Submitted: 09 February, 2023 Accepted: 19 April, 2023 Published: 03 January, 2024 DOI:10.22514/jocpd.2024.002

Journal of Clinical Pediatric Dentistry

ORIGINAL RESEARCH

The influence of orthopedic rapid maxillary expansion on the deviation of the nasal septum

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Abstract

Nasal septal deviation (NSD) is one of the most common abnormalities impacting the maxillofacial development of children. Herein, we investigated the impact of orthopedic rapid maxillary expansion (RME) on the nasomaxillary complex and NSD in pediatric patients. The study sample consisted of a total of 40 patients divided into two groups. The experimental group included 26 patients (13 females and 13 males) with skeletal maxillary transversal constriction and NSD greater than 1 mm, while the control group comprised 14 patients (6 females and 8 males) with skeletal maxillary transversal constriction but no NSD. All the patients were treated for approximately 15 days with the tooth-tissue born RME device. The activation procedure was to turn the transversal Hyrax screw a quarter turn, twice a day. After that, the device was left in place for a period of five months to facilitate passive retention. Radiographic analysis was performed on posteroanterior (PA) cephalometric radiographs taken at pre-expansion (T1) and post-expansion (T2). The data were evaluated using the Mann-Whitney U and Wilcoxon Sign tests. The experimental group showed a statistically significant decrease ($p < 0.05$) in the distance from the axis of symmetry to middle of nasal septum (SNM-mid) and to inferior part of the nasal septum (SNI-mid) measurements, indicating a reduction in NSD. Additionally, both experimental and control groups showed a statistically significant increase ($p < 0.05$) in maxillofacial measurements, including the distance between the nose length (X-SNM and SNM-SNAC), width of the nasal cavity (Pir L-R), basal maxillary width (Mx L-R), vestibular cuspid of upper first molars (CVM + L-R) and lower first molars (CVM-L-R). Based on the study findings, RME was considered effective in achieving craniofacial improvement in pediatric patients with NSD, which positively impacted their healthy growth and development. The improvement in the nasomaxillary complex was similar between genders.

Keywords

Orthodontics; Maxillary expansion; Nasal septum; Gender

1. Introduction

The nasal septum plays an important role in the structural and aesthetic composition of the nose, which not only provides support and structure to the nasal dorsum and caudal portion but also regulates nasal airflow [1, 2]. The septum comprises a vertical lamina consisting of two bony sections and a cartilage, which typically undergoes minor displacement [3, 4]. The upper section is formed by the perpendicular plate of the ethmoid bone, while the inferior and posterior portions are made up of the independent bone (vomer) that extends from the concha edge on the frontal bone into the nares [5]. The sphenoidal bone remnants also contribute to the formation of the nasal septum [6, 7].

Nasal septal deviation (NSD) refers to the displacement of the nasal septum from its midline position due to developmental or acquired causes [8]. A deviated septum can obstruct the nasal airway, making it difficult to breathe through the nose. This can lead to symptoms such as dryness, recurrent sinusitis, frequent nosebleeds or crusting of the nose [9]. In addition, nasal airway insufficiency during growth and development may lead to persistent mouth breathing, resulting in moderate to severe maxillary constriction and vertical skeletal development patterns [10]. The main component of the wrong functional matrix formed in cases of mouth breathing is the tongue. To improve airway relaxation and facilitate breathing, the tongue is positioned down and forward, causing the tongue root to move forward and relax the nasopharyngeal area. The head extends to relieve the airway, resulting in increased tension in the suprahyoid muscles and upward displacement of the hyoid bone with the tongue root. These positional changes cause morphological changes in craniofacial development, creating a balance of forces in the maxillofacial system [11, 12].

The maxillary bones form the border of the nasal cavity, and it has been proposed that RME can lead to lateral movements of the nasal walls, thus expanding the nasal cavity's dimensions by opening the midpalate suture [13, 14]. Additionally, a deviated growth pattern of the nasal septum is a significant factor in the development of skeletal and dental asymmetry. Asymmetric growth of the nasal septum can result in facial skeletal asymmetries, suggesting that the human nasal septum may serve as a growth center for the face [15, 16]. Although many studies have investigated nasal septal deviation and expansion [17–19], there is no available data on how the maxillary segments move in the different genders.

Nasal breathing is essential for the proper growth and development of the craniofacial complex. According to the functional matrix theory, there is a close relationship between dentofacial morphology and nasal breathing. The maintenance of proper dentofacial morphology and occlusion is crucial for maintaining a healthy position of the temporomandibular joint [7, 12, 20, 21]. However, the incidence of nasal septal deviation (NSD) in the population is quite high, ranging from 19.4% to 65% [22, 23].

Although many studies have investigated the impact of RME on the size of the nasal cavity and airway [24–27], the data on the effects of RME on the nasal septum are limited. Previous studies have used PA cephalometric radiographs [3, 14, 27, 28], which provide two-dimensional evaluation, or 3D imaging systems (*i.e.*, cone beam computed tomography (CBCT)) [7, 18, 24, 29, 30] to assess the dimensions of the nasal cavity or any nasal septal alterations caused by RME. While CBCT scans can provide accurate 3D diagnosis of NSD in imaging studies [18, 22], their excessive radiation dose limits their routine use in orthodontic clinics for diagnosing maxillary skeletal transversal constriction in pediatric patients [31]. Hence, PA cephalometric radiographs remain the primary diagnostic tool in clinical settings [14].

