ORIGINAL ARTICLE
ALLERGY & RHINOLOGY
DOI: 10.5152/B-ENT.2021.20618

Effect of Rapid Maxillary Expansion Treatment on the Nasal Floor and Nasal Soft Tissue: Report on 26 Patients

Ufuk Ok[1], Burcu Ece Koru[2]

[1]Department of Orthodontics, Faculty of Dentistry, İstanbul Gelişim University, İstanbul, Turkey
[2]Department of Orthodontics, Faculty of Dentistry, İstanbul Aydın University, İstanbul, Turkey

Cite this article as: Ok U, Koru BE. Effect of Rapid Maxillary Expansion Treatment on the Nasal Floor and Nasal Soft Tissue: Report on 26 Patients. B-ENT 2022;18(1):7-14.

ABSTRACT

Objective: Rapid maxillary expansion may result in transverse and sagittal alterations of the maxilla and base of the nose. rapid maxillary expansion-induced changes in soft and skeletal tissues could influence midfacial aesthetics. In this study, we aimed to determine the short-term effects of rapid maxillary expansion on the midface soft and skeletal tissue structures by reviewing cone-beam computed tomography imaging retrospectively.

Methods: The study included 26 patients who underwent rapid maxillary expansion, of whom 13 were women and 13 were men (mean age 11.29 years; standard deviation 1.56, range 9.5-14.4 years). All selected patients underwent multi-slice cone-beam computed tomography twice; pre-rapid maxillary expansion (T0) and post-rapid maxillary expansion (T1). To compare the T0 and T1 results, 7 skeletal tissues, 4 soft tissues, and 3 angle variables were evaluated.

Results: A statistically significant elevation of all variables related to soft (alar base and alar curvature) and skeletal tissues (N-ANS; $P < 0.05$) was found. Comparisons between T0 and T1 revealed significant changes in the pyriform aperture width (anterior nasal width, posterior nasal width, and anterior nasal floor width; $P < .001$). When the beta coefficient was considered in simple regression analysis, the difference in the value of anterior nasal floor revealed a positive effect that was 3.91 times that of the change in the al-al alar base width.

Conclusion: Rapid maxillary expansion caused significant positional changes in the soft tissues around the nose of young and growing patients. The maxillary transverse width variable, T1-T0 difference, was found to impact the alar base width owing to the effects on the anterior nasal floor. Therefore, the anticipated changes should be explained to patients with pre-rapid maxillary expansion.

Keywords: Rapid maxillary expansion; midfacial change; soft tissue change

Introduction

Frequent malocclusion and maxillary transverse deficiency affect 10% of adults and 21% of children.[1] It is frequently associated with a dental or skeletal posterior cross-bite (unilateral or bilateral), high palatal arch, dental crowding, and narrow nasal cavity, frequently causing jaw and masticatory dysfunction and influencing speech, oral health, and maxillary face and midfacial aesthetics.[2]

Rapid maxillary expansion (RME) is a highly successful technique for treating transverse abnormalities in children, expanding the breadth of the maxilla, and opening the midpalate suture by introducing cross-force into the maxillary teeth, thus relieving the transverse deficiency of the maxilla.[3,4] Other dental and skeletal effects include the pterygoid process of the sphenoid bone, temporomandibular joint, pharyngeal structures, middle ear, and nasal cavity.[5,6] Following on from studies that examined the effects of RME on the nasal cavity,[7,8] others[4,9] examined the skeletal and dental changes and changes in soft and hard tissues of the face owing to expansion of the bone.[10,11] These changes in soft tissue can affect the aesthetics of the patients' faces[12] and are important in post-RME respiration. The rhinometry results of Zeng et al[13] showed an increase in nasal flow and a decrease in nasal resistance post-expansion. Ottaviano et al[14] reported that RME could lead to improved olfactory function post-treatment,

Corresponding Author: Ufuk Ok, dtufukok@hotmail.com
Received: July 13, 2021 Accepted: August 31, 2021 Available Online Date: 18 October, 2021
Available online at www.b-ent.be

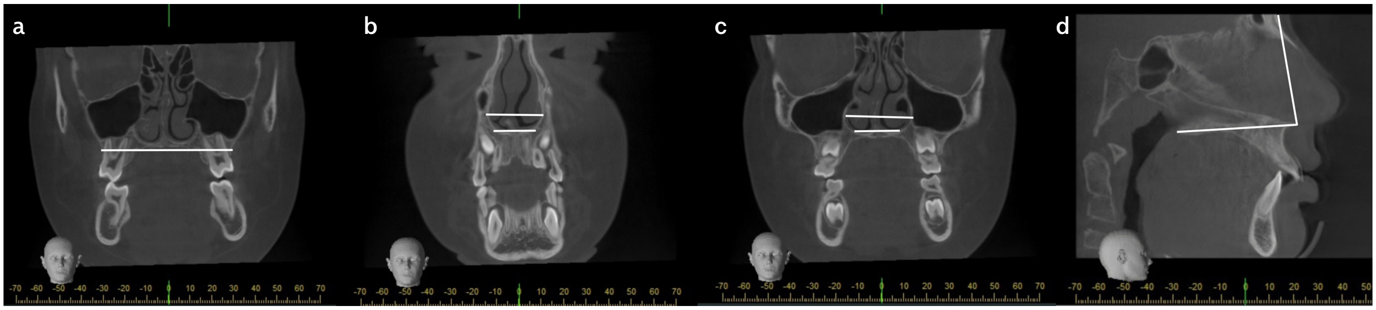

Figure 1. a-d. Skeletal linear measurements. (a) Maxillary expansion measurement with coronal image. (b) Anterior nasal floor and width measurements. (c) Posterior nasal floor and posterior nasal width measurements. (d) Anterior nasal spines (ANS) - posterior nasal spines and N-ANS measurements.

