Changes in Nasopharyngeal Airway Following Orthopedic and Surgically Assisted Rapid Maxillary Expansion

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Introduction: The aim of this study was to compare changes in soft-palate morphology and nasopharyngeal relations after orthopedic rapid maxillary expansion (RME) and surgically assisted RME (SARME).

Methods: A group of 10 patients received RME, a second group of 10 patients received SARME, and a third group of 10 patients served as an untreated control group. Lateral and posteroanterior cephalograms were obtained for each individual at preexpansion/precontrol and postexpansion/postcontrol. In addition to descriptive parameters, the angulation, length, and thickness of the soft palate and superior and inferior pharyngeal spaces and the ratios of the length of the soft palate to the length of the superior and inferior pharyngeal spaces were evaluated. Paired *t*-tests were performed to analyze changes within groups, and analysis of variance and Duncan tests were used to compare changes among groups.

Results: No statistically significant differences were found in changes in measurements related to soft-palate morphology or nasopharyngeal dimensions among the SARME, RME, and control groups; however, increases in soft-palate angulation and superior and inferior pharyngeal spaces after expansion/control were greater in the SARME group than in other groups.

Conclusions: No statistically significant differences were found between changes in the nasopharyngeal airway after RME and SARME.

Key Words: Rapid maxillary expansion surgically assisted rapid maxillary expansion, nasopharyngeal airway

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Rapid maxillary expansion (RME) as a treatment for respiratory disturbances was first proposed by Angell[1] in the 19th century. Since its reintroduction by Haas[2] in 1961, it has become a common treatment modality for the correction of maxillary transverse deficiency in younger patients. Although not explicitly stated, both these classic studies point to the fact that maxillary constriction inevitably sets in motion a chain reaction between respiration and craniofacial morphologic development (Fig. 1).[3]

Cycle of Respiration and Craniofacial Development

Rapid maxillary expansion generates high forces on various structures in the craniofacial complex. As a child matures, the amount of force required to achieve expansion increases, and less skeletal expansion and more dental tipping occur.[4] For adult patients, surgically assisted RME (SARME), which offers more parallel expanded maxillary bony segments for expansion, is required.[5] The increase in segments with SARME raises the possibility that it might also be more effective than RME in increasing nasopharyngeal dimensions.

The objective of the current study was to define and compare the changes in nasopharyngeal airway and soft-palate dimensions in patients treated by orthopedic RME and those treated by SARME.

SUBJECTS AND METHODS

Subjects

This study examined lateral cephalometric radiographs from 30 subjects (Table 1). Twenty subjects were patients at the Ankara University Faculty of Dentistry, and 10 subjects were randomly selected from the faculty's longitudinal archives as controls. Inclusion criteria for the maxillary expansion groups were (1) presence of posterior bilateral crossbite with skeletal involvement, (2) no future orthognathic surgery required, and (3) no preexpansion orthodontics applied.

The RME group was composed of 10 patients (6 males, 4 females) with a mean age of 15.51 years (range, 13.33–17.58 years) and a minimum skeletal age of 15 years, according to Greulich-Pyle hand-wrist analysis.[6] The SARME group was composed of 10 patients (7 males, 3 females) with a mean age of 19.01 years (range, 16.25–25.58 years) and a minimum skeletal age of 17 years, according to Greulich-Pyle hand-wrist analysis.[6] Of the 10 patients in the SARME group, 6 patients were older than 17 years, and 4 patients were 17 years or younger. The latter 4 were initially treated by RME, but their treatment was continued with surgical assistance because of discomfort, pain, and resistance to expansion. Patients in the RME group had completed 99.2% (minimum: 98.61%, maximum: 99.8%) of their growth potential, and patients in the SARME group had completed 99.51% (minimum: 99.1%, maximum: 100%) of their growth potential.[6] In addition, a control group was composed of 10 untreated subjects (6 males, 4 females) matched to the RME group for sex and age (Table 1) to assess the effects of nasopharyngeal growth over a 1-year follow-up period. (Because