This study was designed to investigate the impact of RME on nasal septal deviation to provide new insights into treating complex maxillofacial deformities caused by a deviated nasal septum in adolescents. Moreover, unlike previous studies, this research examines the movement of maxillary segments in young adolescent patients with septal deviation based on gender.

2. Materials and methods

2.1 Subjects

The study cohort comprised 40 patients divided into an experimental group and a control group. The experimental group consisted of 26 patients (13 females and 13 males) aged between 8.3 and 13.1 years (mean age, 10.7 ± 2.1 years) with maxillary skeletal transversal constriction and a septal deviation of more than 1 mm [1, 7, 17, 18, 24]. The control group consisted of 14 patients (6 females and 8 males) (mean age, 11.2 ± 1.10) who required maxillary expansion but without NSD. All patients presented with a bilateral posterior crossbite, and their septal deviations were diagnosed by the same clinician based on their medical history, orthodontic material analysis and nasal examination.

The inclusion criteria were:

• Patients who are still in the growth and development stage (pre-pubertal and pubertal patients);

• Absence of systemic disease;

• Discrepancy in the skeletal maxillary transversal plane requiring the use of an appliance for RME;

• Full pair of PA cephalometric radiographs, including one obtained before cementing the expander and one taken immediately after the appliance was removed.

And the exclusion criteria were:

• Congenital or dental abnormalities;

• Systemic disorders;

• Previous orthodontic treatment.

2.2 Sample size

An initial statistical evaluation was conducted to determine the sample size, considering a power of 90%, a two-tailed analysis, and a significance level of 1% (to correct for multiple comparisons), based on the mean of the measurements at post-expansion (T2) (35.23 ± 2.83) and the mean of the measurements at pre-expansion (T1) (30.24 ± 1.53) obtained from a population of 6 patients (our preliminary results). The results indicated a minimum sample size of 7 individuals per group to obtain reliable comparative analytic results.

2.3 Treatment procedure

The occlusal-coverage bonded type device used in this study was activated by turning the transversal Hyrax screw (G&H Orthodontics, Franklin, IN) a quarter turn twice daily (0.25 mm per turn) until the desired level of expansion was achieved (overcorrection by 20%). The active expansion treatment period lasted approximately 15 days, after which the device was left in place for passive retention for about 5 months. Each device was fabricated by the same orthodontic technician.

2.4 PA cephalometric radiography measurements and assessment

All participants underwent PA cephalometric radiographs during the T1 and T2 periods (Fig. 1), with T2 radiographs taken after the expansion appliance was removed. The same technician captured all PA cephalometric radiographs using the same X-ray machine (Sirona Orthophos XG Plus, Bensheim, Germany) and exposure settings. Only good-quality radiographs were considered for assessment. Cephalometric reference points were obtained following the tracing of the radiographs using a lead pencil with a 0.3 mm lead diameter on frosted acetate tracing paper with a thickness of 0.003 inches (Fig. 2). The definition of landmarks is presented in Table 1, and the measurement planes on the nasal septum, skeletal base and dentoalveolar structures are presented in Table 2. A second examiner verified the landmark placement and anatomical outlines.

2.5 Error of the study

The examiner (H.U.) repeated all measurements on 20 PA cephalometric radiographs of 10 randomly selected patients: three in the female experimental group, three in the male experimental group, and four in the control group to determine

FIGURE 1. PA cephalometric radiographs. (A) PA of a patient with nasal septal deviation before rapid maxillary expansion (RME). (B) PA of a patient with nasal septal deviation after rapid maxillary expansion (RME).

