Original Article

Long-term assessment of conventional and mini-screw–assisted rapid palatal expansion on the nasal cavity

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ABSTRACT

Objectives: To evaluate the long-term effects of mini-screw–assisted rapid palatal expansion (MARPE), rapid palatal expansion (RPE), and controls on the nasal cavity with cone-beam computed tomography (CBCT).

Materials and Methods: A total of 180 CBCT scans that were part of a previous randomized trial were evaluated retrospectively for 60 patients at pretreatment (T1), postexpansion (T2), and posttreatment (T3). Patients were randomly assigned into 3 groups: MARPE, RPE, and controls (time period T1 to T3; MARPE: 2 years 8 months; RPE: 2 years 9 months; control: 2 years 7 months). Nasal height, nasal length, nasion–ANS height, ANS–PNS length, pyriform height, and nasal septal deviation angle were measured. The changes in alar width, alar base width, anterior nasal cavity width, posterior nasal cavity width, maxillary intermolar width, and maxillary intercanine width were also evaluated.

Results: The alar base width, posterior nasal cavity width, anterior nasal cavity width, maxillary intercanine width, and maxillary intermolar width significantly increased ($P < .05$), and the nasal septal deviation angle significantly decreased ($P < .05$) in both the MARPE and RPE groups as compared with controls in the short term. In the long term, the nasal septal deviation angle was significantly decreased ($P < .05$) in the MARPE and RPE groups as compared with controls, and the posterior nasal cavity width was significantly increased ($P < .05$) in the MARPE group compared with the RPE group and controls.

Conclusions: MARPE and RPE led to a significant increase in the nasal cavity and alar base width compared with controls in the short term. In the long term, a significant increase was observed only in the posterior nasal cavity width with MARPE. Both MARPE and RPE led to a minimal decrease in nasal septal deviation angle in comparison with controls. (*Angle Orthod.* 2022;92:315–323.)

KEY WORDS: Mini-screw–assisted rapid palatal expansion; Rapid palatal expansion; Nasal cavity; Nasal septal deviation

INTRODUCTION

Transverse discrepancy of the maxilla often leads to the development of posterior crossbite and is prevalent in 9% to 23% of the population.[1] Rapid palatal expansion (RPE) is commonly used for the treatment of transverse maxillary constriction to correct the posterior crossbite in adolescent orthodontic patients.[2] An alternative to conventional RPE is mini-screw–assisted rapid palatal expansion (MARPE).[3] In contrast to a tooth-borne expander used in the RPE design, the MARPE appliance is anchored to the palatal bone using mini-implants.

The skeletal and dental effects of RPE and MARPE have been reported in previous studies.[4,5] However, the effects of RPE on the nasal cavity and soft tissues of the nose have not been investigated comprehensively. Previous studies have investigated the effect of

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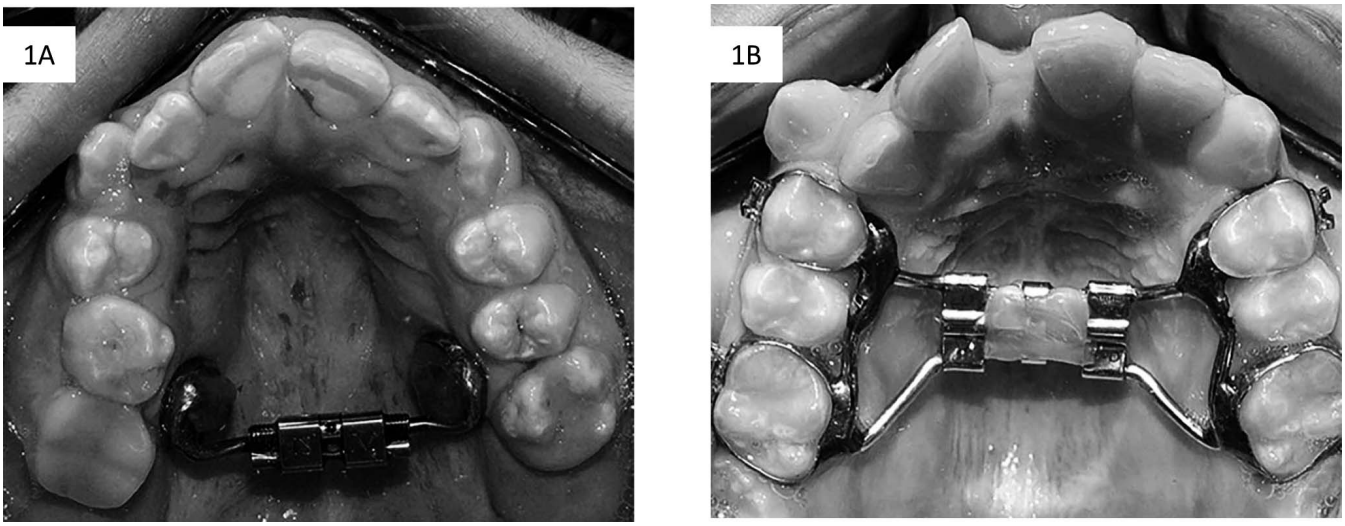

Figure 1. Design of the expansion appliances. (A) MARPE appliance. (B) RPE appliance.

maxillary expansion on facial parameters using photographic analysis, clinical examinations, and two-dimensional (2D) posteroanterior cephalograms in the short term following expansion.[6,7] However, such methods have disadvantages such as frontal photographic error, examiner bias, patient movement during the clinical examination, as well as magnification, distortion, and difficulty in identifying structures accurately in traditional radiographs.

