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Nasal Airway Changes Due to Rapid Maxillary Expansion Timing

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ABSTRACT

The purpose of this study was to evaluate the effect of rapid maxillary expansion (RME) on nasal minimum cross-sectional area (MCA) using acoustic rhinometry (AR) in two groups of subjects who were treated before and after the pubertal growth spurt. The sample consisted of 29 patients with maxillary constriction and a control sample of 15 subjects. Both samples were divided into two groups according to individual skeletal maturation as assessed by the cervical vertebral maturation (CVM) method. Group I T (early-treated) consisted of 16 patients (eight girls and eight boys). Group I C (early-control) consisted of eight patients, and both groups had not reached the pubertal peak (CVM Stage 1–3). Group II T (late-treated) consisted of 13 patients (eight girls and five boys). Group II C (late-control) consisted of seven patients, and both groups were at a stage during or after the pubertal peak (CVM Stage 4–6). AR records were obtained for each treated subject before treatment (T_1), after expansion (T_2), and immediately after a three-month retention period (T_3); only T_1 and T_3 records were obtained for controls. The overall increase in MCA was significantly greater in the early- and late-treated groups (group I T, group II T) as compared with the early and late controls. (group I C, group II C) ($P < .05$). The results of the present study suggest that even the overall (T_1–T_3) increase for MCA in group I T is greater (0.34 mm) than the increase for MCA in group II T (0.19 mm), but the difference was not significant ($P > .05$).

KEY WORDS: Rapid maxillary expansion, Acoustic rhinometry, Minimum cross-sectional area, Cervical vertebral maturation.

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INTRODUCTION Return to TOC

Rapid maxillary expansion (RME) is an extremely advantageous procedure in the treatment of cases of real and relative maxillary transverse deficiency and cases of inadequate nasal capacity exhibiting chronic nasal respiratory problems. RME causes an increase in nasal cavity width,[1–4] lowering of the palatal vault, and straightening of the nasal septum[5] and improves the nasal respiration. RME creates an increase in nasal cavity width associated with a nasal resistance reduction, with the greatest reduction occurring generally in patients with the highest initial resistance.[6]

Several investigators have studied the effects of RME and reported a significant increase in nasal cavity width[1,4,6–8] and decreases in nasal resistance after expansion.[3,6,7] However Wertz[9] reported that no airway justification existed for RME unless an obstruction was present in the anteroinferior aspect of the nose, the area most affected by maxillary expansion. Haas[10] stated that, “It would be great interest, however, to follow a similar study on a larger sample of patients treated with a maximum anchorage appliance.” Haas reported a mean increase of 4.1 mm in the nasal cavity width for the 100 cases in his study.

One of the most important factors affecting the success of RME is the age of the patient. The patients who underwent RME treatment before a peak in skeletal growth showed significantly greater short-term increases in the width of the nasal cavities and more pronounced craniofacial changes than patients treated during or slightly after the peak.[11]

Lamparski[12] reported the cervical vertebrae were as valid as the hand-wrist area for assessing skeletal age. He cited six stages corresponding to six different maturational phases in the cervical vertebrae that can be identified during the pubertal period. Several studies[11,13,14] have been carried out since then.

For decades, investigators have sought an objective means of nasal airway assessment applicable to a broad spectrum of patients. Recently, Hilberg et al[15] introduced acoustic rhinometry (AR) as a useful tool for measuring nasal cavity dimensions. AR is an objective method enabling measurements of the relationship between the cross-sectional area of the nasal cavity and the distance into the nasal cavity. The method is based on analysis of the sound reflection from the nasal cavity taking into account the properties of incident sound submitted to the nasal cavity along with associated reflected sound waves.