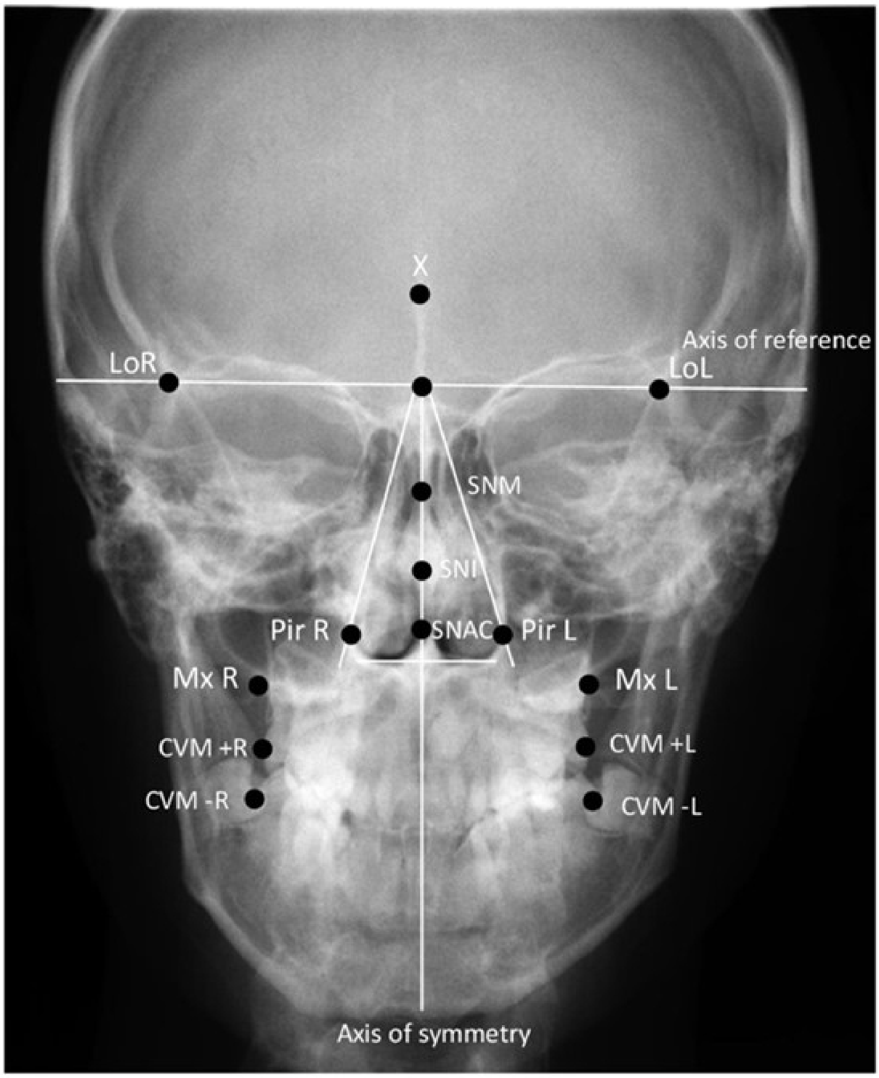

FIGURE 2. Reference points on PA cephalometric radiography. The reference points from which the measurements were made are presented on the PA cephalometric radiograph of the patient with nasal septum deviation.

TABLE 1. The definition of PA cephalometric radiography landmarks. Detailed explanations of the reference points from which measurements are made are presented.

Abbreviations	PA Cephalometric Radiography Landmark Definitions
X	Crossing point between the perpendicular plate of the ethmoid and the projection of the floor of the anterior cranial fossa
SNM	Middle of nasal septum
SNI	Inferior part of the nasal septum
SNAC	Anterior crest part of the nasal septum
Pir	Piriform hiatus
Mx	Crossing point of the maxillary tuber and the zygomatic arch
CVM+	The most prominent point of the vestibular mesial cuspid-upper left and right
CVM−	The most prominent point of the vestibular mesial cuspid-lower left and right
Axis of reference	Axis that passes through LoL and LoR
Axis of symmetry	Perpendicular of the axis of reference that passes through point X

TABLE 2. The definition of PA cephalometric radiography measurements on the nasal septum, skeletal base, and dentoalveolar structures.

Planes	PA Cephalometric Radiography Measurement Definitions
X-SNM	The distance between the points X and SNM
SNM-SNAC	The distance between SNM and SNAC
SNM-mid	The distance from the axis of symmetry to SNM
SNI-mid	The distance from the axis of symmetry to SNI
Pir L-R	The width of the piriform hiatus
Mx L-R	Basal maxillary width
CVM + L-R	The distance between the most prominent point of the vestibular mesial cuspid of upper left and right 1. molar
CVM-L-R	The distance between the most prominent point of the vestibular mesial cuspid of lower left and right 1. molar
Mx L/axis-R/axis	Subtracting the left maxillary point/symmetry axis plane length from the right maxillary point/symmetry axis plane length
CVM + L/axis-R/axis	Subtracting the left upper molar/symmetry axis plane length from the right upper molar/symmetry axis plane length
CVM-L/axis-R/axis	Subtracting the left lower molar/symmetry axis plane length from the right lower molar/symmetry axis plane length
U midline-axis	The distance from the upper midline point to the axis of symmetry
L midline-axis	The distance from the lower midline point to the axis of symmetry

method error. The intraclass correlation coefficient (ICC) for all measurements was found to be nearly 1.00, indicating that the measurements could be repeated with negligible error that would not impact the results.

2.6 Statistical analysis

Statistical analysis was performed using the SPSS software (version 22.0; SPSS, Chicago, IL, USA). The suitability of the parameters to the normal distribution was evaluated with Kolmogorov-Smirnov and Shapiro-Wilks tests, and it was determined that the parameters did not show a normal distribution The Mann-Whitney U test was used to compare parameters between the two groups, while the Wilcoxon Sign test was used for within-group comparisons. The continuity (Yates) correction was used to compare qualitative data. A p-value < 0.05 was considered for determining statistical significance.

3. Results

The results showed no statistically significant differences between the groups regarding gender distribution ($p > 0.05$) (Table 3).

TABLE 3. Evaluation of groups in terms of gender.

	Experimental n (%)	Control n (%)	p
Female	13 (50%)	6 (42.9%)	0.921
Male	13 (50%)	8 (57.1%)	

Continuity (yates) correction.

The changes in dentoalveolar and skeletal measurements obtained from PA cephalometric radiographs are presented in Table 4. We observed that the experimental and control groups both showed a statistically significant increase in X-SNM and SNM-SNAC at the end of treatment ($p < 0.05$).

The SNM-mid and SNI-mid values of the experimental group at T1 and T2 were significantly higher than those of the control group ($p < 0.05$). Within the experimental group, the mean values of SNM-mid and SNI-mid were statistically significantly reduced at T2 compared to T1 ($p < 0.05$). However, there was no significant change in SNM-mid and SNI-mid values between T1 and T2 in the control group.