Cone-beam computed tomography (CBCT) provides a three-dimensional (3D) representation of the head and neck structures without magnification and can be used to accurately quantify the structures of the head and neck. Thus, in recent years, the effect of RPE on nasal soft tissue changes has been investigated with CBCT.[8–10] However, only the short-term effects of expansion on the nasal cavity were observed in these studies, and long-term changes have not been investigated.[9,10] In addition, in some studies, the changes in the nasal cavity with expansion were not compared with controls.[8,7] Even though a recent study investigated the long-term effects of conventional RPE on the nasal cavity, the effects of MARPE were not investigated.[11] Thus, there is a need for the assessment of the effects of MARPE on the nasal cavity. To evaluate changes with expansion appliances on the nasal cavity conclusively, it is imperative to assess the effects of different types of expansion appliances in comparison with controls over a longer period.

Thus, the objective of this study was to evaluate the short-term and long-term effects of MARPE and RPE on the nasal cavity in comparison with a matched control group using CBCT. The null hypothesis was that there would be no difference in the nasal cavity parameters among MARPE, RPE, and controls.

MATERIALS AND METHODS

This retrospective study was approved by the Institutional Review Board at the University of Connecticut for the secondary use of CBCT scans (IRB No. SM 1168). All patients in this retrospective study were treated orthodontically in the clinical setting at the University of Alberta, Edmonton, Canada. All patients were part of a randomized controlled clinical trial and randomly assigned to three groups: MARPE, RPE, and control.[12] The inclusion criteria were patients aged 11–15 years, presence of bilateral posterior crossbite, no history of prior orthodontic treatment, absence of temporomandibular disorders, absence of surgical interventions such as adenoidectomy and tonsillectomy, and absence of craniofacial syndromes. Randomization of patients led to three groups with no significant difference in the initial parameters (Supplemental Table 1). In the MARPE group, two mini-implants were inserted in the palatal region (length: 12 mm; diameter: 1.5 mm; Straumann GBR System, Andover, Mass; Figure 1A). In the RPE group, a tooth-borne expander was anchored to the molars and premolars (Figure 1B). The activation of the expansion appliance was two turns per day (0.25 mm per turn, 0.5 mm per day) until posterior crossbite overcorrection was achieved.

All CBCT scans were recorded with the same machine (NewTom 3G device 0.25 voxels, 110 kV, 6.19 mAs, and 8-mm aluminum filtration) at three time points. The initial CBCT was recorded at pretreatment (T1) for all three groups. The second CBCT was recorded at postexpansion for the MARPE and RPE groups and 6 months after the initial CBCT in controls (T2). At T2, orthodontic treatment was performed with fixed preadjusted edgewise appliances in the MARPE, RPE, and control patients. The final CBCT was

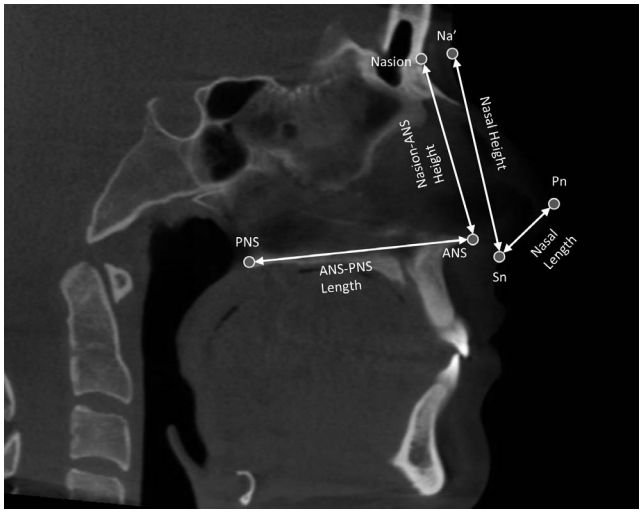

Figure 2. Landmarks: Na′, soft tissue nasion; ANS, anterior nasal spine; PNS, posterior nasal spine; Pn, pronasale; Sn, subnasale. Parameters: nasion-ANS height, ANS-PNS length, nasal height, nasal length.

recorded at posttreatment (T3) for all three groups (time period T1 to T3: MARPE: 2 years 8 months; RPE: 2 years 9 months; control: 2 years 7 months). A total of 180 CBCTs were evaluated in the study, and 4 were excluded due to motion artifacts. The mean age of the patients was 13.69 years in the MARPE group (SD: 1.74 years, 20 patients), 13.9 years in the RPE group (SD: 1.14 years, 21 patients), and 13.3 years in the control group (SD: 1.49 years, 19 patients). The patients were informed about radiation exposure with CBCT. The potential risks from radiation exposure with recorded CBCT were minimal. For the CBCT scans, the radiation dosage could be as low as 50 μSv,[13] and the yearly limit of the effective dose for infrequent radiation exposure is 5 mSv.[14]

The CBCTs were reconstructed with digital imaging and communication in medicine (DICOM) data using Dolphin Imaging software (V11.9, Chatsworth, Calif). The CBCT scans were oriented in a standardized manner as described by Troung et al.[11] Nasal height (NH), nasal length (NL), nasion–ANS height (NAH), ANS–PNS length (APL), pyriform height (PH), and nasal septal deviation angle (NSDA) were measured in the CBCT scans. Changes in alar width (AW), alar base width (ABW), anterior nasal cavity width (ANCW), posterior nasal cavity width (PNCW), maxillary intermolar width (IMW), and maxillary intercanine width (ICW) were also evaluated. The degree of nasal septal deviation was classified as mild ($\leq$8°), moderate (9°–15°), or severe ($\geq$16°).[15] The landmarks and parameters used in the study are described in Table 1 and Figures 2, 3, and 4. One investigator (Dr Mehta) performed all measurements. Twenty randomly selected CBCTs were analyzed by the same investigator (Dr Mehta) after 4 weeks for intrarater reliability and another investigator (Dr Gandhi) for interrater reliability.