with further improvements observed after six months. Therefore, understanding the effects of RME is important.[9,11]

Computed tomography (CT) is recognized as a reliable way to measure and display soft and skeletal tissue thickness.[15] Nonetheless, it has scarcely been used in three-dimensional (3D) nasal cavity examinations, and most of the studies on this subject have focused on changes in the nasal cavity width.[12,16-18] Furthermore, rhinometry and acoustic rhinometry are used to investigate post-RME nasal airways.[19,20] However, the effect of RME on the nasal floor and soft tissues have not yet been investigated together. In this study, we aimed to evaluate the short-term impact of RME on midface soft tissues using cone-beam CT (CBCT), 7 skeletal tissues, 4 soft tissues, and 3 angle variables.

Methods

This retrospective study was approved by the Istanbul Aydin University's committee for ethics in institutional research (decision no. 2020/316) and was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. Written informed consent was obtained from the patients who agreed to take part in the study. The CBCT images of patients diagnosed with transverse maxillary deficiency and treated with RME, who had CBCT scans pre-treatment (T0) and 4 months after active expansion at the beginning of fixed orthodontic treatment (T1), had no craniofacial abnormalities, and had undergone no previous orthodontic treatment were included in the study. Among the 26 patients included, 8 had bilateral-posterior cross-bite, 15 had unilateral cross-bite, and 3 had maxillary transverse deficiency without a dental cross-bite with a history of nasal airway issues. Of the 26 patients, 13 were women and 13 were men, with a mean age of 11.29 years with a standard deviation (SD) of 1.56 (range 9.5-14.4 years). Patients with craniofacial abnormalities, periodontal or dental diseases, or syndromes were excluded.

Main Points

- Rapid maxillary expansion (RME) was determined to cause significant positional soft tissue changes around the nose of young and growing patients.
- These changes increase the nose width, alar, and curvature parts.
- Clinicians should discuss these potential effects with their patients pre-RME.

The first maxillary molars were banded, and a Hyrax appliance was applied. The appliance screw (Leone, NY, USA) was activated with 4-quarter initial activations and 2-quarter turns twice a day until the palatal cusps of the maxillary first molars reached the buccal cusps of the mandibular first molars for over-expansion. Four months after activation of the appliances, they remained in their position as passive retainers, helping form the mid-palatal suture bone. Cone-beam computed tomography was performed twice, pre-RME (T0) and 6 months after placement of the expansion appliance (T1).

Maxillary Expansion Measurement

Transverse skeletal expansion was assessed using coronal images from the buccal surfaces of the maxilla with linear measurements passing through the molar bifurcation (M-M). The impact of arch expansion involved alveolar and skeletal impacts (Figure 1a).

Measurement of the Skeletal Midfacial Area

The area was estimated using the CBCT images. The aperture piriformis was measured in the anterior and posterior regions. The width of the anterior nasal in the interval within the outermost points of the lower third lateral walls of the pyriform aperture was measured in millimeters at the coronal plane passing through the N point with linear measurements at 2 levels, anterior nasal floor (ANF) and anterior nasal width (ANW) (Figure 1b). The posterior region was measured at the coronal plane that passes through point S with linear estimations of 2 separate levels, the posterior nasal floor (PNF) and posterior nasal width (PNW) (Figure 1c).

Images were fixed to a plane parallel to the Frankfort horizontal (FH) plane, connecting the posterior nasal spines (PNS) to the cervical vertebra parallel to the FH plane, which is known as the PNS palate, for sagittal measurement. In this image, these distances are indicated as ANS-PNS and N-ANS (Figure 1d).

Soft Tissue Measurement

Measurement of the soft tissue was estimated using multiplanar slides and axial and sagittal images.

The measurement of the height between the $N_{(soft)}$ and PrN points, as well as the length between PrN and SbN points, was performed linearly using sagittal images (Figure 2a). Similarly, for the soft tissue width, the linear distance between $al_{(right)}$ and $al_{(left)}$ for the alar base and the distance between $ac_{(right)}$ and $ac_{(left)}$ for alar curvature were measured in millimeters using axial images (Figure 2b). In Figures 2c and d in the sagittal image, the nasolabial angle and SNA angle (an angle measuring