At T1, the mean Pir L-R value of the experimental group was significantly higher than that of the control group ($p < 0.05$); however, there was no significant difference between the groups at T2 ($p > 0.05$). The increase in Pir L-R length during the T1–T2 period was statistically significant for both groups ($p < 0.05$).

The Mx L-R, CVM + L-R and CVM-L-R lengths showed a statistically significant increase at T2 compared to T1 in both the experimental and control groups ($p < 0.05$). The CVM + L-R and CVM-L-R lengths of the experimental group were significantly higher than those of the control group at T2 ($p < 0.05$).

In addition to a significant decrease in the Mx L/axis-R/axis value during the T1–T2 period within both the experimental and control groups ($p < 0.05$), the Mx L/axis-R/axis value of the experimental group was significantly higher than that of the control group ($p < 0.05$).

The U midline-axis and L midline-axis measurements of the experimental group at T1 and T2 were significantly higher than those of the control group ($p < 0.05$); however, the mean increase in these values was not statistically significant within either group ($p > 0.05$).

The changes in dentoalveolar and skeletal measurements in females obtained from PA cephalometric radiographs are presented in Table 5, and the changes in measurements in males are presented in Table 6. Both male and female participants in the experimental group demonstrated a statistically significant increase in X-SNM and SNM-SNAC at the end of treatment ($p < 0.05$). Although not statistically significant, there was an increase in X-SNM and SNM-SNAC values in the T1–T2 period in the female control group ($p > 0.05$).

The SNM-mid and SNI-mid values of both male and female participants in the experimental group at T1 and T2 were significantly higher than those of the control group ($p < 0.05$). Within the experimental group, the mean values of SNM-mid and SNI-mid were statistically significantly reduced at T2 compared to T1 in both male and female participants ($p < 0.05$). However, there was no statistically significant change in the T1–T2 period within the control group.

Both male and female participants in both the experimental and control groups showed a statistically significant increase in Pir L-R, Mx L-R, CVM + L-R and CVM-L-R length at the end of treatment ($p < 0.05$).

In addition to a statistically significant decrease in Mx L/axis-R/axis value during the T1–T2 period within both male and female participants in the experimental group ($p < 0.05$), this value was significantly higher in the experimental group compared to the control group for both males and females ($p < 0.05$). However, the decrease in Mx L/axis-R/axis value in the T1–T2 period was not statistically significantly higher within the female and male control group ($p > 0.05$).

Comparison of changes in dentoalveolar and skeletal measurements on PA cephalometric radiographs in the female and male experimental groups are shown in Table 7. Further, the variation of measurements within each gender group was similar to the variation of measurements within the entire experimental group during the T1–T2 period. However, there were no statistically significant differences between male and female participants in any measurement at T1 and T2 ($p > 0.05$).

4. Discussion

NSD is a common condition in the general population and is often the primary structural cause of nasal constriction [1–3]. According to the functional matrix theory, severe maxillofacial complex deformities are seen in pediatric patients who cannot make nasal breath [7, 20, 21]. Maxillary skeletal transversal constriction is one of them and RME is currently applied to treat this malformation [9]. As the maxillary bones form the anatomical basis of the nasal cavity, their position and movement can impact the nasal structures [2, 13, 20, 26, 27, 32]. Given these factors, studies exploring the effects of RME on the maxillofacial complex have been reviewed. Although

TABLE 4. Intergroup and intragroup evaluation of dentoalveolar and skeletal measurements.

	Experimental (n = 26)	Control (n = 14)	^{1}p
	Mean ± SD (median)	Mean ± SD (median)	
X-SNM			
T1	24.15 ± 3.50 (24.00)	26.36 ± 4.33 (26.00)	0.107
T2	25.02 ± 3.76 (24.00)	27.00 ± 4.72 (27.00)	0.176
^{2}p	0.001*	0.030*	
SNM-SNAC			
T1	32.63 ± 4.89 (34.00)	31.43 ± 2.95 (31.50)	0.139
T2	33.83 ± 4.88 (34.50)	32.39 ± 2.94 (33.00)	0.128
^{2}p	0.001*	0.002*	
SNM-mid			
T1	1.64 ± 0.60 (1.60)	0.11 ± 0.14 (0.10)	0.001*
T2	1.46 ± 0.53 (1.50)	0.14 ± 0.13 (0.10)	0.001*
^{2}p	0.001*	0.206	
SNI-mid			
T1	1.36 ± 0.51 (1.50)	0.18 ± 0.19 (0.10)	0.001*
T2	1.14 ± 0.63 (1.00)	0.17 ± 0.18 (0.10)	0.001*
^{2}p	0.002*	0.715	
Pir L-R			
T1	33.46 ± 2.14 (33.50)	31.14 ± 2.41 (31.00)	0.006*
T2	34.73 ± 2.33 (34.00)	33.68 ± 2.74 (34.00)	0.319
^{2}p	0.001*	0.001*	
Mx L-R			
T1	66.63 ± 3.22 (66.30)	66.43 ± 2.79 (65.50)	0.733
T2	68.12 ± 3.36 (68.00)	68.61 ± 3.22 (68.00)	0.787
^{2}p	0.001*	0.001*	
CVM + L-R			
T1	56.58 ± 2.94 (56.00)	61.21 ± 3.24 (62.00)	0.001*
T2	59.54 ± 2.75 (59.50)	63.93 ± 3.99 (64.50)	0.001*
^{2}p	0.001*	0.001*	
CVM-L-R			
T1	57.15 ± 2.87 (57.00)	62.29 ± 3.29 (63.00)	0.001*
T2	57.92 ± 2.84 (58.30)	63.64 ± 3.77 (64.00)	0.001*
^{2}p	0.001*	0.002*	
Mx L/axis-R/axis			
T1	0.74 ± 0.25 (0.80)	0.31 ± 0.23 (0.40)	0.001*
T2	0.56 ± 0.30 (0.50)	0.24 ± 0.19 (0.30)	0.002*
^{2}p	0.026*	0.030*	
CVM + L/axis-R/axis			
T1	0.30 ± 0.25 (0.30)	0.26 ± 0.27 (0.20)	0.482
T2	0.27 ± 0.17 (0.30)	0.21 ± 0.16 (0.20)	0.280
^{2}p	0.370	0.305	
CVM-L/axis-R/axis			
T1	0.73 ± 0.65 (0.50)	0.27 ± 0.27 (0.20)	0.010*
T2	0.40 ± 0.28 (0.40)	0.19 ± 0.17 (0.20)	0.015*
^{2}p	0.001*	0.054	
U midline-axis			
T1	1.18 ± 0.84 (1.30)	0.46 ± 0.42 (0.40)	0.009*
T2	1.23 ± 1.09 (0.80)	0.52 ± 0.45 (0.40)	0.042*
^{2}p	0.604	0.078	
L midline-axis			
T1	1.20 ± 0.92 (0.90)	0.19 ± 0.14 (0.20)	0.001*
T2	1.66 ± 1.14 (1.20)	0.21 ± 0.21 (0.20)	0.001*
^{2}p	0.327	0.782	