Statistical Analysis

Analysis of variance (ANOVA) F-test determined that 19 samples per group would enable detection of a 0.8 standard deviation mean difference among the groups from T1 to T3 for 80% power at a 5% significance level.

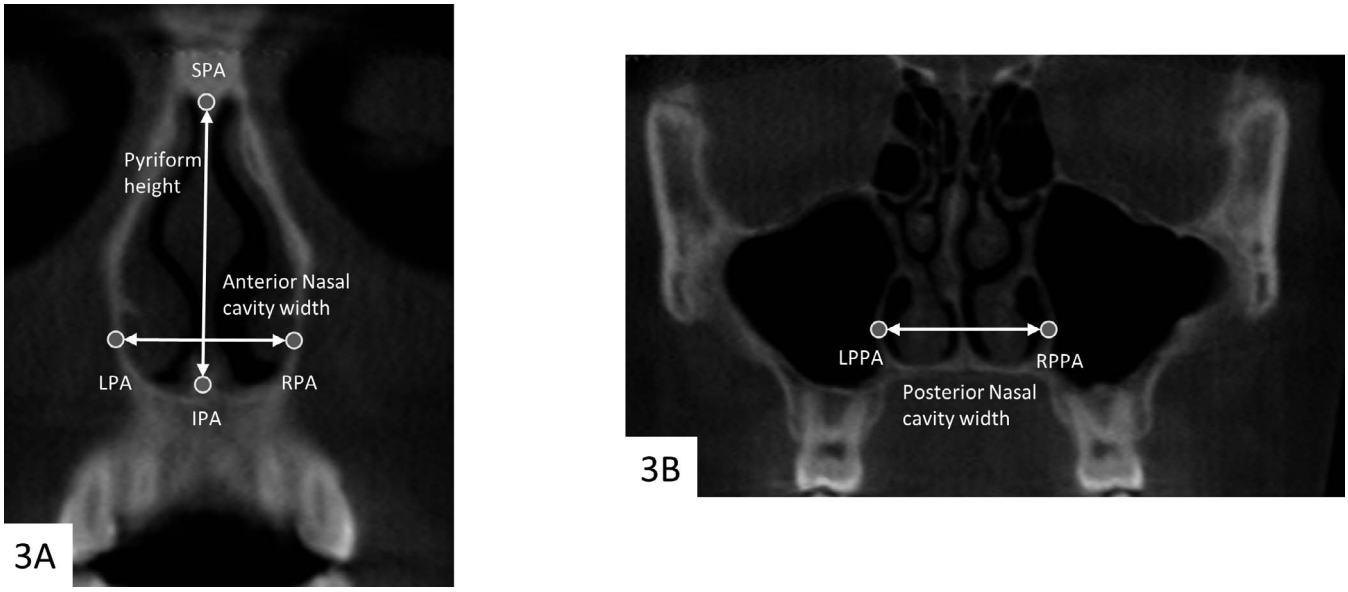

Figure 3. (A) Landmarks: SPA, superior pyriform aperture; IPA, inferior pyriform aperture; LPA, left pyriform aperture; RPA, right pyriform aperture. Parameters: pyriform height, anterior nasal cavity width. (B) Landmarks: LPPA, left posterior pyriform aperture; RPPA, right posterior pyriform aperture. Parameters: posterior nasal cavity width.

Table 1. Boundaries for the Airway Measurements and Description of the Parameters

Parameter	Description
Soft tissue landmarks	
Alar point	The most lateral point on the contour of the nostril
Alar base point	The most lateral point on the base insertion of the contour of nostril
Nasion′ (Na ′)	The soft tissue equivalent of nasion on the most anterior aspect of frontonasal suture
Pronasale (Pn)	The most anterior point on the nose in the midsagittal plane
Subnasale (Sn)	The intersection point between the base of the nose and upper lip in the midsagittal plane
Hard tissue landmarks	
Nasion (Na)	The anterior most point on the frontonasal suture
Anterior Nasal Spine (ANS)	The point on the anterior tip of nasal spine
Posterior nasal spine (PNS)	The point on the most posterior part of palatine bone
Superior pyriform aperture (SPA)	The superior most point of the bony anterior limitation of the nasal skeletal down the midsagittal plane
Inferior pyriform aperture (IPA)	The inferior most point of the bony anterior limitation of the nasal skeletal down the midsagittal plane
Left pyriform aperture (LPA)	The left most point on the pyriform aperture identified on the coronal slice passing through the maxillary right canine
Right pyriform aperture (RPA)	The right most point on the pyriform aperture identified on the coronal slice passing through the maxillary right canine
Left posterior pyriform aperture (RPPA)	The left most point on the pyriform aperture identified on the coronal slice passing through the furcation of maxillary right first molar
Right posterior pyriform aperture (RPPA)	The right most point on the pyriform aperture identified on the coronal slice passing through the furcation of maxillary right first molar
Parameters	
Nasal height (NH)	The measurement of the distance from nasion′ to subnasale
Nasal length (NL)	The measurement of the distance from pronasale to subnasale
Nasion–ANS height (NAH)	The measurement of the distance from nasion to anterior nasal spine (ANS)
ANS–PNS length (APL)	The measurement of the distance between anterior nasal spine (ANS) and posterior nasal spine (PNS)
Alar width (AW)	The measurement of the distance between most prominent points on the ala of the nose on the left and right
Alar base width (ABW)	The measurement of the distance between the most prominent points on the base of the ala on the left and right
Pyriform height (PH)	The measurement of the height from superior pyriform aperture to the inferior pyriform aperture
Nasal septal deviation angle (NSDA)	The angle between the line drawn from maxillary spine to crista-galli and another line from crista-galli to the apex of septal deviation
Anterior nasal cavity width (ANCW)	The width of nasal cavity measured on the coronal slice passing through maxillary right canine from LPA to RPA
Posterior nasal cavity width (PNCW)	The width of nasal cavity measured on the coronal slice passing through the furcation of maxillary right first molar from LPPA to RPPA
Maxillary intermolar width (IMW)	The measurement of the width between the maxillary first molars measured at the central fossa on the coronal slice passing through the furcation of maxillary right first molar
Maxillary intercanine width (ICW)	The measurement of the width between the maxillary canines measured at the central fossa on the coronal slice passing through the maxillary right canine