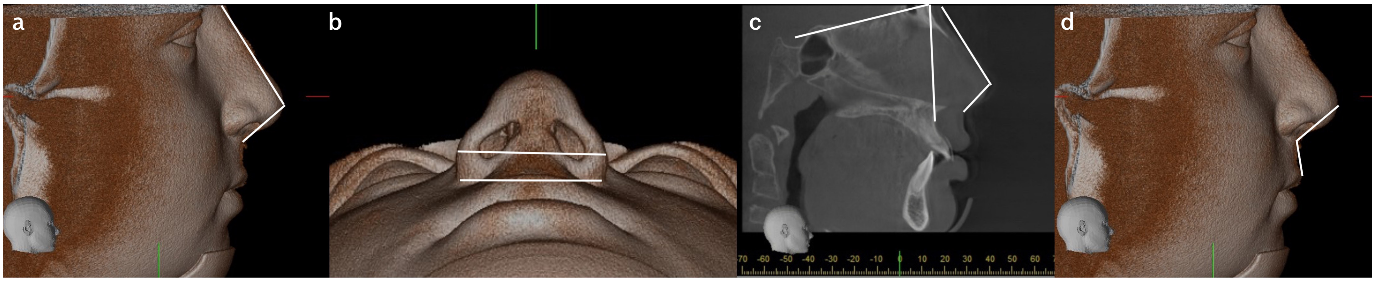

Figure 2. a-d. Soft tissue measurements and sella-nasion to A (SNA) point angle. (a) Distances between N(soft) and PrN, PrN and SbN, and nose tip angle. (b) Measurements of the alar base and alar curvature. (c) SNA angle. (d) Nasolabial angle

Table 1. Results of the Skeletal Measurement Variables

n=26			T0	T1	ΔT (T1-T0)	t*	P
Linear measurements	Maxillary transverse widths		57.28 ± 2.80	61.70 ± 3.59	4.24 ± 2.43	−9.498	.001
	ANS-PNS		49.87 ± 4.28	50.0 ± 3.27	0.52 ± 1.52	-	.231
	N-ANS		46.15 ± 4.80	46.39 ± 4.63	1.10 ± 1.08	-	.001
Apertura piriformis	Anterior	ANW	22.80 ± 1.63	25.05 ± 1.87	2.15 ± 1.59	−7.194	.001
		ANF	10.96 ± 3.88	12.92 ± 2.87	2.60 ± 1.69	-	.001
	Posterior	PNW	19.44 ± 1.81	22.46 ± 3.09	2.79 ± 1.95	-	.001
		PNF	28.28 ± 4.41	30.14 ± 4.27	1.75 ± 1.11	−8.141	.001

Normally distributed data are presented (paired t-test) as the mean (SD) and are shown in tables with t-values. Non-normally distributed data (Wilcoxon signed ranks test) are expressed as the median (interquartile range) without t-values.
ANS, anterior nasal spines; PNS, posterior nasal spines; SNA, sella-nasion to A point; ANW, anterior nasal width; ANF, anterior nasal floor; PNF, posterior nasal floor; PNW, posterior nasal width.

the anteroposterior relationship of the maxillary basal arch on the anterior cranial base, which shows the degree of maxillary prognathism), created by the junction of the sella-nasion and nasion-A lines, were measured.

Statistical Analysis

Normality of the data distribution was evaluated using the Kolmogorov-Smirnov test. The t-test was used to analyze the normally distributed data, and the nonparametric data were analyzed using the Wilcoxon test to compare the pre and post-RME variables. A P value of < .05 was considered statistically significant. To investigate the influence of the independent variable on the dependent variable, a simple regression analysis was employed. The Statistical Package for the Social Sciences version 26.0 (Armonk, New York, USA) was used for data analysis.

Results

Normally distributed data were presented as the mean (SD), and non-normally distributed data were expressed as the median (interquartile range) without t-values. The 26 patients (13 men and 13 women) included in this study all suffered from maxillary transverse deficiency and were referred for RME treatment.

In the skeletal results, there were significant differences in the maxillary transverse width (MTW), N-ANS, ANW, PNW, ANF, and PNF, except for ANS-PNS (Table 1). The MTW differed significantly from 57.28 (2.80) to 61.70 (3.04) (P < .001). ANS-PNS increased from 49.87 (4.28) to 50 (3.27), indicating an insignificant difference before and after treatment (P = .231). N-ANS increased significantly from 46.15 (4.80) to 46.39 (4.63) (P < .001). ANW increased from 22.80 (1.63) to 25.05 (1.87) (P < .001), and PNW values increased from 19.44 (1.81) to 22.46 (3.09) (P < .001). Before and after treatment, the ANF values were reported to be 10.96 (3.88) and 12.82 (2.97) before and after treatment, respectively (P < .001). PNF increased significantly from 28.38 (4.41) to 30.14 (4.27) (P < .001).

There were significant differences in the soft tissue and angle measurements before and after RME treatment related to the alar base, alar curvature, and SNA angle (P < .05) (Table 2). Moreover, significant differences were observed for PrN–SbN (P < .05). The alar base width increased from 30.23 (2.01) to 31.81 (2.74) (P < .001). The SNA angle increased from 30.69 (4.56) to 30.96 (3.43) (P < .001), whereas the SNA angle increased from 80.40 (1.4) to 82.20 (2.8) (P < .001). $N_{(soft)-}$PrN increased from 41.92 (2.52) to 43.47 (3.10) (P = .006). In addition, the difference in PrN–SbN before (15.90 [2.92]) and after (15.96 [1.44]) treatment was significant (P = .001). The nasolabial angle increased from 117.06 (8.49) to 117.76 (11.95); however, this difference was not significant (P = .712). Finally, $N_{(soft)-}$PrN-SbN (nose tip angle) reduced from 101.20 (5.83) to 101.01 (6.15); however, this difference was not significant (P = .911).

