DOI: 10.4274/TurkJOrthod.2026.2025.25

TURKISH JOURNAL OF
ORTHODONTICS

Original Article

Investigation of the Effects of Tooth-Borne, Tooth-Bone-Borne and Bone-Borne Rapid Maxillary Expansion Appliances on the Nasomaxillary Complex Using CBCT

Gizem Yazdan Özen[1], İsmail Ceylan[2]

[1]Kafkas University Faculty of Dentistry, Department of Orthodontics, Kars, Türkiye
[2]Atatürk University Faculty of Dentistry, Department of Orthodontics, Erzurum, Türkiye

Cite this article as: Yazdan Özen G, Ceylan İ. Investigation of the effects of tooth-borne, tooth-bone-borne and bone-borne rapid maxillary expansion appliances on the nasomaxillary complex using CBCT. *Turk J Orthod.* 2026; 39(1): 17-25

Main Points

- All three rapid maxillary expansion modalities (tooth-borne, tooth-bone-borne, and bone-borne) provide significant skeletal expansion in the nasomaxillary complex.
- Bone-borne appliances demonstrate greater skeletal effects compared to hybrid and traditional tooth-borne (Hyrax) appliances.
- The expansion observed in the mandibular dental arch during active treatment tends to show partial relapse or lose statistical significance during the retention period.
- Cone-beam computed tomography-based analysis is highly reliable for evaluating the multidimensional changes associated with different maxillary expansion protocols.

ABSTRACT

Objective: This study aimed to investigate the effects of tooth-borne, tooth-bone-borne, and bone-borne rapid maxillary expansion (RME) on the nasomaxillary complex in individuals with maxillary transverse constriction using cone-beam computed tomography (CBCT), and to compare the outcomes of these expansion modalities.

Methods: CBCT images from 45 patients (aged 10-17 years) with maxillary transverse constriction who were treated with RME were evaluated. Patients were divided into three groups according to the appliance used: tooth-borne (Hyrax), tooth-bone-borne (hybrid), and bone-borne. CBCT records were obtained at three time points: before treatment, after active expansion, and after a 3-month retention period. Dentoalveolar and skeletal measurements were performed on the CBCT images. Intergroup comparisons were conducted using one-way ANOVA and Kruskal-Wallis tests, while intragroup comparisons were performed using repeated-measures ANOVA and Friedman tests.

Results: CBCT evaluation revealed no statistically significant intergroup differences in dental and skeletal measurements. However, all RME groups showed significant increases between time points, most of which were maintained after the retention period. In the mandible, increases in intercanine, interpremolar, and intermolar widths, observed during the active expansion phase, partially relapsed or lost their statistical significance following retention.

Conclusion: All RME modalities produced significant skeletal and dental expansion in the maxilla, with the bone-borne appliance showing greater skeletal effects than the hybrid and tooth-borne appliances.

Keywords: Maxillary expansion, palatal expansion technique, cone-beam computed tomography, orthodontic appliances

Corresponding author: Asst. Prof. Gizem Yazdan Özen, **e-mail:** dtgzmyazdan@gmail.com **ORCID:** orcid.org/0000-0002-8875-8267
Received: March 1, 2025 **Accepted:** January 08, 2026 **Publication Date:** March 31, 2026

Copyright© 2026 The Author(s). Published by Galenos Publishing House on behalf of Turkish Orthodontic Society.
This is an open access article under the Creative Commons AttributionNonCommercial 4.0 International (CC BY-NC 4.0) License.

INTRODUCTION

One of the most common skeletal anomalies affecting the maxilla is maxillary transverse deficiency, which is typically characterized by a narrow palatal arch and is often accompanied by an anterior and/or posterior crossbite.[1] The most commonly used treatment for this condition is rapid maxillary expansion (RME).[2,3]

However, forces transmitted to the teeth during RME may cause several undesirable effects, including buccal tipping of the posterior teeth,[4] alveolar bone fenestrations,[5] and root resorptions.[6] To minimize these complications, Ludwig et al.[7] proposed using a hybrid Hyrax appliance. Accordingly, various types of RME appliances have been introduced, including tooth-borne, tooth-bone-borne, and bone-borne expanders.[8,9]

The concept of RME has been gradually developed and refined by researchers such as Haas,[10] Biederman,[11] and Coffin. Haas reported that his acrylic-supported appliance reduced buccal tipping of the teeth and promoted greater skeletal expansion.[10] In 1973, Biederman[11] introduced a hygienic RME appliance supported by the permanent first molars and premolars, noting that it was more flexible than earlier designs. Subtelny later suggested that in patients with an increased vertical dimension, incorporating a bite plane into the RME appliance could help limit dental tipping and improve the transmission of expansion forces through the tooth roots to the nasomaxillary complex.[12]

Recent technological advances have enabled digitally guided expansion protocols that allow precise and safe placement of mini-implants for skeletal anchorage. Wilmes et al.[13] described the digitally planned quadexpander, a device that facilitates maxillary expansion through purely bone-borne support. Through virtual implant insertion planning and computer-aided design/computer-aided design-manufactured guides, this approach ensures optimal implant positioning in areas of adequate bone while minimizing the risk of root damage and other complications. Such innovations demonstrate how digital planning enhances both accuracy and clinical efficiency in modern expansion therapy.