^{1}*Mann-Whitney U Test;* ^{2}*Wilcoxon Sign Test;* *$^{*}p < 0.05$.*

TABLE 5. Intergroup and intragroup evaluation of dentoalveolar and skeletal measurements in females.

	Experimental (n = 13)	Control (n = 6)	^{1}p
Female	Mean ± SD (median)	Mean ± SD (median)	
X-SNM			
T1	23.23 ± 3.70 (23.00)	23.67 ± 4.08 (22.50)	0.965
T2	23.92 ± 3.73 (24.00)	24.50 ± 4.18 (22.50)	0.564
^{2}p	0.024*	0.070	
SNM-SNAC			
T1	34.58 ± 2.74 (36.00)	33.83 ± 1.72 (34.00)	0.376
T2	35.77 ± 2.80 (37.00)	34.67 ± 1.37 (35.00)	0.288
^{2}p	0.006*	0.059	
SNM-mid			
T1	1.40 ± 0.56 (1.50)	0.03 ± 0.05 (0.00)	0.002*
T2	1.30 ± 0.52 (1.30)	0.10 ± 0.09 (0.10)	0.003*
^{2}p	0.042*	0.102	
SNI-mid			
T1	1.30 ± 0.42 (1.50)	0.25 ± 0.20 (0.20)	0.001*
T2	1.10 ± 0.35 (1.00)	0.20 ± 0.16 (0.10)	0.001*
^{2}p	0.016*	0.285	
Pir L-R			
T1	33.15 ± 2.15 (33.00)	32.17 ± 2.14 (31.50)	0.283
T2	34.23 ± 2.39 (34.00)	34.50 ± 2.17 (34.00)	0.753
^{2}p	0.002*	0.026*	
Mx L-R			
T1	66.12 ± 2.79 (66.00)	66.92 ± 2.62 (66.00)	0.756
T2	67.35 ± 3.00 (68.00)	69.00 ± 3.41 (68.00)	0.477
^{2}p	0.001*	0.026*	
CVM + L-R			
T1	56.46 ± 1.33 (56.00)	61.00 ± 3.03 (61.50)	0.004*
T2	59.31 ± 1.18 (60.00)	63.67 ± 4.37 (64.50)	0.059
^{2}p	0.002*	0.041*	
CVM-L-R			
T1	57.00 ± 1.29 (57.00)	62.33 ± 3.20 (63.00)	0.002*
T2	57.77 ± 1.78 (59.00)	63.50 ± 3.51 (64.00)	0.002*
^{2}p	0.011*	0.038*	
Mx L/axis-R/axis			
T1	0.84 ± 0.26 (0.90)	0.28 ± 0.25 (0.30)	0.002*
T2	0.55 ± 0.31 (0.50)	0.23 ± 0.22 (0.20)	0.037*
^{2}p	0.024*	0.083	
CVM + L/axis-R/axis			
T1	0.33 ± 0.24 (0.30)	0.35 ± 0.29 (0.40)	0.965
T2	0.31 ± 0.17 (0.40)	0.22 ± 0.16 (0.20)	0.317
^{2}p	0.475	0.102	
CVM-L/axis-R/axis			
T1	0.92 ± 0.74 (0.70)	0.35 ± 0.31 (0.40)	0.100
T2	0.44 ± 0.36 (0.30)	0.20 ± 0.19 (0.20)	0.167
^{2}p	0.012*	0.083	
U midline-axis			
T1	1.32 ± 0.97 (1.30)	0.52 ± 0.45 (0.50)	0.135
T2	1.35 ± 1.15 (1.20)	0.58 ± 0.48 (0.50)	0.146
^{2}p	0.789	0.046*	
L midline-axis			
T1	1.14 ± 0.86 (0.70)	0.20 ± 0.14 (0.20)	0.003*
T2	1.55 ± 1.11 (1.00)	0.30 ± 0.28 (0.30)	0.002*
^{2}p	0.483	0.157	

*[1]Mann-Whitney U Test; [2]Wilcoxon Sign Test; *$p < 0.05$.*

TABLE 6. Intergroup and intragroup evaluation of dentoalveolar and skeletal measurements in males.

