05 cm in group II), whereas at the molar the enhancement was statistically significant only when RME was anchored on the deciduous teeth (0.56 cm).

The greater skeletal transverse effect obtained in group II can be explained considering the lesser interdigitation of the suture when patients are at an earlier age and the higher number of activations required to reach hypercorrection when the RME is anchored on the deciduous second molars.

Statistically nonsignificant increases in the intercanine dental distance at the apex level were recorded in both groups, whereas at the cusp level, the increase was relevant when RME was anchored on the permanent first molars.

Intermolar dental distance, measured at the apex level, was greater at post-treatment in both groups; as expected, the amount of variation was greater in group I [8,16,27].

Measurements on the sagittal slices showed a slight increase in ANS-PNS distance (0.13 cm), with a nonsignificant difference between the two groups. These differences can be assigned only to craniofacial complex growth.

The distance between the upper right central incisor and PNS perpendicular, measured on three levels, was enhanced. The variations were greater in group II at all heights considered. In both groups, the increases obtained could be linked to point A advancement after the maxillary expansion [28] and to the maxillary complex growth influence.

Table 3
Dentoalveolar results (inclination−nasal base plane)

Parameter	Group I: RME anchored on first permanent molars (n = 6)			Group II: RME anchored on second deciduous molars (n = 6)		
	Mean	SD	SE	Mean	SD	SE
Inclination 16-nasal base plane						
T_0	93.477	7.480	3.054	106.215	9.494	3.876
T_1	95.382	8.416	3.436	109.365	4.826	1.970
Variation	+1.905	7.214	2.945	+3.150	7.578	3.094
Inclination 26-nasal base plane						
T_0	93.363	10.055	4.105	101.901	11.176	4.563
T_1	95.718	6.030	2.462	106.792	6.410	2.617
Variation	+2.355	10.366	4.232	+4.892	8.640	3.527
Inclincation 36-nasal base plane						
T_0	99.349	11.373	4.643	101.741	6.645	2.713
T_1	94.956	9.490	3.874	98.939	4.606	1.881
Variation	−4.393	5.943	2.426	−2.803	8.124	3.316
Inclincation 46-nasal base plane						
T_0	101.366	6.597	2.693	102.242	6.573	2.683
T_1	96.586	5.657	2.309	101.634	1.091	0.446
Variation	−4.780	4.489	1.833	−0.608	7.349	3.000

Values are°. $P < .001$.

Table 4
Dentoalveolar results (linear measures)

Parameter	Group I: RME anchored on first permanent molars (n = 6)			Group II: RME anchored on second deciduous molars (n = 6)		
	Mean	SD	SE	Mean	SD	SE
Transverse canine diameter						
At root apex						
T_0	2.483	0.291	0.119	2.823	0.121	0.054
T_1	2.611	0.393	0.161	2.926	0.254	0.114
Variation	+0.127	0.301	0.123	+0.103	0.178	0.080
At crown						
T_0	2.920	0.280	0.114	2.814	0.260	0.116
T_1	3.284	0.381	0.155	2.888	0.360	0.161
Variation	+0.364	0.225	0.092	+0.073	0.212	0.095
Transverse molar diameter						
At mesiopalatine root apex						
T_0	3.040	0.205	0.084	3.078	0.339	0.138
T_1	3.435	0.152	0.062	3.168	0.552	0.225
Variation	+0.395	0.216	0.088	+0.090	0.256	0.105
At crown						
T_0	3.202	0.306	0.125	3.295	0.270	0.110
T_1	3.598	0.207	0.084	3.543	0.432	0.177
Variation	+0.396	0.148	0.061	+0.248	0.171	0.070
PNS projection						
From 21 root apex						
T_0	4.097	0.450	0.184	3.589	0.167	0.068
T_1	4.147	0.465	0.190	3.751	0.267	0.109
Variation	+0.050	0.133	0.054	+0.163	0.270	0.110
From 21 CEJ						
T_0	4.200	0.524	0.214	3.666	0.195	0.080
T_1	4.202	0.580	0.237	3.977	0.329	0.134
Variation	+0.002	0.152	0.062	+0.311	0.230	0.094
From 21 crown tip						
T_0	4.792	0.615	0.251	4.239	0.303	0.124
T_1	4.766	0.726	0.296	4.668	0.344	0.140
Variation	−0.026	0.196	0.080	+0.429	0.161	0.066
From 26 destovestibular root apex						
T_0	1.778	0.625	0.255	1.348	0.132	0.054
T_1	1.896	0.669	0.273	1.564	0.194	0.079
Variation	+0.111	0.182	0.074	+0.216	0.103	0.042
From 26 CEJ						
T_0	1.246	0.653	0.266	0.775	0.164	0.067
T_1	1.399	0.668	0.273	1.178	0.228	0.093
Variation	+0.153	0.170	0.070	+0.403	0.298	0.122
From 26 distal cusp tip						
T_0	1.198	0.665	0.272	0.600	0.184	0.075
T_1	1.262	0.762	0.311	1.004	0.210	0.086
Variation	+0.064	0.179	0.073	+0.404	0.259	0.106

Values are mm. $P < .001$.

Similarly, the distance between the upper first molar and PNS perpendicular increased.

There is no agreement in the scientific literature about RME effects with respect to palatal height [16,29].

In our study, although the method was the same as the one used by Gohl et al. [16], a variation in palatal vault height was recorded, with enhancements of 0.071 cm in group I and 0.090 cm in group II. We can conclude that RME has a minimal influence on palatal vault height increment.