Recent studies have increasingly focused on the skeletal and airway effects of microimplant-assisted rapid palatal expansion (MARPE) using three-dimensional imaging modalities. Li et al.[14] demonstrated that MARPE can induce significant long-term increases in nasal and nasopharyngeal volumes, emphasizing MARPE's potential effects beyond skeletal expansion. These findings highlight the value of cone-beam computed tomography (CBCT)-based analyses in understanding the multidimensional changes associated with skeletal anchorage-assisted expansion and underscore the need for further high-quality research to clarify its comprehensive clinical benefits.[15]

Although many studies have examined various RME protocols, relatively few have directly and comparatively investigated their effects on the nasomaxillary complex. Based on this gap in the literature, the present study aims to contribute to a more comprehensive understanding of this topic.

Accordingly, the aim of this study is to evaluate the effects of tooth-borne, tooth-bone-borne, and bone-borne RME appliances on the nasomaxillary complex using CBCT and to identify differences among these appliances. The research hypothesis (H_1) is that tooth-borne, tooth-bone-borne, and bone-borne RME methods have significantly different effects on the nasomaxillary complex, whereas the null hypothesis (H_0) is that no significant differences exist among them.

METHODS

This prospective clinical study was approved by the Atatürk University Faculty of Medicine Clinical Research Ethics Committee (approval no: 1, date: 30.09.2021). All participants were informed in detail about the purpose, methodology, potential risks, and benefits of the study, and written and verbal informed consent was obtained prior to participation.

Sample size estimation was performed using G*Power software, software based on previously reported data, and a minimum of 10 patients per group was required to detect a statistically significant difference with 80% power and 95% confidence.

The study sample were divided into three groups (n=15 per group) based on the type of RME appliance used: Group 1, tooth-borne (Hyrax); Group 2, tooth-bone-borne (Hybrid Hyrax); Group 3, bone-borne (mini-screw-supported system). The age distribution of the groups is shown in Table 1.

The inclusion criteria for this study were patients aged between 10 and 17 years, clinically and/or radiographically diagnosed with maxillary transverse deficiency, with no prior orthodontic treatment, no congenital or genetic craniofacial anomalies, and no history of systemic or neuromuscular disorders. The exclusion criteria included poor-quality CBCT images, missing posterior teeth in the maxilla, prior dentofacial orthopedic treatment, skeletal Class III malocclusion, anterior open bite, or significant facial asymmetry.

As part of the imaging protocol, CBCT scans were obtained at three standardized time points: before treatment (T0), after completion of active maxillary expansion (T1), and after a 3-month retention period (T2). All scans were performed at the Atatürk University Faculty of Dentistry, with the patient's head and neck stabilized, in accordance with the (as low as reasonably achievable) principle. Imaging was carried out using a NewTom VGi EVO 3D CBCT unit (NewTom FP, Quantitative Radiology, Milano, Italy) with standardized acquisition parameters (110 kVp, 3.0 mA, 1.8 s exposure time, 0.3-mm focal spot, 19Å~24 cm field of view). The images were obtained in (Digital Imaging and Communications in Medicine) format and analyzed using Dolphin Imaging Software. Each CBCT scan delivered an effective dose of approximately 0.087 mSv.

The first group was treated with a Hyrax appliance (Figure 1), the second group with a hybrid appliance (Figure 2), and the third group with a mini-screw-assisted expansion appliance (Figure 3). In the hybrid appliance group, two miniscrews (2 mm in diameter and 7 mm in length; Lomas, Mondeal, Germany) were inserted under local anesthesia into the anterior maxilla, positioned perpendicular to the palate, between the roots of the upper canine and first premolar, and approximately 4-6 mm from the midline. In the bone-supported appliance group, four mini-screws of the same dimensions were placed in the anterior and posterior palatal regions of the maxilla: in the anterior region, between the canine and premolar roots or between premolar roots, depending on the case; in the posterior region, between the premolar and molar roots. The anterior screws were positioned 4-6 mm from the midline, while the posterior screws were positioned approximately 8-10 mm from the midline.

No screw activation was performed on the day of appliance placement. Starting the next day, activation was performed at a rate of two quarter-turns per day. On the 5th day, an occlusal radiograph was taken to assess midpalatal suture opening. If opening was observed, activation was continued at the same rate up to 20 quarter turns; then it was reduced to 1 quarter turn per day until 40 quarter turns, and follow-up was performed every 10 turns. In patients in whom no opening of the midpalatal suture was observed, the screw was activated for an additional 10 quarter-turns, followed by a waiting period of 5-7 days without further activation. The patients were then recalled for evaluation; an occlusal radiograph was taken; and upon observing suture opening, activation was continued until a total of 40 quarter-turns was achieved. After completion of the expansion, the screw was stabilized and a 3-month retention phase was initiated.