As the maxillary bone is anatomically adjacent to the base of the nose, a simple regression analysis was used to determine the effect of its expansion rate on the change in the base. The MTW variable (T1–T0 difference) had a significant effect on ANF but not on the posterior nasal floor width (P > .05) (Table 3).

As MTW and ANF were positively correlated, a second regression test was implemented to investigate the relationship between ANF, the soft tissue, and angles (Table 4).

Table 2. Soft Tissue and Angle Results

n=26			T0	T1	∆T (T1-T0)	*t**	*P*
Linear measurements	Al - Al Alar base widths		30.23 ± 2.01	31.81 ± 2.74	1.52 ± 1.40	−5.674	.001
	Ac - Ac Alar curvature widths		30.69 ± 4.56	30.96 ± 3.43	1.03 ± 2.13	-	.001
	N - PrN		41.92 ± 2.52	43.47 ± 3.10	1.33 ± 2.43	−3.030	.006
	PrN - SbN		15.90 ± 2.92	15.96 ± 1.44	0.32 ± 1.16	-	.001
Angular measurements	Skeletal	SNA	80.40 ± 1.4	82.20 ± 2.8	1.81 ± 1.71	-	.001
	Soft tissue	Nasolabial angle	117.06 ± 8.49	117.76 ± 11.95	0.67 ± 9.18	−0.374	.712
		N - PrN - SbN Nose tip angle	101.20 ± 5.83	101.01 ± 6.15	-0.17 ± 8.04	0.113	.911

Normally distributed data are presented (paired *t*-test) as the mean (SD) and are shown in tables with *t*-values. Non-normally distributed data (Wilcoxon signed ranks test) are expressed as the median (interquartile range) without *t*-values.
SNA, Sella-nasion to A point; PrN, The point of the angle between the septum of the nose and the surface of the upper lip; SbN, The point of the angle between the septum of the nose and the surface of the upper lip.

Table 3. Effect of the Maxillary Transverse Width Variable on the Anterior and Posterior Nasal Floor Width

Dependent Variable	Independent Variable	*B*	Std. error	Beta	*t*	*P*	Model
Anterior nasal floor width	Constant	3.66	0.70	0.31	5.25	.01	*F* = 2.36 *P* = .03
	uv	−0.22	0.14		−1.54	.14	
Posterior nasal floor width	Constant	4.25	0.78	−0.35	5.48	.01	*F* = 3.16 *P* = .08
	uv	−0.28	0.16		−1.78	.09	

The al-al alar base width variable had a statistically significant effect on the ANF variable (*F* (1.23): 20.4, $P < .05$). When the beta coefficient was considered, the difference in the value of ANF revealed a positive effect that was 3.91 times that of the change in the al-al alar base width. Moreover, 47% of the change in the al-al alar base width could be explained by the ANF variable.

The nasolabial angle variable had a statistically significant effect on the ANF variable (F (1.23) = 4.69, $P < .05$). Considering the beta coefficient, the change in the ANF value has a positive 0.55-fold effect on the change in the nasolabial angle value. Moreover, 1.7% of the change in the nasolabial angle could be explained by the ANF variable. Other variables did not significantly affect the ANF variable ($P > 0.05$).

Discussion

Since the introduction of RME in 1860,[21] its dental and skeletal impact, as well as its effect on the nasal cavity, have been of interest to clinicians. Because the nasal cavity and maxilla are closely related,[22] any changes to the maxilla can affect the shape[23] and physiology of the nose.[24] It has been observed that patients with maxillary problems suffer from respiratory disorders because of nasal congestion, which can have serious consequences for the growth of facial features and facial aesthetics, especially in young patients.[25] Modern research has concentrated on the role of soft tissue in maintaining the substantiality of RME treatment results and aesthetic effects after the procedure.[10,26] However, studies on the soft tissue of the nose are very rare, and most studies in this area have focused on the skeletal effects of RME.[12] Owing to the unintended effects of this treatment on face shape and the increasing importance of this issue for patients, this should be considered an important topic for research.

Although most studies have focused on the width of the nose, the results of RME treatment show that after the procedure, the effects are manifested in all 3 dimensions of the nose. The results of our study on skeletal changes showed that the pyriform aperture width increased significantly ($P < .001$, average 2.15 ± 1.59 and 2.60 ± 1.69). These findings are consistent with those of previous studies.[22,26-28] The studies conducted by Smith et al[10] also showed increments in the width of the nose, but only Cross et al[3] results showed statistical significance. As they have been associated with upper airway dimensions, sex, age, skeletal age, and mandibular inclination were also considered.[29,30] However, as the nose is in the center of the face, various factors, such as age, sex, and other facial structures (orbital structures, circummaxillary sutures, and spheno-occipital synchondrosis), can affect the shape of the nose.[31] Therefore, to verify the accuracy of the results obtained, further studies should consider other parameters.

In our study, CBCT images were analyzed, and only the effect of maxillary expansion on the nasal floor and soft tissue of the nose was investigated. In this study, a significant increase in the skeletal maxillary width was observed, which is in agreement with previous studies. There was also a significant increase in the anterior nasal floor and alar base widths between T0 and T1, which was in disagreement with previous studies. Despite the significant increase in the maxillary width, no significant increase in the PNF was found compared with that of the maxillary width.