	Experimental (n = 13)	Control (n = 8)	¹p
Male	Mean ± SD (median)	Mean ± SD (median)	
X-SNM			
T1	25.08 ± 3.15 (25.00)	28.38 ± 3.46 (27.00)	0.036*
T2	26.12 ± 3.61 (26.00)	29.63 ± 3.25 (28.50)	0.041*
²p	0.006*	0.015*	
SNM-SNAC			
T1	30.69 ± 5.85 (32.00)	29.63 ± 2.33 (29.50)	0.490
T2	31.88 ± 5.79 (32.50)	30.69 ± 2.63 (30.30)	0.468
²p	0.002*	0.026*	
SNM-mid			
T1	1.88 ± 0.55 (1.60)	0.16 ± 0.16 (0.20)	0.001*
T2	1.63 ± 0.50 (1.50)	0.16 ± 0.16 (0.10)	0.001*
²p	0.007*	1.000	
SNI-mid			
T1	1.42 ± 0.61 (1.00)	0.13 ± 0.18 (0.10)	0.001*
T2	1.18 ± 0.84 (1.00)	0.15 ± 0.20 (0.10)	0.004*
²p	0.048*	0.317	
Pir L-R			
T1	33.77 ± 2.17 (34.00)	30.38 ± 2.45 (30.00)	0.005*
T2	35.23 ± 2.25 (36.00)	33.06 ± 3.10 (33.00)	0.123
²p	0.003*	0.010*	
Mx L-R			
T1	67.15 ± 3.64 (66.50)	66.06 ± 3.03 (65.50)	0.467
T2	68.88 ± 3.64 (68.00)	68.31 ± 3.28 (67.80)	0.637
²p	0.001*	0.010*	
CVM + L-R			
T1	56.69 ± 4.03 (56.00)	61.38 ± 3.58 (62.00)	0.015*
T2	59.77 ± 3.77 (58.00)	64.13 ± 3.98 (64.50)	0.029*
²p	0.001*	0.011*	
CVM-L-R			
T1	57.31 ± 3.92 (57.00)	62.25 ± 3.58 (62.50)	0.011*
T2	58.08 ± 3.68 (57.00)	63.75 ± 4.20 (64.00)	0.010*
²p	0.015*	0.016*	
Mx L/axis-R/axis			
T1	0.65 ± 0.20 (0.70)	0.33 ± 0.23 (0.50)	0.003*
T2	0.47 ± 0.30 (0.60)	0.25 ± 0.18 (0.30)	0.034*
²p	0.075*	0.098	
CVM + L/axis-R/axis			
T1	0.26 ± 0.26 (0.20)	0.19 ± 0.25 (0.10)	0.393
T2	0.24 ± 0.17 (0.20)	0.20 ± 0.17 (0.20)	0.768
²p	0.650	1.000	
CVM-L/axis-R/axis			
T1	0.55 ± 0.50 (0.50)	0.21 ± 0.23 (0.20)	0.052
T2	0.35 ± 0.19 (0.40)	0.18 ± 0.18 (0.20)	0.048*
²p	0.042*	0.396	
U midline-axis			
T1	1.05 ± 0.70 (1.20)	0.41 ± 0.41 (0.40)	0.032*
T2	1.12 ± 1.05 (0.70)	0.48 ± 0.46 (0.40)	0.156
²p	0.875	0.301	
L midline-axis			
T1	1.27 ± 1.00 (1.20)	0.19 ± 0.15 (0.20)	0.003*
T2	1.76 ± 1.21 (1.80)	0.15 ± 0.13 (0.10)	0.001*
²p	0.441	0.180	

¹*Mann-Whitney U Test;* ²*Wilcoxon Sign Test;* *$p < 0.05$.

TABLE 7. Intergroup and intragroup evaluation of dentoalveolar and skeletal measurements of female and male in the experimental group.