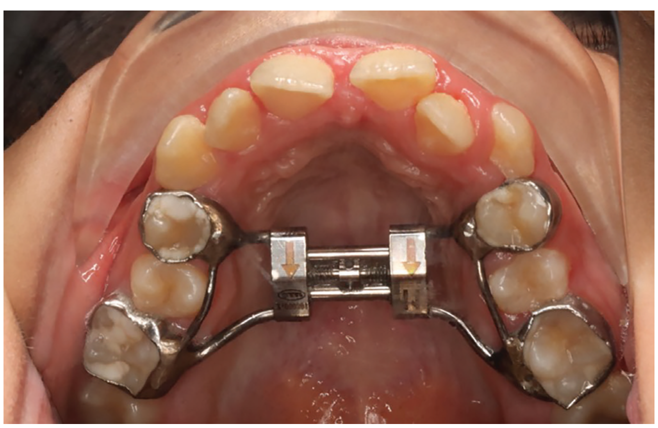

Figure 1. Hyrax expansion appliance.

Only individuals with skeletal maxillary constriction were included in the study. The diagnosis was established through a combined evaluation of the patients' digital dental models and cone beam computed tomography images. Palatal morphology was assessed on dental models, while nasal, zygomatic, and maxillary widths were evaluated on CBCT images. Cases showing significant dentoalveolar compensation, such as buccal tipping without basal deficiency, were excluded.

CBCT measurement parameters and their definitions are provided in Table 2 and detailed images of the measurement landmarks are shown in Figures 4 and 5. Skeletal transverse measurements included orbital, nasal, zygomatic, and maxillary widths. Dental measurements included maxillary and mandibular intercanine, interpremolar, and intermolar distances, defined as the distances between reference points on the respective teeth.

The intraclass correlation coefficient (ICC) was used, and all measurements demonstrated excellent agreement (ICC >0.90).[16] Tomographic measurements for 21 randomly selected patients were repeated after one month to assess intra-observer reliability.[17]

Statistical Analysis

All statistical analyses were performed using IBM SPSS 20 (Statistical Package for Social Sciences) software (IBM Corp., Chicago, IL, USA). Descriptive statistics were calculated for all variables, and normality was evaluated using the Shapiro-

Figure 2. Hybrid expansion appliance: (A) miniscrew placement; (B) appliance design.

Figure 3. Mini-screw-assisted expansion appliance: (A) screw insertion sites; (B) appliance design.

Table 1. Age distribution of the RME groups

Group	Hyrax	Hybrid	Mini-screw	p
Mean±Sd. (year)	15.50±2.096624	14.30±1.494523	15.08±1.652079	NS

NS, non-significant; RME, rapid maxillary expansion; Sd, standard deviation

Table 2. CBCT measurement parameters used in the study

Measurement name (code)	Definition
Orbital width (OrR-OrL)	The distance between the right and left orbital (Or) points
Nasal width (NcR-NcL)	The distance between the right and left nasal (Nc) points
Zygomatic width (ZygR-ZygL)	The distance between the right and left zygomatic (Zyg) points
Maxillary width (MxR-MxL)	The distance between the right and left maxillary (Mx) points
Maxillary canine distance (maxillary canine)	The distance between the reference points of the maxillary canine teeth
Maxillary premolar distance (maxillary premolar)	The distance between the reference points of the maxillary premolar teeth
Maxillary molar distance (maxillary molar)	The distance between the reference points of the maxillary molar teeth
Mandibular canine distance (mandibular canine)	The distance between the reference points of the mandibular canine teeth
Mandibular premolar distance (mandibular premolar)	The distance between the reference points of the mandibular premolar teeth
Mandibular molar distance (mandibular molar)	The distance between the reference points of the mandibular molar teeth

Wilk and Kolmogorov-Smirnov tests. For comparisons among groups, one-way ANOVA or the Kruskal-Wallis test was used as appropriate. For within-group comparisons across time points, repeated measures ANOVA or the Friedman test was applied. Post-hoc analyses were performed where necessary, and a p-value <0.05 was considered statistically significant.

RESULTS

Analysis of skeletal measurements in the transverse direction revealed that, in general, there were no significant differences between the groups (p>0.05). In contrast, there were statistically significant differences between periods (p<0.05; Table 3). The abbreviations and descriptions of the related measurements are as follows: OrR-OrL: The distance between the right and left orbital (Or) points; NcR-NcL: The distance between the right and left nasal (Nc) points; ZygR-ZygL: The distance between the right and left zygomatic (Zyg) points; MxR-MxL: The distance between the right and left maxillary (Mx) points.