A study that investigated the CBCT airway growth of 1300 patients found a consistent increase in upper airway volume in children aged between 6 and 20 years.[32] Most previous studies regarding the assessment of RME skeletal effects focused on short-term effects with an average follow-up of only 3 to

Table 4. Effect of the Anterior Nasal Floor Width Variable on the Angle and Soft Tissue Values

Dependent Variable	Independent Variable	*B*	Std. Error	Beta	*t*	*P*	Model
Alar curvature (Ac – Ac)	Constant	0.75	0.52	0.36	1.44	.16	F = 3.49 *P* = .07
	FG	0.31	0.17		1.87	.07	
Alar base (Al – Al)	Constant	−9.89	2.73	0.69	-3.63	.01	F = 20.4 *P* = .01 R^2 = 0.47
	FG	3.91	0.87		4.52	.01	
N-ANS	Constant	0.98	0.42	0.17	2.33	.03	F = 0.68 *P* = .41
	FG	0.11	0.13		0.83	.42	
ANS-PNS	Constant	−1.00	0.61	0.18	−1.64	.11	F = 0.76 *P* = .39
	FG	0.17	0.19		0.87	.39	
PrN - SbN	Constant	0.16	0.49	0.10	0.33	.74	F = 0.21 *P* = .64
	FG	0.07	0.16		0.47	.65	
N - PrN	Constant	1.44	1.02	0.03	1.41	.17	F = 0.01 *P* = .89
	FG	0.04	0.33		0.13	.90	
Nose tip angle	Constant	−3.82	3.30	0.26	−1.16	.26	F = 1.64 *P* = .21
	FG	1.34	1.05		1.28	.21	
SNA angle	Constant	2.26	0.67	-0.08	3.37	.00	F = 0.14 *P* = .70
	FG	−0.08	0.21		−0.39	.70	
Nasolabial angle	Constant	−0.38	0.80	0.41	−0.47	.64	F = 4.69 *P* = .04 R^2 = 0.170
	FG	0.55	0.25		2.17	.04	

ANS, anterior nasal spines; PNS, posterior nasal spines; SNA, sella-nasion to A point; std, standard.

6 months. Consequently, most did not find any significant effect from growth owing to this short interval before and after RME.[12,16-18] In short-term studies, the aim is usually to analyze the effect of RME on nasal changes in various facial structures, and the fact that growth may affect long-term results is ignored. In our study, there were no control groups.

Our study examined the linear and angular parameters to examine the skeletal effects of RME on soft tissue using CBCT. The SNA angle was also considered to examine the possible anterior and posterior maxillary movements. Examination of the SNA angle and its comparison with the pre-treatment angle showed a significant increase of 1.81° ± 1.71°, indicating an anterior movement of the maxilla. These findings are in agreement with those of Ramoglu et al[33] who found that post-RME values remained constant but reported a significant SNA increase after semi-RME. Some studies have reported a post-RME and SNA increase.[23] In a review study, Lione et al[4] addressed the unintended consequences of RME treatment. Their research showed that downward maxillary movement caused downward and backward mandibular movements.

Our results showed that in soft tissue nasal structures, the highest increase was in the soft tissue width with an average increase of 1.52 mm (±1.4) ($P < .001$). The alar width also increased with the same statistical significance ($P < .001$) to 1.03 mm (± 2.13). A review of related studies shows that few have obtained similar values for post-RME nasal soft tissue changes,[11,34] and some reported higher values than our results.[12,35] Corbridge et al[36] showed that from a coronal plane point of view, skeletal structures become pyramidal-like during RME. Our results showed that the alar base showed the highest increase. This may be because the distance between the alar base and coronal plane is less than the distance between the alar and coronal planes. Therefore, the alar base is more affected by the ANF. Thus, soft tissues and nasal cartilage appear to reduce the impact of bone expansion.

Examination of the length of the soft tissue of the nose showed a significant increase ($P < .001$) with an average of 0.32 mm (± 1.16) observed after RME. Previous studies by Karaman et al[28] and Magnusson et al[12] indicated greater increases, whereas Yilmaz et al[34] found smaller increases. Although all the results of these studies were statistically significant, Kilic et al[37] reported a 0.23 mm increase in the length of the soft tissue that was not significant ($P > .05$).

In this study, which was performed to examine the soft tissue height changes after RME, there was a significant ($P < .001$) average increase of 1.33 mm (± 2.43). In the literature, the only study that has examined the height of soft tissue in the nose is that of Magnusson et al.[12] However, they found no significant increase (0.18 mm; $P > .05$) but did observe post-RME changes following surgical disjunction.

The primary disadvantage of CBCT is its limited dynamic range in revealing differentiation within the soft tissue and the existence of metal artefacts.[38] It performs well in bone investigations, with excellent bone/mucosa/air contrast; however, its low-density resolution is a disadvantage in soft tissue contrast investigations.[39] Furthermore, numerous variables influence CBCT, including the dosage necessary, patient position, technology used to interpret the pictures, and the analyst's competence.[40]

Rhinomanometry, acoustic rhinometry (AR), endoscopy, and optical rhinometry (ORM) are clinical procedures used to evaluate nasal airway patency. AR describes the physical structure of a nasal channel, whereas rhinomanometry measures pressure/flow correlations during the breathing process.[19] Tarhan et al[41] compared AR data with CT images to assess the accuracy of AR measurements in predicting the nasal passage area and the ability of AR to estimate the paranasal sinus size and ostium size in living individuals. They found a good correlation between the cross-sectional areas measured by AR and CT in the frontal nasal cavity. Sakai et al[19] also compared nasal widths in coronal sections in the inferior and middle turbinate regions with their respective narrowest areas in the same anatomical location, as measured in AR. They reported favorable connections.