Shapiro-Wilk test and QQ plot were used to determine the normality of distribution of data. As the data were found to be normally distributed, parametric tests were used for the statistical analysis. The mean differences from T1 to T2 and T1 to T3 within MARPE, RPE, and controls were analyzed using paired *t* tests. The mean differences among the three groups were analyzed with ANOVA F-test. Tukey honest significant difference method was used for adjusting the *P* values for multiple testing between-group comparisons. The interrater reliability and intrarater reliability were measured using intraclass correlation coefficients (ICCs) and Bland-Altman plots. GraphPad Prism (V9, GraphPad Software, La Jolla, Calif) was used for statistical analysis. a *P* value less than .05 was considered to be statistically significant.

RESULTS

The ICC ranged from 0.96 to 0.99, and the Bland-Altman bias from –0.13 to 0.14 indicated good reproducibility with intrarater and interrater measurements (Supplemental Table 2).

Short-term Changes From Pretreatment (T1) to Postexpansion (T2) Within the Three Groups

In the short term, there was a significant increase in the ABW (0.63 mm and 0.89 mm for MARPE and RPE,

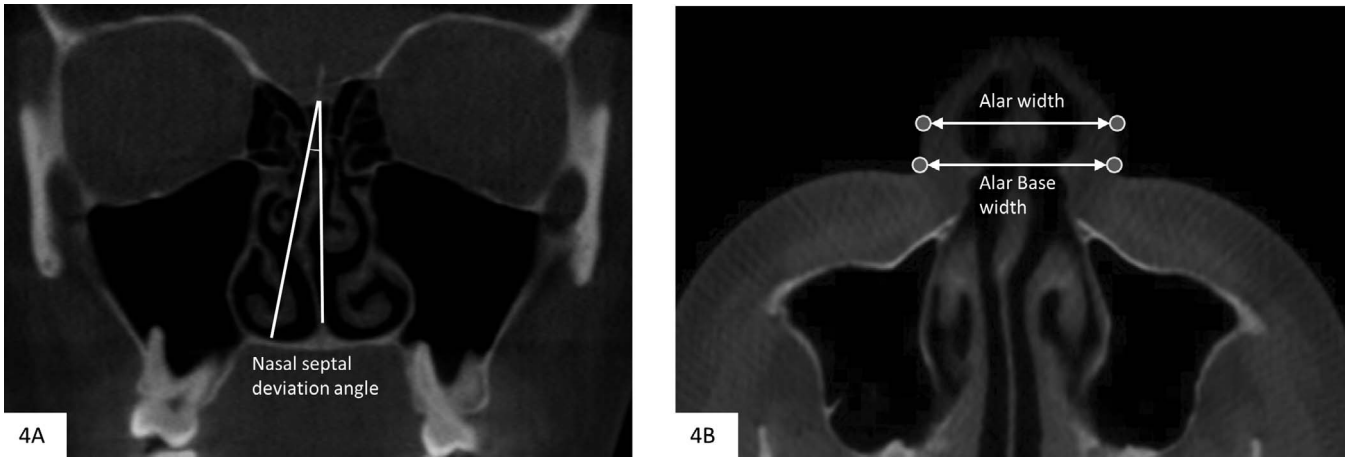

Figure 4. (A) Nasal septal deviation angle. (B) Alar width and alar base width.

respectively), PNCW (1.98 mm, 1.67 mm), ANCW (1.6 mm, 1.66 mm), IMW (4.51 mm, 6.07 mm), and ICW (1.78 mm, 2.41 mm, $P < .05$; Tables 2 and 3). The NSDA decreased significantly by 1.03° in MARPE and 0.99° in RPE ($P < .05$; Tables 2 and 3). The percentage of patients with severe NSD changed from 10% to 0% in MARPE and from 10% to 4% in RPE (Supplemental Table 3). For controls, there were no significant differences in the parameters from T1 to T2 (Table 4).

Long-term Changes From Pretreatment (T1) to Posttreatment (T3) Within the Three Groups

For both MARPE and RPE, all parameters that were significantly increased in the short term were also significantly increased in the long term, except for ABW, which did not show a significant change at T3 compared with T1. In addition, at T3, both MARPE and RPE showed a significant increase in NH (2.31 mm, 2.81 mm), NL (1.04 mm, 0.97 mm), NAH (1.14 mm, 1.27 mm), APL (1.14 mm, 0.94 mm), and PH (1.29 mm, 1.24 mm). There was also a significant decrease in the NSDA (1.71°, 1.35°) in MARPE and RPE in the long term ($P < .05$; Tables 2 and 3). The percentage of patients with severe NSD decreased from 10% to 0% in MARPE and from 10% to 0% in RPE (Supplemental Table 3).