Evaluation of maxillary dental measurements indicated no significant intergroup differences (p>0.05), whereas statistically significant differences were observed between periods ($p<0.05$) (Table 4). In contrast, mandibular dental measurements showed no statistically significant differences either between groups or across time periods ($p>0.05$) (Table 4).

DISCUSSION

Midpalatal suture opening and dental changes between two RME appliances-one supported by molars alone and the other supported by both premolars and molars-have previously been compared using occlusal radiographs and dental casts. From a perspective comparable to that of the present study, the intragroup evaluations of the appliance supported by four teeth can be considered with respect to dental effects at different time points. The study included 9 males and 6 females, which is comparable to the present sample (9 females, 6 males). Similarly, the measurement time points were comparable: T1, pretreatment; T2, post-active expansion; T3, after 3 months of retention.[18]

Statistically significant increases in intermolar and intercanine distances between T1 and T3 in the four-tooth-supported RME group and noted no significant relapse in intercanine width between T2 and T3 by Lamparski et al.[18] In contrast, the present study demonstrated statistically significant differences in intercanine width between T1 and T0 ($p<0.001$) and between T2 and T1 ($p<0.01$); in intermolar width between T1 and T0 ($p<0.001$), between T2 and T1, and between T2 and T0 ($p<0.01$) within the same group. These discrepancies may be attributed to differences in measurement methods and age ranges of the study populations. While previous measurements were performed on dental casts, the present study used measurements digitally from CBCT images. Furthermore, the previously reported age range was 7-13 years, whereas the present study included individuals aged 10 to 17

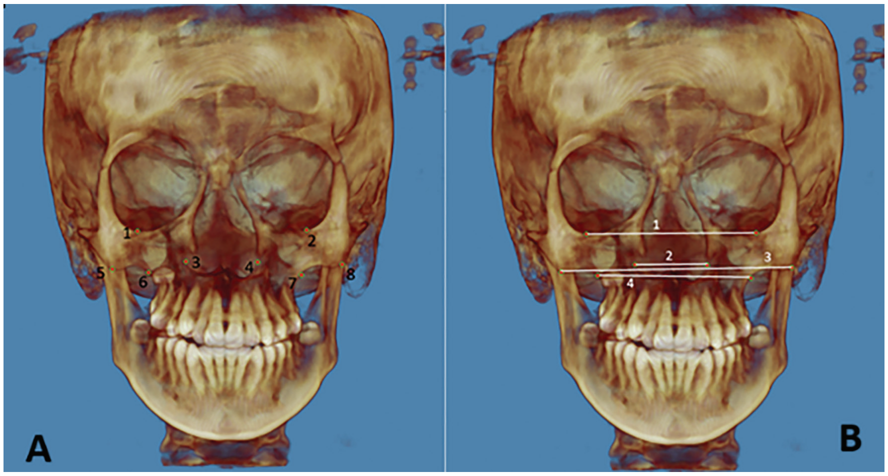

Figure 4. CBCT frontal reference points and skeletal transverse measurements. (A) Reference points: 1. right orbital point; 2. left orbital point; 3. right nasal point; 4. left nasal point; 5. right zygomatic point; 6. right maxillary point; 7. left maxillary point; 8. left zygomatic point (B) Linear measurements: OrR-OrL (The distance between the right and left orbital) 2) NcR-NcL [The distance between the right and left nasal (Nc) points] 3) ZygR-ZygL (The distance between the right and left zygomatic (Zyg) points) 4) MxR-MxL (The distance between the right and left maxillary (Mx) points).
CBCT, cone-beam computed tomography.