Numminen et al[42] in 2003 stated that growing evidence suggested the co-existence of inflammatory disorders and allergies in the upper and lower airways. An objective approach must be used to obtain high-quality upper airway measurements. Acoustic rhinometry and high-resolution CT volumetry were used to assess 48 nasal cavities. According to researchers, AR is a clinically valid approach for assessing nasal cavity geometry in the anterior and central regions of the nasal cavity.

ORM is a novel technology that was established in Germany in 2004 to estimate nasal blood volume as a measure of nasal patency by quantifying light extinction in optical density.[43] It works by measuring visible and near-IR light absorption in tissues using optical spectroscopy.[43] Endoscopy of the paranasal sinuses allows for the examination of anatomical regions as well as the assessment of sinonasal lesions and their connection with endonasal structures. However, endoscopy is an intrusive and expensive procedure that requires local or general anesthesia. It cannot be used in all the patients and may even be associated with serious consequences during RME. Finding an alternate diagnostic method is, therefore, advantageous. CBCT may be used as an alternative to diagnostic sinus endoscopy.[44] In situations of expansion treatments, CBCT scans provide a guide for the precise evaluation of the sinus architecture, which is highly important in both preoperative and post-intervention follow-ups. Thus, combining CBCT scans with other imaging techniques, such as AR, will provide substantial benefits in more efficiently evaluating specific patients.[45]

Previous studies have reported CBCT as an accurate and reliable method of assessing the upper airway in the upright position[46] and suggested that it is capable of accurately defining the boundaries between the airway spaces and soft tissues in both children and adults, with easily identifiable landmarks and negligible magnification.[47] One recently published analysis of prior CBCT studies evaluating changes in the airway before and after RME therapy revealed inconsistent results and a lack of uniformity across the measuring techniques employed.[48] Anandarajah et al[30] established and confirmed a systematic approach of upper airway evaluation using CBCT and used this methodology to show a link between maxillary and mandibular breadth and airway volume in healthy, untreated children. We examined 7 skeletal tissues, 4 soft tissue, and 3 angle variables that could only be investigated using CBCT.

With the advancement in 3D imaging, 3D image reconstruction software, and CBCT,[49] researchers and physicians can more accurately illustrate internal bone structures and measure their changes in all facial and maxillary structures. In their studies, Berger et al[11] and Kulbersh et al[35] showed that RME skeletal changes affected soft tissues with a 1:1 ratio (100%). These values are roughly consistent with the results of our study in which 0.5 mm soft tissue changes (90%) were observed for every 1 mm skeletal increase. For accurate analysis, the accuracy of the selected points and error analysis of the measurement method must be reliable.[37] Our literature review found that most studies did not analyze measurement errors or perform sample size calculation methods. Our results revealed changes in the nose post-RME in 3D. A comparison of T0 and T1 also showed that changes that occur in soft and skeletal tissues in the midface, length, and width had the least effect on the studied structures.

This study had several limitations. First, the observed changes were not permanent responses; all were short-term. The soft tissue alterations identified in this study should be evaluated over a long-term follow-up to establish whether they were simply transitory stretching of the soft tissue or persistent. In the future, studies with a greater number of patients should be conducted. In addition, findings gained from the long-term treatment of transverse maxillary insufficiency with maxillary expansion should be included. As a result, the findings of this study are particularly pertinent to future research. Second, the use of superimposition in 3D imaging is contentious. Third, this study lacked a control group. Fourth, as the follow-up period was only 6 months, we could not assess the permanent or long-term impact of RME on soft tissue. Nevertheless, the short-term therapeutic usefulness of RME on soft tissues cannot be overlooked, as proven by this study.

We demonstrated that RME caused significant positional changes in the soft tissues around the nose in young and growing patients. These changes increased the nose width, alar, and curvature. According to our results, it appears that MTW (T1–T0 difference) influences alar base widths through impact on ANF. Clinicians should discuss all these potential effects with patients before RME.

Ethics Committee Approval: This study was approved by Ethics committee of İstanbul Aydın University (Approval No: 2020/316).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – U.O.; Design – U.O.; Supervision – U.O.; Resources – B.E.K.; Materials – U.O., B.E.K.; Data Collection and/or Processing – U.O., B.E.K.; Analysis and/or Interpretation – U.O., B.E.K.; Literature Search – U.O., B.E.K.; Writing Manuscript – U.O.; Critical Review – U.O.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