In 1994, Scadding et al[16] measured 10 patients with allergic rhinitis using AR and rhinomanometry. They compared minimum cross-sectional area (MCA) and total nasal airway resistance results and reported a significant negative linear correlation between the measurements with $r = -0.6$. In another study, the relationships between subjective sensation of nasal obstruction, data of rhinomanometry and acoustic rhinometry were explored. Strong correlations between nasal airway resistance and MCA were noted.[17]

Acoustic rhinometric measures have been validated by computed tomography (CT),[18] magnetic resonance imaging (MRI),[19] subjective symptoms.[20] Rhinomanometric methods have been used for evaluating nasal resistance[21] and have been found to be objective and sensitive methods for assessing the configuration and measuring the relative changes in the internal dimensions of the nasal cavity.

The purpose of this study was to measure the effects of RME on MCA of nasal cavity of patients, treated before and after the pubertal growth spurt as evaluated with the cervical vertebral maturation (CVM) method, using AR.

MATERIALS AND METHODS Return to TOC

The treatment sample consisted of 29 patients who had undergone acrylic-bonded full tooth and tissue-borne RME appliance therapy in the Department of Orthodontics of Cumhuriyet University. The fabrication and the effects of full-coverage RME appliance have been described previously.[4,8,22] Inclusion criteria included a transverse maxillary deficiency, bilateral crossbite, and no history of nasal disease. Furthermore, the presence of an adequate nasal cavity space was confirmed using an anterior rhinoscopic examination by a single qualified otolaryngologist.

The control group consisted of 15 subjects who were attending the Department of Orthodontic of Cumhuriyet University for active orthodontic treatment. Each subject and their parents volunteered for the study.

Both treated and control groups were divided into two groups according to their skeletal maturity as evaluated using the CVM method (Figure 1) on lateral cephalograms taken before treatment (T_1). Group I T (early-treated) consisted of 16 patients (eight girls and eight boys, mean age 11 years and eight months) and group I C (early-control) consisted of 16 patients (eight girls and eight boys, mean age 12 years and six months). All Group I patients had not reached the pubertal peak in skeletal growth velocity and presented with cervical vertebral stage 1 to 3 (CVM Stage 1–3). Group II T (late-treated) consisted of 13 patients (eight girls and five boys, mean age 14 years and one month), and group II C (late-control) consisted of 13 patients (eight girls and five boys, mean age 13 years and four months). All Group I patients were at a stage during or after the pubertal peak in skeletal growth velocity and presented with cervical vertebral stage 4 to 6 (CVM Stage 4–6).

An acrylic-bonded fully tooth and tissue-borne RME appliance containing a Hyrax screw (GAC, Bohemia, NY) was used to correct the posterior crossbite in the treated subjects. The screw was activated two turns a day until the occlusal aspect of the maxillary lingual cusp of the upper first molars contacted the occlusal aspect of the facial cusp of the mandibular first molars. At that time, the screw was fixed with 0.014 ligature wire, and the appliance left for one week to minimize discomfort during removal. After removal, a new removable retention appliance was used for three months.

Acoustic rhinometry

The method of the AR was fully described by Hilberg et al,[15] and in this study, the PC-based Eccovision (Model AR-1003) from E Benson Hood Laboratories Inc (Pembroke, Mass) was used (Figure 2). This method measures acoustic reflections from the nasal cavity of a sound pulse created by a spark in a sound tube connected with the nasal cavity through a nosepiece. The results are presented as a curve describing the cross-sectional area of the nasal cavity as a function of the distance from the nostrils. From this curve, MCA with the nasal valve, the narrowest segment of nasal cavity can be found (Figure 2).

The measurement of MCA was calculated by a personal computer system. The MCA is expected to be highly correlated with the subjective feeling of nasal patency.[20] Consent was obtained from the local ethical committee before the start of the study. AR data were obtained by the same otolaryngologist for each treated subject T_1, after treatment (T_2), and after three months of retention period (T_3).