4. Conclusions

In our sample, RME treatment after 10 months was associated with significantly increased palatal volume in both groups. It also permits a statistically significant increase in intermolar diameter, resulting in the best choice for posterior crossbite resolution. RME anchored on the deciduous teeth led to a greater intermolar skeletal transverse variation, whereas RME on the permanent teeth led to a greater intermolar dental variation. Upper molar buccal tipping was increased in both groups, but it was greater when RME was anchored on the deciduous teeth, as a consequence of an alveolar bending effect. Lower molar decompensation was more effective when RME was anchored on the permanent teeth.

References

[1] Thilander B, Wahlund S, Lennartsson B. The effect of early interceptive treatment in children with posterior cross-bite. Eur J Orthod 1984;6:25–34.
[2] Babacan H, Sokucu O, Doruk C, Ay S. Rapid maxillary expansion and surgically assisted rapid maxillary expansion effects on nasal volume. Angle Orthod 2006;76:66–71.
[3] Baccetti T, Mucedero M, Leonardi M, Cozza P. Interceptive treatment of palatal impaction of maxillary canines with rapid maxillary expansion: A randomized clinical trial. Am J Orthod Dentofacial Orthop 2009;136:657–61.
[4] Lagravere M, Carey J, Heo G, et al. Transverse, vertical and anteroposterior changes from bone-anchored maxillary expansion vs. traditional rapid maxillary expansion: a randomized clinical trial. Am J Orthod Dentofacial Orthop 2010;137:e304–12.
[5] Ballanti F, Lione R, Fanucci E, Franchi L, Baccetti T, Cozza P. Immediate and post-retention effects of rapid maxillary expansion investigated by computed tomography in growing patients. Angle Orthod 2009;79:24–9.
[6] Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the mid palatal suture. Angle Orthod 1961;31:73–89.
[7] Pangrazio-Kulbersh V, Wine P, Haughey M, Pajtas B, Kaczynski R. Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders. Angle Orthod 2012;82:448–57.
[8] Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2004;126:569–75.
[9] Ladner PT, Muhl ZF. Changes with orthodontic treatment when maxillary expansion is a primary goal. Am J Orthod Dentofacial Orthop 1995;108:184–93.
[10] Da Silva Filho OG, Montes LA, Torelly LF. Rapid maxillary expansion in the deciduous and mixed dentition evaluated through postero-anterior cephalometric analysis. Am J Orthod Dentofacial Orthop 1995;107:268–75.
[11] Spillane LM, McNamara JA. Maxillary adaptation to expansion in the mixed dentition. Semin Orthod 1995;1:176–87.
[12] Brieden CM, Pangrazio-Kulbersh V, Kulbersh R. Maxillary skeletal and dental changes with Frankel appliance therapy. Angle Orthod 1984;54:226–32.
[13] Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2010;137(4 Suppl):S71–8.
[14] Christie KF, Boucher N, Chung CH. Effects of bonded rapid palatal expansion on the transverse dimensions of the maxilla: a cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2010;137(4 Suppl):S79–85.
[15] Baysal A, Karadede I, Hekimoglu S, et al. Evaluation of root resorption following rapid maxillary expansion using cone-beam computed tomography. Angle Orthod 2012;82:488–94.
[16] Gohl E, Nguyen M, Enciso R. Three-dimensional computed tomography comparison of the maxillary palatal vault between patients with rapid palatal expansion and orthodontically treated controls. Am J Orthod Dentofacial Orthop 2010;138:477–85.
[17] Veltri A, Maiolino A, Ferrari D, Veltri N. New device for rapid palatal expansion in mixed dentition [in Spanish] Mondo Ortodontico 2010;35:187–92.
[18] Becker A, Smith P, Behar R. The incidence of anomalous maxillary lateral incisors in relation to palatally-displaced cuspids. Angle Orthod 1981;51:24–9.
[19] Walker L, Enciso R, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2005;128:418–23.
[20] Mischkowski RA, Pulsfort R, Ritter L, et al. Geometric accuracy of a newly developed cone-beam device for maxillofacial imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:551–9.
[21] Lagravere MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2008;134:112–6.
[22] Ricketts RM, Roth RH, Chaconas SJ, Schulhof RJ, Engel GA. Orthodontic diagnosis and planning. Denver, CO: Rocky Mountain Data Systems; 1982.
[23] Riolo ML, Moyers RE, McNamara JA, Hunter WS. An atlas of craniofacial growth: cephalometric standards from the University School Growth Study. Monograph 2. Craniofacial Growth Series. Ann Arbor, MI: Center for Human Growth and Development, University of Michigan; 1974.
[24] McNamara Jr JA, Baccetti T, Franchi L, Herberger TA. Rapid maxillary expansion followed by fixed appliances: a long-term evaluation of changes in arch dimensions. Angle Orthod 2003;73:344–53.
[25] Kartalian A, Gohl E, Adamina M, Enciso R. Cone-beam computer tomography evaluation of the maxillary dentoskeletal complex after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2010;138:486–92.
[26] Wertz R. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970;58:41–66.
[27] Garib DG, Henriques JFC, Janson G, Freitas MR, Coelho RA. Rapid maxillary expansion-tooth tissue-borne vs. tooth borne expanders: a computed tomography evaluation of dentoskeletal effects. Angle Orthod 2005;75:548–57.
[28] Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod 1970;57:219–55.
[29] Linder-Aronson S, Lindgren J. The skeletal and dental effects of rapid maxillary expansion. Br J Orthod 1979;6:25–9.