1. Dimberg L, Lennartsson B, Arnrup K, et al. Prevalence and change of malocclusions from primary to early permanent dentition: a longitudinal study. Angle Orthod 2015; 85: 728-34. [Crossref]
2. Yi F, Liu S, Lei L, et al. Changes of the upper airway and bone in microimplant-assisted rapid palatal expansion: A cone-beam computed tomography (CBCT) study. J Xray Sci Technol 2020; 28: 271-83. [Crossref]
3. Cross DL and McDonald JP. Effect of rapid maxillary expansion on skeletal, dental, and nasal structures: a postero-anterior cephalometric study. Eur J Orthod 2000; 22: 519-28. [Crossref]
4. Lione R, Franchi L and Cozza P. Does rapid maxillary expansion induce adverse effects in growing subjects? Angle Orthod 2013; 83: 172-82. [Crossref]
5. Ballanti F, Lione R, Fanucci E, et al. Immediate and post-retention effects of rapid maxillary expansion investigated by computed tomography in growing patients. Angle Orthod 2009; 79: 24-9. [Crossref]
6. Rosa M, Lucchi P, Manti G, et al. Rapid Palatal Expansion in the absence of posterior cross-bite to intercept maxillary incisor crowding in the mixed dentition: a CBCT evaluation of spontaneous changes of untouched permanent molars. Eur J Paediatr Dent 2016; 17: 286-94.
7. Ballanti F, Baldini A, Ranieri S, et al. Corrigendum to "Is there a correlation between nasal septum deviation and maxillary transversal deficiency? A retrospective study on prepubertal subjects" Int J Pediatr Otorhinolaryngol 2016; 83: 109-12. [Crossref]
8. Fastuca R, Meneghel M, Zecca PA, et al. Multimodal airway evaluation in growing patients after rapid maxillary expansion. Eur J Paediatr Dent 2015; 16: 129-34.
9. Baldini A, Nota A, Santariello C, et al. Sagittal dentoskeletal modifications associated with different activation protocols of rapid maxillary expansion. Eur J Paediatr Dent 2018; 19: 151-5. [Crossref]
10. Smith T, Ghoneima A, Stewart K, et al. Three-dimensional computed tomography analysis of airway volume changes after rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2012; 141: 618-26. [Crossref]
11. Berger JL, Pangrazio-Kulbersh V, Thomas BW, et al. Photographic analysis of facial changes associated with maxillary expansion. Am J Orthod Dentofacial Orthop 1999; 116:563-71. [Crossref]
12. Magnusson A, Bjerklin K, Kim H, et al. Three-dimensional computed tomographic analysis of changes to the external features of the nose after surgically assisted rapid maxillary expansion and orthodontic treatment: a prospective longitudinal study. Am J Orthod Dentofacial Orthop 2013; 144: 404-13. [Crossref]
13. Zeng J and Gao X. A prospective CBCT study of upper airway changes after rapid maxillary expansion. Int J Pediatr Otorhinolaryngol 2013; 77: 1805-10. [Crossref]
14. Ottaviano G, Maculan P, Borghetto G, et al. Nasal function before and after rapid maxillary expansion in children: A randomized, prospective, controlled study. Int J Pediatr Otorhinolaryngol 2018; 115: 133-8. [Crossref]
15. Palaisa J, Ngan P, Martin C, et al. Use of conventional tomography to evaluate changes in the nasal cavity with rapid palatal expansion. Am J Orthod Dentofacial Orthop 2007; 132: 458-66. [Crossref]
16. De Felippe NL, Bhushan N, Da Silveira AC, et al. Long-term effects of orthodontic therapy on the maxillary dental arch and nasal cavity. Am J Orthod Dentofacial Orthop 2009; 136: 491-8. [Crossref]
17. Furtado Á, Furtado GC, El Haje O, et al. Soft-tissue cone-beam computed tomography (ST-CBCT) technique for the analysis of skeletal, dental and periodontal effects of orthopedic rapid maxillary expansion. J Clin Exp Dent 2018; 10: 883-90. [Crossref]
18. Garrett BJ, Caruso JM, Rungcharassaeng K, et al. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2008; 134: 8-9. [Crossref]
19. Sakai Rhus, Marson Fal, Sakuma Etı, et al. Correlation between acoustic rhinometry, computed rhinomanometry and cone-beam computed tomography in mouth breathers with transverse maxillary deficiency. Braz J Otorhinolaryngol 2016 2016: 11-25. [Crossref]
20. Fouke JM and Jackson AC. Acoustic rhinometry: effects of decongestants and posture on nasal patency. J Lab Clin Med 1992; 119: 371-6. [Crossref]
21. Haas Aj. The Treatment Of Maxillary Deficiency By Openıng The Midpalatal Suture. Angle Orthod 1965; 35: 200-17. [Crossref]
22. Chung C-H and Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2004; 126: 569-75. [Crossref]
23. Haralambidis A, Ari-Demirkaya A, Acar A, et al. Morphologic changes of the nasal cavity induced by rapid maxillary expansion: a study on 3-dimensional computed tomography models. Am J Orthod Dentofacial Orthop 2009; 136: 815-21. [Crossref]
24. Halicioğlu K, Kiliç N, Yavuz İ, et al. Effects of rapid maxillary expansion with a memory palatal split screw on the morphology of the maxillary dental arch and nasal airway resistance. Eur J Orthod 2010; 32: 716-20. [Crossref]
25. Tecco S, Festa F, Tete S, et al. Changes in head posture after rapid maxillary expansion in mouth-breathing girls: a controlled study. Angle Orthod 2005; 75: 171-6. [Crossref]
26. Görgülü S, Gokce SM, Olmez H, et al. Nasal cavity volume changes after rapid maxillary expansion in adolescents evaluated with 3-dimensional simulation and modeling programs. Am J Orthod Dentofacial Orthop 2011; 140: 633-40. [Crossref]
27. da Silva Filho OG, Montes LA and Torelly LF. Rapid maxillary expansion in the deciduous and mixed dentition evaluated through posteroanterior cephalometric analysis. Am J Orthod Dentofacial Orthop 1995; 107: 268-75. [Crossref]
28. Basciftci FA and Karaman AI. Effects of a modified acrylic bonded rapid maxillary expansion appliance and vertical chin cap on dentofacial structures. Angle Orthod 2002; 72: 61-71. [Crossref]
29. Muto T, Yamazaki A, Takeda S, et al. Relationship between the pharyngeal airway space and craniofacial morphology, taking into account head posture. Int J Oral Maxillofac Surg 2006; 35: 132-6. [Crossref]
30. Anandarajah S, Abdalla Y, Dudhia R, et al. Proposal of new upper airway margins in children assessed by CBCT. Dentomaxillofac Radiol 2015; 44: 20140438. [Crossref]
31. Bazargani F, Feldmann I and Bondemark L. Three-dimensional analysis of effects of rapid maxillary expansion on facial sutures and bones. Angle Orthod 2013; 83: 1074-82. [Crossref]
32. Schendel SA, Jacobson R and Khalessi S. Airway growth and development: a computerized 3-dimensional analysis. J Oral Maxillofac Surg 2012; 70: 2174-83. [Crossref]
33. Sabri R. Treatment of a severe arch-length deficiency with anteroposterior and transverse expansion: long-term stability. Am J Orthod Dentofacial Orthop 2010; 137: 401-11. [Crossref]
34. Yilmaz BS and Kucukkeles N. Skeletal, soft tissue, and airway changes following the alternate maxillary expansions and constrictions protocol. Angle Orthod 2014; 84: 868-77. [Crossref]
35. Pangrazio-Kulbersh V, Wine P, Haughey M, et al. Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders. Angle Orthod 2012; 82: 448-57. [Crossref]
36. Corbridge JK, Campbell PM, Taylor R, et al. Transverse dentoalveolar changes after slow maxillary expansion. Am J Orthod Dentofacial Orthop 2011; 140: 317-25. [Crossref]