Because the time span between the two measurements (T_1–T_2) was from 23 to 27 days, the "growth factor" was not considered. Therefore, only T_1 and T_3 records were obtained for the controls. AR measurements were taken at the same room temperature (20°C) and at constant humidity. The patients were allowed to rest for 30 minutes before recordings commenced, and the device was calibrated according to the manufacturer's instruction during this period. After calibration, decongestant nasal spray (Iliadin, Santa Farma, Turkey) was applied to the nostrils. This was done to eliminate mucosal variations attributable to the nasal cycle. After a 10-minute delay, the nosepiece was placed to the nostril and NAR was measured four times for each nostril. AR was performed to measure the MCA at the anterior one to five cm from the nostril. This procedure was repeated four times for every measurement, and we used the mean values of all the measurements. The MCA was calculated by adding the values obtained for the left and right nasal nostrils, respectively.

Statistical analysis

Data was obtained for each MCA measurement at T_1, T_2, and T_3 for the treated group, and at T_1 and T_3 for the control group. Because of the short time interval between T_1 and T_2, the measurement at T_2 was eliminated for the control group. The results were calculated using the software SPSS for Windows (release 10.0.0, SPSS Inc, Chicago, Ill). The mean differences between the different time points (T_1–T_2, T_2–T_3, and T_1–T_3) were all studied using the Freidman and Wilcoxon's signed rank test. A Mann-Whitney *U*-test was applied for comparison of the groups.

RESULTS Return to TOC

Pretreatment vs posttreatment (T_1 vs T_2)

Comparison of treatment effects in group I T vs group II T. In group I T and in group II T, treatment was associated with an increase in the mean values for MCA ($P < .05$) (Table 1). No statistically significant differences were found between the two groups ($P > .05$) (Table 2).

Posttreatment vs postretention (T_2 vs T_3)

Comparison of retention in group I T vs group II T. Although the decrease in the mean values for MCA in group I T was not significant ($P > .05$) (Table 1), the reduction for MCA in group II T was significant ($P < .05$) (Table 1). However, when the differences between the groups (early-treated vs late-treated) were compared, no significant difference was found ($P > .05$) (Table 2).

Pretreatment vs postretention (T_1 vs T_3)

Overall treatment changes in group I T vs group I C. There were significantly greater increments ($P < .05$) in group I T compared with the controls (Table 3).

Overall treatment changes in group II T vs group II C. There were significantly greater increments ($P < .05$) in group II T compared with the controls (group II C) (Table 3).

Overall treatment changes in group I T vs group II T. No statistically significant differences ($P > .05$) were found between the groups (Table 2).

DISCUSSION Return to TOC

The aim of the present study was to evaluate the effect of RME in MCA of nasal cavity by AR and investigate probable difference for MCA between the groups by starting RME before the pubertal peak in skeletal maturation (group I T) and after the pubertal peak in skeletal maturation (group II T) as assessed by the CVM method. Franchi and Baccetti[23] and Franchi et al[13] detected the greatest increment in mandibular and craniofacial growth during the interval from stage 3 to stage 4.

RME produced a significant increase in MCA of the nasal cavity in both group I T and group II T just after treatment (T_1–T_2). Evaluation of the overall changes (T_1–T_3) revealed that in both group I T and group II T, RME produced an statistically significant increase of 0.34 cm^2 (*P*

< .05) and 0.19 cm^2 ($P < .05$), and a significant gain over the controls of 0.26 cm^2 ($P < .05$) and 0.17 cm^2 ($P < .05$) in MCA, respectively. Although the increase in MCA was greater in group I T, the difference was not statistically significantly greater ($P > .05$).

The RME treatment is able to induce more pronounced transverse craniofacial changes at the skeletal level when the subjects were treated before the peak in skeletal maturation. The rationale of RME, as a treatment modality for skeletal correction of maxillary transverse narrowness, has been reported many times.[1–4,8] The positive changes in respiratory physiology are the benefits of this treatment.[3,6,7] Hershey et al[6] noted that "data from our investigation indicate that RME does provide a 45% reduction of nasal resistance as well as significant widening of nasal passages." Also, other investigators have reported that RME reduces nasal airway resistance[1,3,6,7] and increases the nasal cross-sectional area.[3] The results of two studies[3,6] showed a significant negative correlation because the increase in MCA and reduced nasal resistance was similar at 45% after RME treatment.