In controls, there was a significant increase in NH (2.58 mm), NL (1.17 mm), NAH (1.13 mm), APL (1.01 mm), and PH (1.67 mm). In addition, there was a significant increase in the NSDA (2.04°), PNCW (0.63 mm), ANCW (0.74 mm), IMW (3.64 mm), and ICW (1.24 mm) in controls at T3 compared with T1 (Table 4). The percentage of patients with severe NSD

Table 2. Parameters for the MARPE Group, Pretreatment (T1), Postexpansion (T2), and Posttreatment (T3)

	Mean (SD) T1	Mean (SD) T2	Mean (SD) T3	Mean (95% CI) T2–T1	% Change (T2–T1)	Mean (95% CI) T3–T1	% Change (T3-T1)	*P* Value* (T2 vs T1)	*P* Value* (T3 vs T1)
Nasal height (NH)	50.79 (4.79)	50.96 (4.58)	52.75 (4.41)	0.18 (−1.20, 1.55)	0.33	2.31 (1.29, 3.33)	3.72	.792	<.001*
Nasal length (NL)	17.79 (1.88)	18.09 (1.56)	18.82 (2.49)	0.31 (−0.10, 0.71)	1.69	1.04 (0.35, 1.73)	5.79	.129	.005*
Nasion–ANS height (NAH)	49.88 (5.36)	50.10 (4.82)	50.53 (4.27)	0.22 (−0.49, 0.93)	0.44	1.14 (0.01, 2.26)	1.3	.526	.048*
ANS–PNS length (APL)	51.10 (4.03)	51.32 (3.98)	52.53 (3.54)	0.22 (−0.04,0.48)	0.43	1.14 (0.48,1.80)	2.80	.096	.002*
Alar width (AW)	34.60 (2.88)	34.96 (2.77)	34.86 (2.54)	0.37 (−0.36, 1.09)	1.04	0.52 (−0.35, 1.39)	0.75	.304	.223
Alar base width (ABW)	32.83 (2.76)	33.46 (2.68)	32.85 (2.23)	0.63 (0.17, 1.08)	1.92	0.31 (−0.98, 1.61)	0.06	.010*	.621
Pyriform height (PH)	39.03 (5.57)	39.72 (5.82)	39.50 (3.99)	0.70 (−0.08, 1.47)	1.77	1.29 (0.41, 2.17)	1.2	.076	.007*
Nasal septal deviation angle (NSDA)	9.75 (3.27)	8.72 (3.3)	8.29 (3.9)	−1.03 (−1.73, −0.33)	−11.81	−1.71 (−2.66, −0.75)	−17.61	.006*	.002*
Posterior nasal cavity width (PNCW)	29.22 (3.46)	31.20 (3.86)	30.82 (3.14)	1.98 (1.25, 2.70)	6.78	1.75 (1.16, 2.35)	5.48	<.001*	<.001*
Anterior nasal cavity width (ANCW)	20.02 (2.75)	21.62 (2.83)	20.71 (1.86)	1.60 (1.03, 2.17)	7.99	1.15 (0.63, 1.67)	3.33	<.001*	.017*
Maxillary intermolar width (IMW)	42.04 (3.54)	46.55 (4.44)	47.06 (2.23)	4.51 (3.46, 5.55)	10.73	5.24 (3.98, 6.50)	11.94	<.001*	<.001*
Maxillary intercanine Width (ICW)	31.48 (2.96)	33.26 (2.98)	33.64 (1.81)	1.78 (1.24, 2.33)	5.65	2.21 (0.97, 3.44)	6.86	<.001*	.002*

* Significant at $P < .05$.

Table 3. Parameters for the RPE Group, Pretreatment (T1), Postexpansion (T2), and Posttreatment (T3)

	Mean (SD) T1	Mean (SD) T2	Mean (SD) T3	Mean (95% CI) T2–T1	% Change (T2–T1)	Mean (95% CI) T3–T1	% Change (T3–T1)	*P* Value* (T2 vs T1)	*P* Value* (T3 vs T1)
Nasal height (NH)	51.12 (3.49)	51.89 (3.64)	54.02 (4.50)	0.77 (−0.30, 1.84)	1.51	2.81 (1.45, 4.16)	5.67	.148	<.001*
Nasal length (NL)	18.80 (2.43)	18.91 (2.24)	19.77 (2.74)	0.11 (−0.40, 0.63)	0.59	0.97 (0.30, 1.65)	5.16	.649	.007*
Nasion–ANS height (NAH)	50.46 (3.35)	50.67 (3.15)	51.75 (2.61)	0.21 (−0.50, 0.93)	0.42	1.27 (0.41, 2.12)	2.56	.538	.006*
ANS–PNS length (APL)	51.96 (4.36)	52.37 (4.24)	52.64 (4.38)	0.40 (−0.38, 1.19)	0.79	0.94 (0.15, 1.72)	1.31	.297	.022*
Alar width (AW)	35.40 (3.03)	35.65 (3.19)	35.81 (3.08)	0.25 (−0.31, 0.82)	0.71	0.50 (−0.13, 1.13)	1.16	.362	.114
Alar base width (ABW)	33.13 (3.11)	34.01 (3.05)	33.48 (2.79)	0.89 (0.28, 1.49)	2.66	0.53 (−0.23, 1.28)	1.06	.006*	.162
Pyriform height (PH)	38.85 (3.36)	39.03 (3.29)	40.18 (3.05)	0.18 (−0.61, 0.97)	0.46	1.24 (0.18, 2.29)	3.42	.637	.024*
Nasal septal deviation angle (NSDA)	9.96 (4.4)	8.98 (3.97)	8.51 (3.30)	−0.99 (−1.75, −0.22)	−9.84	−1.35 (−2.66, −0.03)	−14.56	.014*	.045*
Posterior nasal cavity width (PNCW)	29.40 (2.76)	31.08 (3.04)	30.37 (3.33)	1.67 (0.93, 2.41)	5.71	0.78 (0.11, 1.45)	3.30	<.001*	.024*
Anterior nasal cavity width (ANCW)	19.66 (2.38)	21.31 (1.68)	20.65 (2.62)	1.66 (0.75, 2.57)	8.39	0.93 (0.08, 1.78)	5.04	.001*	.033*
Maxillary intermolar width (IMW)	42.38 (3.04)	48.45 (3.58)	46.72 (2.90)	6.07 (5.09, 7.05)	14.32	4.20 (3.13, 5.28)	10.24	<.001*	<.001*
Maxillary intercanine Width (ICW)	33.22 (3.36)	35.63 (3.33)	34.12 (1.70)	2.41 (1.72, 3.11)	7.25	1.46 (0.36, 2.56)	2.71	<.001*	.012*

* Significant at $P < .05$.

changed from 10% to 21% in controls (Supplemental Table 3).