	Female (n = 13)	Male (n = 13)	^{1}p
Experimental	Mean ± SD (median)	Mean ± SD (median)	
X-SNM			
T1	23.23 ± 3.70 (23.00)	25.08 ± 3.15 (25.00)	0.094
T2	23.92 ± 3.73 (24.00)	26.12 ± 3.61 (26.00)	0.110
^{2}p	0.024*	0.006*	
SNM-SNAC			
T1	34.58 ± 2.74 (36.00)	30.69 ± 5.85 (32.00)	0.099
T2	35.77 ± 2.80 (37.00)	31.88 ± 5.79 (32.50)	0.110
^{2}p	0.006*	0.002*	
SNM-mid			
T1	1.40 ± 0.56 (1.50)	1.88 ± 0.55 (1.60)	0.087
T2	1.30 ± 0.52 (1.30)	1.63 ± 0.50 (1.50)	0.216
^{2}p	0.042*	0.007*	
SNI-mid			
T1	1.30 ± 0.42 (1.50)	1.42 ± 0.61 (1.00)	0.957
T2	1.10 ± 0.35 (1.00)	1.18 ± 0.84 (1.00)	0.937
^{2}p	0.026*	0.048*	
Pir L-R			
T1	33.15 ± 2.15 (33.00)	33.77 ± 2.17 (34.00)	0.393
T2	34.23 ± 2.39 (34.00)	35.23 ± 2.25 (36.00)	0.261
^{2}p	0.002*	0.003*	
Mx L-R			
T1	66.12 ± 2.79 (66.00)	67.15 ± 3.64 (66.50)	0.554
T2	67.35 ± 3.00 (68.00)	68.88 ± 3.64 (68.00)	0.485
^{2}p	0.001*	0.001*	
CVM + L-R			
T1	56.46 ± 1.33 (56.00)	56.69 ± 4.03 (56.00)	0.979
T2	59.31 ± 1.18 (60.00)	59.77 ± 3.77 (58.00)	0.854
^{2}p	0.002*	0.001*	
CVM-L-R			
T1	57.00 ± 1.29 (57.00)	57.31 ± 3.92 (57.00)	0.897
T2	57.77 ± 1.78 (59.00)	58.08 ± 3.68 (57.00)	0.717
^{2}p	0.011*	0.015*	
Mx L/axis-R/axis			
T1	0.84 ± 0.26 (0.90)	0.65 ± 0.20 (0.70)	0.052
T2	0.55 ± 0.31 (0.50)	0.47 ± 0.30 (0.60)	0.959
^{2}p	0.024*	0.075*	
CVM + L/axis-R/axis			
T1	0.33 ± 0.24 (0.30)	0.26 ± 0.26 (0.20)	0.364
T2	0.31 ± 0.17 (0.40)	0.24 ± 0.17 (0.20)	0.310
^{2}p	0.475	0.650	
CVM-L/axis-R/axis			
T1	0.92 ± 0.74 (0.70)	0.55 ± 0.50 (0.50)	0.224
T2	0.44 ± 0.36 (0.30)	0.35 ± 0.19 (0.40)	0.937
^{2}p	0.012*	0.042*	
U midline-axis			
T1	1.32 ± 0.97 (1.30)	1.05 ± 0.70 (1.20)	0.456
T2	1.35 ± 1.15 (1.20)	1.12 ± 1.05 (0.70)	0.699
^{2}p	0.789	0.875	
L midline-axis			
T1	1.14 ± 0.86 (0.70)	1.27 ± 1.00 (1.20)	0.856
T2	1.55 ± 1.11 (1.00)	1.76 ± 1.21 (1.80)	0.837
^{2}p	0.483	0.441	

*[1]Mann-Whitney U Test; [2]Wilcoxon Sign Test; *$p < 0.05$.*

there have been many previous studies on the nasal airway changes and RME [13, 20, 26, 27], there was a limited number of studies on NSD and RME [17–19] and no study on how the nasal septum and maxillary segments move in the different genders of pediatric patients.

Previous studies have explored changes in craniofacial morphology resulting from upper airway obstruction and variations in the severity of NSD according to gender [33, 34]. However, no study has examined the effects of RME treatment on NSD by gender in pediatric patients. In our study, the sample size was determined using power analysis, and the results showed that the number of females and males was balanced to enable accurate comparisons of changes in NSD between genders.

The precise role of the nasal septum in the development of the facial skeleton remains unclear. While some researchers, such as Hartman *et al.* [15], propose that the nasal septum acts as a key growth center, others suggest that septal growth plays more of a supportive role in facial development [12, 15, 21, 34]. In this study, the X-SNM and SNM-SNAC values were used to assess the length of the nasal septum. Our findings showed that these values increased in both groups at the end of the treatment, but there was no significant difference between the experimental and control groups at T1 and T2. These results suggest that RME treatment can increase nasal septal length, possibly due to growth during the T1–T2 period. Furthermore, our study suggests that nasal septal growth in young adolescents with NSD may progress similarly to those without deformity. Current literature suggests that NSD may impact nasal bone growth and facial morphology [35]. However, this present study did not directly investigate whether NSD changes in 6 months due to growth and development. To account for this, the control group was designed to include patients without NSD.

Seidita *et al.* [17] investigated the impact of surgically assisted rapid maxillary expansion (SARME) on the nasal septal region and found minor changes in most patients (93.1%). Gokce *et al.* [24] stated that the severity of NSD is modified by the RME procedure. However, Atac *et al.* [28] reported that neither SARME nor RME caused nasal septum positional alterations in adolescent patients. Bruno *et al.* [18] also evaluated the effects of RME treatment on NSD in patients with mild and severe forms and concluded that there were no significant changes in the NSD area and tortuosity over time. Our findings indicated that the SNM-mid and SNI-mid values of the experimental group were consistently higher than those of the control group at both T1 and T2. This was expected since these measurements are indicative of the degree of NSD. However, the significant decrease in the means of these values within the experimental group at T2 suggests that RME treatment can effectively correct NSD, confirming our null hypothesis and supporting the notion that RME can be used as a viable treatment option for complex maxillofacial deformities resulting from deviated nasal septum in pediatric patients.