RME apparently alters the nasal valve area, which, in the normal nose, presents the smallest nasal cross-sectional area and provides the most significant nasal airway resistance during breathing. The nasal valve lies obliquely in the sagittal plane and in the region between the caudal end of the upper lateral cartilage, the septum, and the inferior rim of the periform aperture, just beyond the anterior ends of the inferior turbinates. Nasal airway resistance is affected mostly by the anterior segment of the nasal cavity, where the narrowest segment (nasal valve) is located. By rhinomanometric evaluation, a small change in the valve region causes a disproportionately large change in nasal resistance. Large changes in the posterior part of the nasal cavity cause disproportionately small changes in nasal resistance.[24]

AR can provide reliable data for only five cm from the nostrils because of the presence of the paranasal sinuses in the posterior part of the nose, which constitute a distal source of measurement error.[25,26] In the present study, the AR-calculated distance from the nostril to the nasal valve area ranged from 1.41 to 2.2 cm. Clinical studies on human subjects have documented significant correlations between MCA in the anterior part of the nasal cavity measured by various imaging modalities (MRI, CT) and AR.[27,28] A recent study indicated that the nasal valve area could be accurately assessed with AR, and the AR findings were significantly correlated with CT findings.[29]

AR has been used for characterizing the geometry of the nasal cavity for assessing the dimensions of nasal obstructions and the cross-sectional area at any distance from the nostril can be measured directly. AR provides a minimally invasive, convenient, and accurate method to measure the dimensions of the nasal airway.[15]

In the present study, the relapse tendencies were also evaluated. After the retention period (T_2–T_3), the increase in MCA in group I T remained almost stable ($P > .05$) and in group II T, MCA showed a statistically significant reduction ($P < .05$). This possibly means that in older patients the rigidity of articular bones to the midpalatal suture negatively affects the stability of the increase in MCA after RME. Wertz and Dreskin[30] also noted greater and more stable orthopedic changes in patients under the age of 12 years. However, surprisingly, this difference between groups I T and II T was not statistically significant ($P > .05$).

The use of vasoconstrictive nose drops was advocated by Linder-Aronson and Backstrom[31] to lessen the effect of mucosal swelling mainly at the anterior aspect of the inferior turbinates. This was recommended to give a better indication of the effect of the bony structures of the nasal cavity on nasal resistance. Linder-Aronson and Aschan[7] found a significant decrease in nasal resistance after expansion when recording nasal resistance with a nasal decongestant. In their view, maxillary expansion normalized the anatomic condition of the nose by decreasing soft-tissue influences and improving "nasal function" to a normal range.

The traditional explanation for the influence of RME on nasal resistance is on the basis of the lateral separation of the walls of the nasal cavity, which occurs concurrently with dental arch expansion. Increasing the distance between the lateral walls of the nasal cavity and the nasal septum may decrease nasal resistance by enlarging the cross-sectional area of the nasal passage to facilitate breathing.[32]

CONCLUSIONS Return to TOC

The effect of RME on MCA of the nasal cavity was evaluated with AR in two groups of subjects. Although not statistically significant, patients treated before the pubertal peak exhibit more increase in MCA and the increase remained more stable. Besides expanding the maxilla, RME is effective in increasing MCA in nasal cavity, which is highly responsible for nasal resistance in both patients treated before the pubertal peak and after the pubertal growth spurt.