Short-term Changes From Pretreatment (T1) to Postexpansion (T2) Among MARPE, RPE, and Controls

There was a significant increase in ABW in RPE compared with controls at T2 ($P < .05$). NSDA decreased significantly in both MARPE and RPE compared with controls in the short term ($P < .05$). In addition, PNCW, ANCW, ICW, and IMW increased significantly in MARPE and RPE compared with controls. However, IMW was significantly increased in RPE compared with MARPE ($P < .05$; Table 5).

Changes From Postexpansion (T2) to Posttreatment (T3) Among MARPE, RPE, and Controls

The comparison among the three groups from T2 to T3 revealed that there was a significant increase in NSDA in controls compared with RPE and MARPE ($P < .05$). In addition, there was a significant increase in PNCW in controls from T2 to T3 compared with RPE ($P < .05$; Table 6).

Long-term Changes From Pretreatment (T1) to Posttreatment (T3) Among MARPE, RPE, and Controls

The long-term comparison among MARPE, RPE, and controls from T1 to T3 showed that there was a

Table 4. Parameters for the Control Group, Pretreatment (T1), Postexpansion (T2), and Posttreatment (T3)

	Mean (SD) T1	Mean (SD) T2	Mean (SD) T3	Mean (95% CI) T2–T1	% Change (T2–T1)	Mean (95% CI) T3–T1	% Change (T3–T1)	*P* Value* (T2 vs T1)	*P* Value* (T3 vs T1)
Nasal height (NH)	49.26 (3.93)	49.74 (4.44)	51.95 (4.43)	0.48 (−0.52, 1.48)	0.97	2.58 (1.02, 4.14)	5.46	.323	.003*
Nasal length (NL)	17.24 (2.62)	17.76 (2.27)	18.49 (1.90)	0.52 (−0.24, 1.27)	3.02	1.17 (0.28, 2.06)	7.25	.168	.013*
Nasion–ANS height (NAH)	50.01 (3.91)	50.20 (3.57)	51.26 (3.45)	0.19 (−0.37, 0.76)	0.38	1.13 (0.39, 1.87)	2.50	.477	.005*
ANS–PNS length (APL)	51.70 (4.42)	51.88 (4.81)	52.76 (4.35)	0.18 (−0.50, 0.86)	0.35	1.01 (0.34, 1.68)	2.05	.577	.005*
Alar width (AW)	33.42 (3.66)	33.48 (3.22)	33.84 (3.43)	0.07 (−0.30, 0.43)	0.18	0.38 (−0.62, 1.38)	1.26	.704	.436
Alar base width (ABW)	31.82 (3.64)	31.89 (3.44)	32.38 (3.49)	0.08 (−0.11, 0.27)	0.22	0.52 (−0.34, 1.37)	1.76	.399	.221
Pyriform height (PH)	38.82 (3.50)	38.94 (3.37)	40.39 (4.11)	0.13 (−0.64, 0.89)	0.31	1.67 (0.14, 3.20)	4.04	.729	.035*
Nasal septal deviation angle (NSDA)	9.36 (5.46)	9.06 (5.99)	11.43 (5.23)	−0.29 (−1.41, 0.82)	−3.21	2.07 (0.32, 3.8)	22.12	.587	.023*
Posterior nasal cavity width (PNCW)	28.92 (2.37)	28.93 (2.40)	29.48 (2.48)	0.02 (−0.20, 0.23)	0.03	0.63 (0.14, 1.11)	1.94	.871	.014*
Anterior nasal cavity width (ANCW)	20.53 (2.36)	20.74 (2.72)	20.94 (2.77)	0.22 (−0.21, 0.64)	1.02	0.74 (0.18, 1.30)	2.00	.298	.013*
Maxillary intermolar width (IMW)	42.61 (3.20)	42.63 (3.15)	45.96 (4.00)	0.02 (−0.16, 0.21)	0.05	3.64 (2.52, 4.75)	7.86	.805	<.001*
Maxillary intercanine width (ICW)	32.96 (3.09)	33.14 (2.96)	34.03 (2.00)	0.19 (−0.02, 0.39)	0.55	1.24 (0.07, 2.40)	3.25	.067	.038*

* Significant at $P < .05$.

Table 5. Comparison of the Parameters Among MARPE, RPE, and Control Groups (T2–T1)