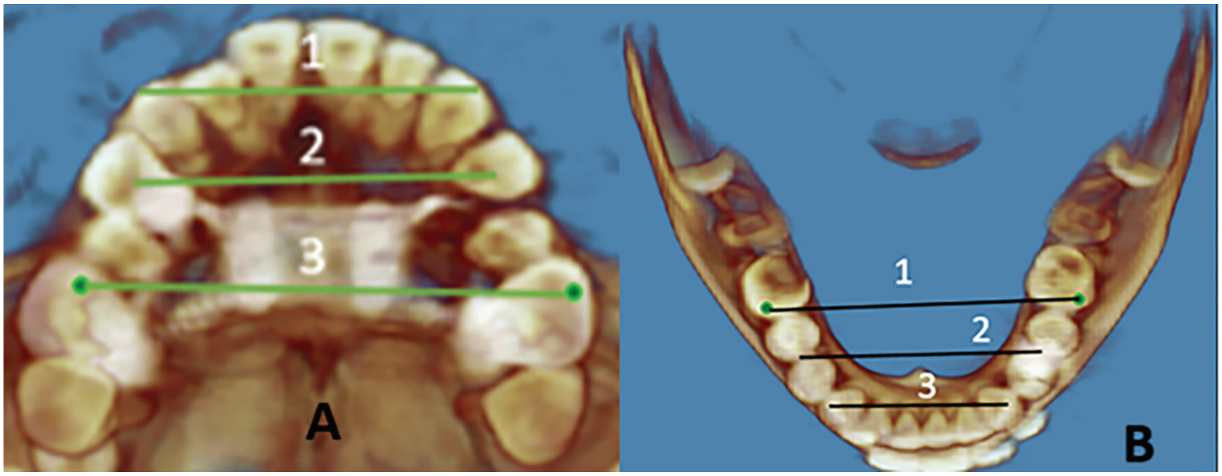

Figure 5. Dental arch measurements. (A) Maxillary measurements: 1. Intercanine distance; 2. Interpremolar distance; 3. Intermolar distance (B) Mandibular measurements: 1. Intermolar distance in the mandible; 2. Interpremolar distance in the mandible; 3. Intercanine distance in the mandible.

Table 3. Changes in skeletal transverse dimensions following RME

Measurement timepoint	Hyrax (1)	Hybrid (2)	Mini-Screw (3)	Intergroup
	Mean±SD	Mean±SD	Mean±SD	p-value/post-hoc
OrR-OrL (T0)	63.62±3.00	64.91±3.64	66.95±3.40	0.057$^{\varphi}$
OrR-OrL (T1)	64.28±3.28	65.55±3.83	67.65±3.32	0.037$^{*\delta}$
				(1-3/0,035*)
OrR-OrL (T2)	63.90±3.16	65.27±3.83	67.31±3.38	0.063$^{\varphi}$
Intragroup p	<0.001$^{\omega}$***	<0.001$^{\omega}$***	0.001$^{\sigma}$***	
Post-hoc	T1-T0 (0.000***),	T1-T0 (0.000***),	T1-T0 (0.000***),	
	T2-T1 (0.01**)	T2-T1 (0.006**)	T2-T1 (0.006**)	
NcR-NcL (T0)	24.12±2.74	22.89±1.50	23.08±1.67	0.447$^{\varphi}$
NcR-NcL (T1)	27.72±2.61	27.39±2.17	27.54±2.09	0.967$^{\varphi}$
NcR-NcL (T2)	26.45±2.48	26.69±2.28	26.61±2.09	0.960$^{\delta}$
Intragroup p	<0.001$^{\omega}$***	<0.001$^{\sigma}$***	<0.001$^{\sigma}$***	
Post-hoc	T1-T0 (0.006**),	T2-T0 (0.003**),	T1-T0 (0.006**),	
	T2-T1 (0.006**),	T1-T0 (0.000***),	T2-T1 (0.006**),	
	T2-T0 (0.000***)	T2-T1 (0.006**)	T2-T0 (0.000***)	
ZygR-ZygL (T0)	97.14±5.91	94.45±4.37	97.70±4.41	0.611$^{\delta}$
ZygR-ZygL (T1)	98.67±5.59	95.91±4.39	99.61±3.56	0.417$^{\delta}$
ZygR-ZygL (T2)	97.68±5.74	95.00±4.20	98.54±3.81	0.666$^{\delta}$
Intragroup p	<0.001$^{\omega}$***	<0.001$^{\omega}$***	<0.001$^{\omega}$***	
Post-hoc	T1-T0 (0.000***),	T1-T0 (0.000***),	T1-T0 (0.000***),	
	T2-T1 (0.003**),	T2-T1 (0.005**),	T2-T1 (0.006**),	
	T2-T0 (0.018*)	T2-T0 (0.016*)	T2-T0 (0.014*)	
MxR-MxL (T0)	58.21±3.65	59.69±2.74	60.01±2.16	0.051$^{\varphi}$
MxR-MxL (T1)	61.78±4.16	64.63±2.71	64.97±2.81	0.021$^{\delta*}$
				(1-3 /0.029*)
MxR-MxL (T2)	60.86±4.19	62.59±3.01	63.58±2.81	0.087$^{\varphi}$
Intragroup p	<0.001$^{\omega}$***	0.001$^{\omega}$***	<0.001$^{\sigma}$***	
Post-hoc	T1-T0 (0.000***),	T1-T0 (0.000**),	T1-T0 (0.000***),	
	T2-T1 (0.011*), T2-T0 (0.005**)	T2-T1(0.011*),	T2-T1(0.011*),	
		T2-T0 (0.001**)	T2-T0 (0.005***)	

$^{\varphi}$Kruskal-Wallis Test, $^{\delta}$ANOVA test, $^{\Sigma}$: Friedman Test, $^{\Omega}$: Repeated measure ANOVA.
*p<0.05; **p<0.01; ***p<0,001.
OrR-OrL, right and left orbital width; NcR-NcL, right and left nasal width; ZygR-ZygL, right and left zygomatic width; MxR-MxL, right and left maxillary width; T0, prior to treatment; T1, after active expansion; T2, following a 3-month retention period, SD, standard deviation; RME, rapid maxillary expansion; ANOVA, analysis of variance.