Farronato *et al.* [3], Enoki *et al.* [26] and Bicakci *et al.* [27] reported an increase in the width of the nasal cavity after RME treatment, particularly at the nose floor, which is adjacent to the midpalatal suture. The findings of our study revealed that the mean Pir L-R of the experimental group at T1 was significantly higher than that of the control group, which can be attributed to the increased distance between the nose wings caused by NSD in pediatric patients. Moreover, the increase in Pir L-R length in both groups during the T1–T2 period can be explained by the fact that the maxillary segments form the floor of the nasal cavity, as previously reported in literature [13, 14]. Furthermore, maxillary expansion can also contribute to the enlargement of Pir L-R length.

Atac *et al.* [11] found different expansion rates at the skeletal level and reported that because the sutural connections of the maxilla were weakened in the SARME group, more skeletal expansion was recorded than in the RME group. We observed a significant increase in Mx L-R, CVM + L-R and CVM-L-R lengths at T2 within both the experimental and control groups. These measurements indicate the amount of skeletal and dentoalveolar expansion, so an increase in these values was expected after RME treatment. Additionally, our findings suggest that the expansion made in the upper jaw can also affect the lower jaw. However, the CVM + L-R and CVM-L-R lengths of the experimental group at T2 were higher than those in the control group. This result indicates that dentoalveolar expansion is greater than skeletal expansion in patients with NSD, which may be due to differences in the sutural connections of the maxilla.

According to Hartman *et al.* [15], there is a relationship between lateral and vertical asymmetries in the anterior palate and NSD. However, no studies have been conducted on the symmetry of maxillary expansion in patients with NSD. In our study, the Mx L/axis-R/axis measurement was used to assess the symmetry between the left and right maxillary segments. Our findings showed that this value was higher in the experimental group than in the control group, indicating a greater degree of asymmetry in the maxillary base in patients with NSD. However, after RME treatment, the asymmetry in the right and left maxillary segments were found to decrease in these patients. This result is important in that RME corrects not only NSD but also maxillary asymmetries.

Dental midline discrepancy can change after RME treatment [5, 7, 14, 15]. However, there are conflicting results in the literature. For example, Gokce *et al.* [24] reported an increase in dental midline discrepancy following RME with a hybrid Hyrax expansion device. In contrast, our findings showed that U midline-axis and L midline-axis measurements did not change after RME within both groups. We speculate that the difference in results could be due to the use of different types of expansion devices in our study (occlusal-coverage bonded-type device).

Shams *et al.* [33] conducted a study using CBCTs of adult patients to investigate sex-related alterations in NSD and nasopharynx volume, while Di Francesco *et al.* [34] examined the impact of gender on the severity of sleep apnea and its effect on craniofacial structures. However, there is currently no literature investigating the gender differences in the relationship between RME and NSD in pediatric patients. This study sets our research apart from existing literature. Our findings revealed that X-SNM and SNM-SNAC values increased at the end of the treatment in both female and male experimental groups. Although not statistically significant, the female control group also exhibited an increase in X-SNM and

SNM-SNAC values during the T1–T2 period. These results suggest that nasal septal length increases with RME treatment, regardless of gender, and that growth may also contribute to the increase in these lengths [33, 34].

Our results showed that the variation in measurements within the female and male experimental groups was similar and consistent with the whole experimental group. However, there was no statistically significant difference between the genders in any of the measurements. Since our study was conducted in pediatric patients living in the same region, and the experimental group was composed of children of the same race, this result may be attributed to genetic similarities and environmental factors shared among the study population. These results might have been different if subjects of different races or ethnicities had been included in the study.

This research had some limitations. While CBCT analysis is known for its accuracy and advanced capabilities, this study utilized PA cephalometric radiographs taken as part of routine care for patients undergoing expansion treatment. It should be noted that the sample size in this study was larger than that of many CBCT studies. Additionally, none of the patients in this study had such a significant maxillofacial abnormality that CBCT was required for diagnosis or treatment planning. The authors considered collecting pre- and post-treatment CBCT in patients, but it was not possible due to ethical limits and the increase in radiation dose in pediatric patients.

5. Conclusions

In conclusion, our study showed that RME could effectively treat complex maxillofacial deformities caused by NSD in pediatric patients, regardless of gender, thereby highlighting the positive impact of RME on NSD correction. Further research with larger sample sizes and diverse populations using advanced imaging techniques can provide deeper insights into the role of RME in treating NSD.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

AM and HU—designed the study. HU—performed the research. LF—analyzed the data. MC, MMM and GM—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors have read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This research was conducted in compliance with the Helsinki Declaration, and the protocol was authorized by the University of Aldent Ethics Committee in Tirana, Albania (Protocol number: Protocol 842/2022; Date: 31 October 2022). All patients and their parents provided written consent to participate in the study.

ACKNOWLEDGMENT

Authors thank Meltem Tekbas-Atay, Department of Conservative Treatment, Trakya University, Edirne, Turkey, for editing and last reviewing and Gamze Oney, who helped in verifying landmark placement and anatomical outlines.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest. Giuseppe Minervini is serving as one of the Editorial Board members of this journal. We declare that Giuseppe Minervini had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to MAM.

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How to cite this article: Hande Uzunçıbuk, Maria Maddalena Marrapodi, Luca Fiorillo, Aida Meto, Marco Cicciù, Giuseppe Minervini. The influence of orthopedic rapid maxillary expansion on the deviation of the nasal septum. Journal of Clinical Pediatric Dentistry. 2024; 48(1): 7-18. doi: 10.22514/jocpd.2024.002.