	MARPE Mean (95% CI)	RPE Mean (95% CI)	Control Mean (95% CI)	*P* Value* Overall	*P* Value* MARPE-RPE	*P* Value* MARPE Control	*P* Value* RPE Control
Nasal height (NH)	0.18 (−1.20, 1.55)	0.77 (−0.30, 1.84)	0.48 (−0.52, 1.48)	.743	.722	.922	.930
Nasal length (NL)	0.31 (−0.10, 0.71)	0.11 (−0.40, 0.63)	0.52 (−0.24, 1.27)	.577	.865	.848	.546
Nasion–ANS height (NAH)	0.22 (−0.49, 0.93)	0.21 (−0.50, 0.93)	0.22 (−0.38, 0.82)	>.999	>.999	>.999	>.999
ANS–PNS length (APL)	0.22 (−0.04, 0.48)	0.40 (−0.38, 1.19)	0.18 (−0.50, 0.86)	.851	.896	.996	.861
Alar width (AW)	0.37 (−0.36, 1.09)	0.25 (−0.31, 0.82)	0.07 (−0.30, 0.43)	.756	.954	.738	.886
Alar base width (ABW)	0.63 (0.17, 1.08)	0.89 (0.28, 1.49)	0.08 (−0.11, 0.27)	.045*	.681	.217	.038*
Pyriform height (PH)	0.70 (−0.08, 1.47)	0.18 (−0.61, 0.97)	0.13 (−0.64, 0.89)	.496	.581	.543	.995
Nasal septal deviation angle (NSDA)	−1.03 (−1.73, −0.33)	−0.99 (−1.75, −0.22)	0.19 (−0.31, 0.69)	.018*	.995	.031*	.036*
Posterior nasal cavity width (PNCW)	1.98 (1.25, 2.70)	1.67 (0.93, 2.41)	0.02 (−0.20, 0.23)	<.001*	.745	<.001*	<.001*
Anterior nasal cavity width (ANCW)	1.60 (1.03, 2.17)	1.66 (0.75, 2.57)	0.22 (−0.21, 0.64)	.005*	.992	.016*	.009*
Maxillary intermolar width (IMW)	4.51 (3.46, 5.55)	6.07 (5.09, 7.05)	0.02 (−0.16, 0.21)	<.001*	.023*	<.001*	<.001*
Maxillary intercanine Width (ICW)	1.78 (1.24, 2.33)	2.41 (1.72, 3.11)	0.19 (−0.02, 0.39)	<.001*	.202	<.001*	<.001*

* Significant at $P < .05$.

significant decrease in NSDA in MARPE and RPE compared with controls ($P < .05$). However, it should be noted that there was high individual variation for the measured parameters. In addition, PNCW increased significantly in MARPE compared with RPE and controls at T3 ($P < .05$; Table 7). The MARPE, RPE, and controls showed no significant difference in the other parameters among the groups at posttreatment.

DISCUSSION

The close anatomical relationship between the maxilla and nasal cavity has resulted in the increased attention of orthodontists to identify the effects of expansion on nasal cavity structures. However, the emphasis has been placed on short-term changes with conventional RPE on the nasal cavity,[9,10] and there is a scarcity of literature on the long-term effects of MARPE on the nasal cavity. This is the first study to directly address this topic, investigating the long-term effects of MARPE, RPE, and controls for the correction of posterior crossbite on the nasal cavity. The null hypothesis was rejected as a significant decrease was observed in NSDA in MARPE and RPE compared with controls and a significant increase in the PNCW in MARP compared with RPE and controls in the long-term.

In both MARPE and RPE, there was a significant increase in the PNCW and ANCW as compared with controls at T2 (Table 5). The increase in PNCW was statistically significant even at T3 in MARPE compared

Table 6. Comparison of the Parameters Among MARPE, RPE, and Control Groups (T3–T2)

	MARPE Mean (95% CI)	RPE Mean (95% CI)	Control Mean (95% CI)	*P* Value* Overall	*P* Value* MARPE-RPE	*P* Value* MARPE-Control	*P* Value* RPE-Control
Nasal height (NH)	2.10 (0.39, 3.81)	2.33 (1.49, 3.18)	2.24 (0.44, 4.05)	.973	.971	.989	.996
Nasal length (NL)	0.71 (0.02, 1.41)	0.98 (0.22, 1.74)	0.82 (0.04, 1.61)	.864	.853	.973	.948
Nasion–ANS height (NAH)	0.88 (0.19, 1.57)	1.18 (0.25, 2.11)	1.11 (0.38, 1.84)	.838	.837	.902	.991
ANS–PNS length (APL)	0.96 (0.22, 1.70)	0.49 (−0.57, 1.56)	0.88 (0.07, 1.70)	.706	.716	.992	.795
Alar width (AW)	0.13 (−0.33, 0.60)	0.52 (−0.39, 1.43)	0.42 (−0.56, 1.39)	.758	.752	.862	.980
Alar base width (ABW)	−0.31 (−1.59, 0.98)	−0.26 (−1.04, 0.52)	0.62 (−0.14, 1.39)	.299	.997	.348	.386
Pyriform height (PH)	0.57 (−0.57, 1.70)	1.14 (0.06, 2.22)	1.48 (−0.12, 3.08)	.566	.780	.544	.918
Nasal septal deviation angle (NSDA)	−0.82 (−1.54, −0.09)	−0.32 (−1.47, 0.84)	1.92 (0.20 3.65)	.005*	.824	.007*	.028*
Posterior nasal cavity width (PNCW)	−0.11 (−0.90, 0.68)	−0.86 (−1.55, −0.16)	0.56 (0.07, 1.05)	.010*	.229	.310	.007*
Anterior nasal cavity width (ANCW)	−0.53 (−1.32, 0.26)	−0.34 (−1.21, 0.52)	0.45 (−0.39, 1.29)	.191	.937	.200	.337
Maxillary intermolar width (IMW)	1.10 (−0.41, 2.61)	−1.73 (−3.03, −0.42)	3.57 (2.41, 4.72)	<.001	.007	.023	<.001
Maxillary intercanine width (ICW)	0.37 (−0.84, 1.59)	−0.97 (−2.06, 0.13)	1.06 (−0.10, 2.21)	.035	.200	.658	.030

* Significant at $P < ..05$

Table 7. Comparison of the Parameters Among MARPE, RPE, and Control Groups (T3–T1)