Table 4. Changes in dental arch dimensions following RME

Measurement & timepoint	Hyrax (1)	Hybrid (2)	Mini-screw (3)	Intergroup p/
	Mean±SD	Mean±SD	Mean±SD	Post-hoc
Max. distance between canines (mm) - T0	31.09±3.63	32.90±4.07	32.25±3.38	0.408$^{\delta}$
Max. distance between canines (mm) - T1	34.86±4.14	37.42±5.14	37.72±4.07	0.170$^{\delta}$
Max. distance between canines (mm) - T2	33.29±3.90	35.81±4.69	35.76±3.50	0.164$^{\delta}$
Intragroup p	<0.001$^{\Omega}$***	<0.001$^{\Omega}$***	<0.001$^{\Omega}$***	
Post-hoc	T1-T0 (0.000***), T2-T1 (0.003**)	T1-T0 (0.000***), T2-T0 (0.003**)	T1-T0 (0.006**), T2-T1 (0.006**), T2-T0 (0.000***)	

Table 4. Continued

Measurement & timepoint	Hyrax (1)	Hybrid (2)	Mini-screw (3)	Intergroup p/
	Mean±SD	Mean±SD	Mean±SD	Post-hoc
Max. distance between premolars (mm) - T0	30.05±2.40	31.29±2.39	31.09±2.50	0.423$^{\varphi}$
Max. distance between premolars (mm) - T1	37.27±2.88	36.73±3.24	37.05±4.23	0.916$^{\delta}$
Max. distance between premolars (mm) - T2	36.09±2.78	35.48±3.21	35.55±4.13	0.869$^{\delta}$
Intragroup p	<0.001$^{\Omega}$***	<0.001Ω***	<0.001$^{\Omega}$***	
Post-hoc	T1-T0 (0.000***), T2-T0 (0.003**)	T1-T0 (0.000***), T2-T1 (0.011*), T2-T0 (0.005**)	T1-T0 (0.000***), T2-T1 (0.006**), T2-T0 (0.006**)	
Max. intermolar distance (mm) - T0	42.26±3.58	42.26±2.45	41.36±2.08	0.240$^{\delta}$
Max. intermolar distance (mm) - T1	49.85±3.00	49.66±3.08	46.22±3.57	0.011$^{\delta}$* (1-3)
Max. intermolar distance (mm) - T2	48.49±2.90	48.24±3.17	45.03±3.68	0.018$^{\delta}$* (1-3)
Intragroup p	<0.001$^{\Omega}$***	<0.001$^{\Omega}$***	<0.001$^{\Omega}$***	
Post-hoc	T1-T0 (0.000***), T2-T1 (0.008**), T2-T0 (0.008**)	T1-T0 (0.000***), T2-T1 (0.008**), T2-T0 (0.008**)	T0-T1 (0.000***), T2-T1 (0.014*), T2-T0 (0.014*)	
Mandibular canine distance (mm) - T0	26.07±2.92	27.42±2.04	26.87±2.50	0.113$^{\varphi}$
Mandibular canine distance (mm) - T1	26.65±2.85	27.62±1.84	27.04±2.45	0.545$^{\delta}$
Mandibular canine distance (mm) - T2	26.30±2.97	27.62±1.96	26.93±2.47	0.087$^{\varphi}$
Intragroup p	0.004$^{\Sigma}$**	0.215$^{\Omega}$	0.110$^{\Omega}$	
Post-hoc	T2-T1 (0.000***), T2-T0 (0.005**)			
Mandibular premolar distance (mm) - T0	34.16±2.49	34.50±3.29	35.26±2.35	0.534$^{\delta}$
Mandibular premolar distance (mm) - T1	34.90±2.48	34.98±3.07	35.62±2.26	0.713
Mandibular premolar distance (mm) - T2	34.59±2.54	34.79±3.20	35.41±2.26	0.691$^{\delta}$
Intragroup p	0.006$^{\Omega}$**	0.029$^{\Omega}$*	0.008$^{\Omega}$**	
Post-hoc	T1-T0 (0.000***), T2-T1 (0.005**)	T1-T0 (0.008**)	T1-T0 (0.001***)	
Mandibular intermolar distance (mm) - T0	42.73±2.99	42.04±2.94	41.75±3.24	0.681$^{\delta}$
Mandibular intermolar distance (mm) - T1	43.76±2.76	42.44±3.05	42.45±3.11	0.391$^{\delta}$
Mandibular intermolar distance (mm) - T2	43.01±2.90	42.17±3.00	42.25±3.07	0.633$^{\delta}$
Intragroup p	<0.001$^{\Omega}$***	0.008$^{\Omega}$**	0.005$^{\Omega}$**	
Post-hoc	T1-T0 (0.000***), T2-T1 (0.003**)	T1-T0 (0.001***)	T2-T0 (0.000***)	

$^{\varphi}$Kruskal-Wallis Test, $^{\delta}$ANOVA test, $^{\Sigma}$Friedman Test, $^{\Omega}$Repeated measure ANOVA.
*p<0,05; ** p<0,01; *** p<0,001.
T0, prior to treatment; T1, after active expansion; T2, following a 3-month retention period; SD, standard deviation; RME, rapid maxillary expansion.

years. Age differences between study samples may be more influential than differences in measurement methodology.