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TABLES Return to TOC

TABLE 1. Comparison of T_1, T_2, and T_3 Mean MCA Values (mm^2) of Group I T and Group II T[a]

	MCA			
	Group I T[b] (Early-treated)		Group II T[c] (Late-treated)	
	Mean	SD	Mean	SD
T_1	2.01	0.61	2.17	0.5
T_2	2.42	0.53	2.52	0.57
T_3	2.35	0.54	2.36	0.5

[a] T_1 indicates before treatment; T_2, after expansion; T_3, immediately after a three-month retention period; MCA, minimum cross-sectional area; and SD, standard deviation.
[b] The difference between T_2–T_1 and T_3–T_1 in mean MCA in group I T was statistically significant (P = .000; $P < .05$). The difference between T_3–T_2 was not statistically significant (P = .068; $P > .05$).
[c] The difference between T_2–T_1, T_3–T_2, and T_3–T_1 in mean MCA in group II T was statistically significant (P = .000; $P < .05$).

TABLE 2. Comparisons of Pre- and Posttreatment, Posttreatment and Postretention, and Pretreatment and Postretention MCA Values (mm^2) Between the Groups[a]

	MCA					
	Difference Between Pre- and Posttreatment (T_2–T_1)[b]		Difference Between Posttreatment and Postretention (T_3–T_2)[c]		Difference Between Pretreatment and Postretention (T_3–T_1)[d]	
	Mean	SD	Mean	SD	Mean	SD
Group I T (Early-treated)	0.41	0.28	−0.06	0.21	0.34	0.26
Group II T (Late-treated)	0.34	0.17	−0.15	0.17	0.19	0.16

[a] MCA indicates minimum cross-sectional area; T_1, before treatment; T_2, after expansion; T_3, immediately after a three-month retention period; and SD, standard deviation.
[b] The difference between pre- and posttreatment in mean MCA between the group I T and group II T (P = .758) was not statistically significant ($P > .05$).
[c] The difference between posttreatment and postretention in mean MCA between the group I T and group II T (P = .262) was not statistically significant ($P > .05$).
[d] The difference between pretreatment and postretention in mean MCA between the group I T and group II T (P = .069) was not statistically significant ($P > .05$).

TABLE 3. Comparisons of Pretreatment and Postretention MCA Values (mm^2) Between the Treated Groups and Controls[a]

	MCA, Difference Between Pretreatment and Postretention (T_3–T_1)	
	Mean	SD
Group I T[b] (Early-treated)	0.34	0.26
Group I C (Early-control)	0.08	0.10
Group II T[c] (Late-treated)	0.19	0.16
Group II C (Late-control)	0.02	0.03

[a] MCA indicates minimum cross-sectional area; T_3, immediately after a three-month retention period; T_1, before treatment; and SD, standard deviation.

[b] The difference between pretreatment and postretention in mean MCA between the group I T and group I C (P = .006) was statistically significant ($P < .05$).

[c] The difference between pretreatment and postretention in mean MCA between the group II T and group II C (P = .009) was statistically significant ($P < .05$).

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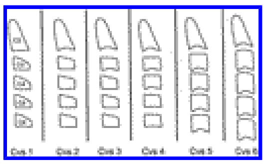

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FIGURE 1. Stages of cervical vertebral maturation. Stage 1: all inferior borders of the bodies are flat. The superior borders are strongly tapered from posterior to anterior. Stage 2: a concavity has developed in the inferior border of the second vertebra. The anterior vertical heights of the bodies have increased. Stage 3: a concavity has developed in the inferior border of the third vertebra. The other inferior borders are still flat. Stage 4: all bodies are now rectangular in shape. The concavity of the third vertebra has increased, and a distinct concavity has developed on the fourth vertebra. Concavities on fifth and sixth are just beginning to form. Stage 5: the bodies have become nearly square in shape, and the spaces between the bodies are visibly smaller. Concavities are well defined on all six bodies. Stage 6: all bodies have increased in vertical height and are higher than they are wider. All concavities have deepened

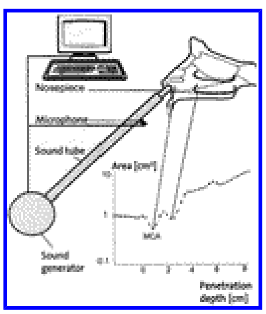

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FIGURE 2. Acoustic rhinometry device and diagram

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