	MARPE Mean (95% CI)	RPE Mean (95% CI)	Control Mean (95% CI)	*P* Value* Overall	*P* Value* MARPE-RPE	*P* Value* MARPE-Control	*P* Value* RPE-Control
Nasal height (NH)	2.31 (1.29, 3.33)	2.81 (1.45, 4.16)	2.58 (1.02, 4.14)	.859	.846	.952	.966
Nasal length (NL)	1.04 (0.35, 1.73)	0.97 (0.30, 1.65)	1.17 (0.28, 2.06)	.927	.990	.967	.922
Nasion–ANS height (NAH)	1.14 (0.01, 2.26)	1.27 (0.41, 2.12)	1.13 (0.39, 1.87)	.969	.976	>.999	.974
ANS–PNS length (APL)	1.14 (0.48, 1.80)	0.94 (0.15, 1.72)	1.01 (0.34, 1.68)	.909	.903	.959	.987
Alar width (AW)	0.52 (−0.35, 1.39)	0.50 (−0.13, 1.13)	0.38 (−0.62, 1.38)	.964	.999	.966	.975
Alar base width (ABW)	0.31 (−0.98, 1.61)	0.53 (−0.23, 1.28)	0.52 (−0.34, 1.37)	.936	.945	.950	.999
Pyriform height (PH)	1.29 (0.41, 2.17)	1.24 (0.18, 2.29)	1.67 (0.14, 3.20)	.842	.998	.884	.852
Nasal septal deviation angle (NSDA)	−1.71 (−2.66, −0.75)	−1.35 (−2.66, −0.03)	2.07 (0.33, 3.81)	<.001*	.923	<.001*	.002*
Posterior nasal cavity width (PNCW)	1.75 (1.16, 2.35)	0.78 (0.11, 1.45)	0.63 (0.14, 1.11)	.012*	.043*	.016*	.921
Anterior nasal cavity width (ANCW)	1.15 (0.63, 1.67)	0.93 (0.08, 1.78)	0.74 (0.18, 1.30)	.654	.878	.627	.900
Maxillary intermolar width (IMW)	5.24 (3.98, 6.50)	4.20 (3.13, 5.28)	3.64 (2.52, 4.75)	.122	.382	.108	.750
Maxillary intercanine width (ICW)	2.21 (0.97, 3.44)	1.46 (0.36, 2.56)	1.24 (0.07, 2.40)	.440	.611	.440	.957

* Significant at $P < .05$.

with RPE and controls (Table 7). The factors contributing to these findings could have been the higher extent of skeletal expansion with MARPE compared with RPE.[16] Although midpalatal suture maturation and density vary with the sex and growth status of patients, more parallel expansion of the midpalatal suture has been reported with MARPE.[4,16,17] The findings of the current study showed that, even after the removal of the expansion appliance, the increase in the PNCW remained stable with MARPE. This could also partially explain the findings of a recent study that demonstrated increased nasopharyngeal volume with the MARPE appliance in the long term.[18] However, there was no difference in ANCW among the three groups in the long term.

The soft tissue nasal width plays a vital role in facial esthetics, and an increased nose width has been reported to negatively affect facial esthetics.[19] RPE was reported to increase soft tissue nasal width in the short term.[20] Thus, the important clinically relevant question for orthodontists is whether these expansion appliances lead to a difference in the outcome of soft tissue nasal width in the long term. In the current study, there was a significant increase in ABW with both MARPE and RPE compared with controls in the short term (Table 5). However, there was no significant change among the three groups for ABW in the long term (Table 7). Thus, it can be concluded that expansion appliances do not adversely affect esthetics of the nose in the long term.

Several studies have evaluated the effect of expansion on the nasal airway, but relatively fewer reports have highlighted the effects of expansion on deviation of the nasal septum.[21–23] The current study showed that there was a significant decrease in the NSDA in MARPE and RPE at T2 as compared with controls (Table 5). This was in agreement with a previous report that showed spontaneous correction of the deviated nasal septum with RPE.[21] However, another study rejected such claims, reporting no effect of RPE on the deviated nasal septum.[22] In contrast to the current study, PA cephalograms were used in those studies, the observation period was 6 months or less, and MARPE appliances were not investigated. Although both MARPE and RPE led to a significant decrease in NSDA in the short term, the interesting finding in the current study was that, in the long term, there was a significant increase in NSDA in controls, whereas MARPE and RPE showed a further decrease in NSDA (Table 7, Supplemental Table 3). Although the mean differences were statistically significant, the effects were variable.

The nasal septum is a vital anatomical structure in the nasal assembly. A deviation of the nasal septum can be a contributing factor that leads to differing degrees of nasal obstruction, disorders of nasal respiration, and altered volume of the maxillary sinus.[23] The prevalence of NSD has been reported to range from 20% in adolescents to 65% in adults.[24] A previous study showed positive effects of RPE on nasal septal deviation.[21] A recent systematic review stated that there was a need for studies on the effects of expansion on the nasal cavity in adolescents.[25] Results of the current study showed that MARPE and RPE can lead to a decreased NSDA compared with controls in both the short and long term. However, functional respiratory tests with rhinomanometry and nasal and oral peak flow measurements would be beneficial for assessing the effects of the change in NSDA on the respiratory system.

Limitations of this study were that a true control group was not available because of the delayed treatment provided to the control group from T2 to T3 and that the patients did not suffer from any respiratory disorders. Further studies should be performed on the effects of MARPE and RPE on the nasal cavity of adolescent patients with breathing disorders and using dynamic evaluation tests.

CONCLUSIONS

- Both MARPE and RPE led to a significant increase in alar base width, posterior nasal cavity width, anterior nasal cavity width, maxillary intermolar width, and maxillary intercanine width as compared with controls in the short term.
- In the long term, MARPE led to a significant increase in the posterior nasal cavity width compared with RPE and controls. Both MARPE and RPE led to a minimal decrease in the nasal septal deviation angle compared with controls. However, MARPE and RPE did not negatively affect the soft tissue nasal width in the long term in comparison with controls.

SUPPLEMENTAL DATA

Supplemental Tables 1, 2, and 3 are available online.

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