Increases in interdental width achieved with monocortical and bicortical miniscrew-assisted hybrid Hyrax appliances were evaluated in individuals aged 18-21 years using CBCT at pretreatment (T0) and at the end of expansion (T1). Since it was unclear whether the second scan corresponded precisely to T1 or T2 in the present study, comparisons were made for both the T1-T0 and T2-T0 periods. Statistically significant increases in intermolar, interpremolar, and intercanine widths were reported in both groups between T0 and T1 (p<0.001).[19] Similarly, the present study demonstrated statistically significant differences in the same parameters between T1 and T0 (p<0.001) and between T2 and T0 (p<0.01). Despite differences in miniscrew diameter (e.g., 1.6 mm), length (8-10 mm), and age range, the findings are consistent. However, because bicortical engagement of miniscrews was not considered in the design of the present study, a direct comparison regarding this aspect was not possible.

The skeletal and dental effects of RME with MARPE and Hyrax appliances have also been evaluated using CBCT and dental models before expansion (T1) and shortly after active expansion (T2). Significantly greater increases in nasal and maxillary widths were reported in the MARPE group, whereas increases in intermolar width were not statistically significant.[20] In contrast, the present study found no significant difference between the same groups in the increase in nasal width after active expansion (p>0.05), whereas the increase in maxillary width was statistically significant (p<0.05). Intermolar width increases differed significantly between groups at both time points: after active expansion (T1) and after the retention period (T2) (p<0.05). These discrepancies may be explained by differences in sample size, appliance design, miniscrew characteristics, and the timing of post-expansion records.

Long-term effects of MARPE and RPE on the nasal cavity and interdental region have also been investigated using CBCT, including a control group. Significant increases in multiple skeletal and dental parameters were observed in the short term, whereas in the long term, MARPE demonstrated a greater increase in posterior nasal cavity width. Although intermolar width increased significantly in the RPE group in the short term (p<0.05), no differences were observed in later periods (p>0.05).[21] The anterior nasal width, comparable to nasal width in the present study, did not differ significantly between MARPE and RPE at any time point. Only the pretreatment and immediate post-expansion periods are comparable to the present study, due to the shorter retention period used. In the present study, although no significant between-group difference in nasal width increase was observed (p>0.05), the increase in intermolar width was significantly greater in the Hyrax group (p<0.05). Despite differences in miniscrew protocols, the findings regarding nasal width and intermolar distance were similar.

The effects of hybrid and Hyrax appliances have also been evaluated before treatment and after a longer retention period. Greater increases in nasal cavity and maxillary widths were reported in the hybrid group, whereas interdental changes were not statistically significant.[22] In contrast, the present study demonstrated no significant intergroup differences in either orthopedic or interdental changes during the T2-T0 period (p>0.05). The discrepancy in orthopedic outcomes may be attributed to the longer retention period (approximately 11 months) used in prebious studies compared with the approximately 3-month retention period used in the present study.

Study Limitations

The main limitation of the present study is the three-month follow-up, which limits assessment of the long-term stability of treatment outcomes. However, tthe inclusion of individuals in the pubertal growth period-considered optimal for orthopedic interventions-was a deliberate methodological choice to enhance the skeletal response to maxillary expansion.

CONCLUSION

RME provided significant skeletal and dental improvements in the maxilla across all appliance groups. Among them, the bone-borne appliance produced the greatest skeletal changes, underscoring its clinical value in cases with pronounced transverse deficiencies. While mandibular dental changes partially relapsed and soft-tissue effects were minimal, the overall findings underscore the effectiveness of RME and the importance of selecting appliances according to clinical needs. Nevertheless, concerns remain regarding the long-term stability of these outcomes, and further well-designed longitudinal studies are warranted.

Ethics

Ethics Committee Approval: This prospective clinical study was approved by the Atatürk University Faculty of Medicine Clinical Research Ethics Committee (approval no: 1, date: 30.09.2021).

Informed Consent: All participants were informed in detail about the purpose, methodology, potential risks, and benefits of the study, and written and verbal informed consent was obtained prior to participation.

Acknowledgments

We would like to thank the Atatürk University Scientific Research Projects Coordination Unit for supporting our study.

This study's data was obtained from the thesis titled "Investigation of the effects of different rapid maxillary expansion methods on the nasomaxillary complex and pharyngeal area by 3D computed tomography and rhinomanometry," completed in 2023 under the supervision of Prof. MD. İsmail Ceylan and authored by MD. Gizem Yazdan Özen at the Institute of Health Sciences, Department of Orthodontics, Atatürk University.