37. Kiliç N, Kiki A, Oktay H, et al. Effects of rapid maxillary expansion on Holdaway soft tissue measurements. Eur J Orthod 2008; 30: 239-43. [Crossref]
38. Güldner C, Diogo I, Windfuhr J, et al. Analysis of the fossa olfactoria using cone beam tomography (CBT). Acta Otolaryngol 2011; 131: 72-8. [Crossref]
39. Hodez C, Griffaton-Taillandier C and Bensimon I. Cone-beam imaging: applications in ENT. Eur Ann Otorhinolaryngol Head Neck Dis 2011; 128: 65-78. [Crossref]
40. de Gabory L, Catherine JH, Molinier-Blossier S, et al. French Otorhinolaryngology Society (SFORL) good practice guidelines for dental implant surgery close to the maxillary sinus. Eur Ann Otorhinolaryngol Head Neck Dis 2020; 137: 53-8. [Crossref]
41. Tarhan E, Coskun M, Cakmak O, et al. Acoustic rhinometry in humans: accuracy of nasal passage area estimates, and ability to quantify paranasal sinus volume and ostium size. J Appl Physiol (1985) 2005; 99: 616-23. [Crossref]
42. Numminen J, Dastidar P, Heinonen T, et al. Reliability of acoustic rhinometry. Respir Med 2003; 97: 421-7. [Crossref]
43. Cheung EJ, Citardi MJ, Fakhri S, et al. Comparison of optical rhinometry to acoustic rhinometry using nasal provocation testing with Dermatophagoides farinae. Otolaryngol Head Neck Surg 2010; 143: 290-3. [Crossref]
44. Zojaji R, Naghibzadeh M, Mazloum Farsi Baf M, et al. Diagnostic accuracy of cone-beam computed tomography in the evaluation of chronic rhinosinusitis. ORL J Otorhinolaryngol Relat Spec 2015; 77: 55-60. [Crossref]
45. Avsever H, Gunduz K, Karakoç O, et al. Incidental findings on cone-beam computed tomographic images: paranasal sinus findings and nasal septum variations. Oral Radiol 2018; 34: 40-8. [Crossref]
46. Guijarro-Martínez R and Swennen GR. Cone-beam computerized tomography imaging and analysis of the upper airway: a systematic review of the literature. Int J Oral Maxillofac Surg 2011; 40: 1227-37. [Crossref]
47. Weissheimer A, Menezes LM, Sameshima GT, et al. Imaging software accuracy for 3-dimensional analysis of the upper airway. Am J Orthod Dentofacial Orthop 2012; 142: 801-13. [Crossref]
48. Di Carlo G, Saccucci M, Ierardo G, et al. Rapid Maxillary Expansion and Upper Airway Morphology: A Systematic Review on the Role of Cone Beam Computed Tomography. Biomed Res Int 2017; 2017: id:5460429. [Crossref]
49. Parsa A, Ibrahim N, Hassan B, et al. Bone quality evaluation at dental implant site using multislice CT, micro-CT, and cone beam CT. Clin Oral Implants Res 2015; 26: 1-7. [Crossref]