Footnotes

Author Contributions

Surgical and Medical Practices – G.Y.Ö, İ.C.; Concept – G.Y.Ö, İ.C.; Design – G.Y.Ö.; Data Collection and/or Processing – G.Y.Ö, İ.C.; Analysis and/or Interpretation – G.Y.Ö, İ.C.; Literature Search – G.Y.Ö.; Writing – G.Y.Ö, İ.C.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Proffit WR, Fields HW, Sarver DM, Ackerman JL. Contemporary Orthodontics. 6th ed. St. Louis, MO: Elsevier; 2018. [CrossRef]
2. Patil GV, Lakhe P, Niranjane P. Maxillary expansion and its effects on circummaxillary structures: a review. *Cureus.* 2023;15(1):e33755. [CrossRef]
3. Bin Dakhil N, Bin Salamah F. The diagnosis methods and management modalities of maxillary transverse discrepancy. *Cureus.* 2021;13(12):e20482. [CrossRef]
4. ZIMRING JF, ISAACSON RJ. Forces produced by rapid maxillary expansion. 3. forces present during retention. *Angle Orthod.* 1965;35:178-186. [CrossRef]
5. Landes CA, Laudemann K, Petruchin O, et al. Comparison of bipartite versus tripartite osteotomy for maxillary transversal expansion using 3-dimensional preoperative and postexpansion computed tomography data. *J Oral Maxillofac Surg.* 2009;67(10):2287-2301. [CrossRef]
6. 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(3):488-494. [CrossRef]
7. Ludwig B, Baumgaertel S, Bowman SJ. Mini-implants in orthodontics: innovative anchorage concepts. *Quintessence*. 2008:188. [CrossRef]
8. Akkaya S, Lorenzon S, Uçem TT. A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures. *Eur J Orthod.* 1999;21(2):175-180. [CrossRef]
9. Mommaerts MY. Transpalatal distraction as a method of maxillary expansion. *Br J Oral Maxillofac Surg.* 1999;37(4):268-272. [CrossRef]
10. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. *The Angle Orthodontist*. 1961;31:73-90. [CrossRef]
11. Biederman W. Rapid correction of class 3 malocclusion by midpalatal expansion. Am J Orthod. 1973;63(1):47-55. [CrossRef]
12. Subtelny JD. Oral respiration: facial maldevelopment and corrective dentofacial orthopedics. *Angle Orthod.* 1980;50(3):147-164. [CrossRef]
13. Wilmes B, Tarraf NE, de Gabriele R, Dallatana G, Drescher D. Procedure using CAD/CAM-manufactured insertion guides for purely mini-implant-borne rapid maxillary expanders. *J Orofac Orthop*. 2022;83(4):277-284. [CrossRef]
14. Li L, Zhai M, Wang M, et al. Three-dimensional evaluation effects of microimplant-assisted rapid palatal expansion on the upper airway volume: a systematic review and meta-analysis. *J Clin Med.* 2023;12(5):1790. [CrossRef]
15. Mehta S, Wang D, Kuo CL, et al. Long-term effects of mini-screw-assisted rapid palatal expansion on airway. *Angle Orthod.* 2021;91(2):195-205. [CrossRef]
16. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med.* 2016;15(2):155-163. [CrossRef]
17. Houston WJ. The analysis of errors in orthodontic measurements. *Am J Orthod.* 1983;83(5):382-390. [CrossRef]
18. Lamparski DG Jr, Rinchuse DJ, Close JM, Sciote JJ. Comparison of skeletal and dental changes between 2-point and 4-point rapid palatal expanders. *Am J Orthod Dentofacial Orthop.* 2003;123(3):321-328. [CrossRef]
19. Mohamed BA, Mohamed KM, Refai WM. Cone beam computed tomography study on changes of monocortical versus bicortical miniscrews assisted palatal expansion. *Egyptian Orthodontic Journal*. 2024;66(1):177-191. [CrossRef]
20. Jia H, Zhuang L, Zhang N, Bian Y, Li S. Comparison of skeletal maxillary transverse deficiency treated by microimplant-assisted rapid palatal expansion and tooth-borne expansion during the post-pubertal growth spurt stage. *Angle Orthod.* 2021;91(1):36-45. [CrossRef]
21. Mehta S, Gandhi V, Vich ML, Allareddy V, Tadinada A, Yadav S. Long-term assessment of conventional and mini-screw-assisted rapid palatal expansion on the nasal cavity. *Angle Orthod.* 2022;92(3):315-323. [CrossRef]
22. Garib D, Miranda F, Palomo JM, et al. Orthopedic outcomes of hybrid and conventional Hyrax expanders. *Angle Orthod.* 2021;91(2):178-186. [CrossRef]