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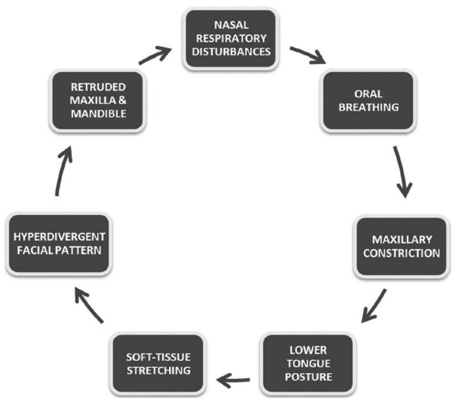

FIGURE 1. Cycle of respiration and craniofacial development.

growth of the airway is complete at approximately 15 years of age,[7] controls were not required for the SARME group.) The same type of expansion appliance and surgical procedure was used in all cases (Fig. 1).

Rapid Maxillary Expansion

An occlusal-coverage Hyrax-type palatal expander was used to eliminate premature contacts during expansion. After bonding of the appliances, patients and their parents were instructed to activate the screws 1 full turn in the morning and 1 full turn in the evening (1 turn = 0.25 mm).

Surgically Assisted RME

Subjects in this group also received occlusal-coverage Hyrax-type palatal expanders. Surgery was performed under local anesthesia. Bilateral incisions were made at the depth of the vestibule from the first molar area to the distal aspect of the lateral incisor. The mucoperiosteum was elevated, and the maxillary bone exposed from the piriform aperture to the pterygomaxillary fissure. After identifying the infraorbital nerve, an osteotomy was performed horizontally from the piriform aperture to the pterygomaxillary fissure well above the teeth apices. The pterygoid plates were not separated from the maxilla. An additional vertical incision was made parallel to the labial frenulum, and the maxilla was separated by malleting a thin osteotome between the central incisors at a level below the anterior nasal spine. The surgical sites were irrigated and sutured. An anterior nasal pack and pressure bandage were applied to patients for 24 hours, and antibiotics, analgesics, and oroantral regimen were prescribed.

Screws were activated immediately after bonding in the RME group and after surgery in the SARME group. For both groups, activation consisted of 2 turns per day and was performed for 2 to 3 weeks until the necessary amount of expansion was achieved. Upon completion of expansion, appliances were left in place for 12 weeks. At the end of the 12-week postexpansion period (T_2), the appliances were removed and replaced by transpalatal arches for the remainder of the conventional orthodontic treatment period.

TABLE 1. Mean, SE, Minimum, and Maximum Values of the Ages of the Subjects in SARME, RME, and Control Groups

			Chronological Age (Year)			
Groups		**n**	**Mean**	**SE**	**Minimum**	**Maximum**
SARME	10	Female: 7 Male: 3	19.01	1.22	16.25	25.58
RME	10	Female: 6 Male: 4	15.51	1.09	13.33	17.58
Control	10	Female: 6 Male: 4	15.27	1.43	13.42	17.00

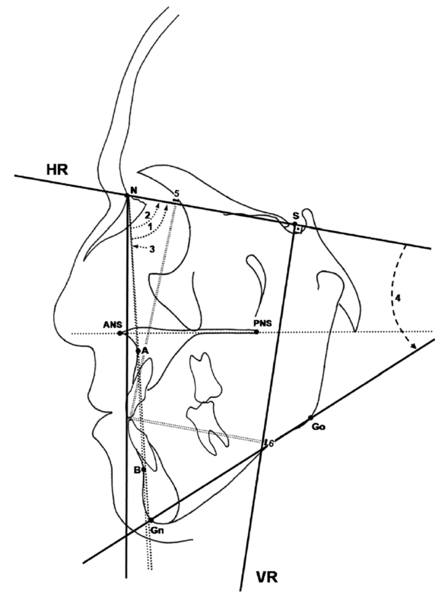

FIGURE 2. Skeletal and dentoalveolar measurements: 1: SNA; 2: SNB; 3: ANB; 4: SN/GoGn; 5: overjet; 6: overbite.

Cephalometric Evaluation

Preexpansion/precontrol (T_1) and postexpansion/postcontrol (T_2) lateral cephalometric radiographs and hand-wrist films were

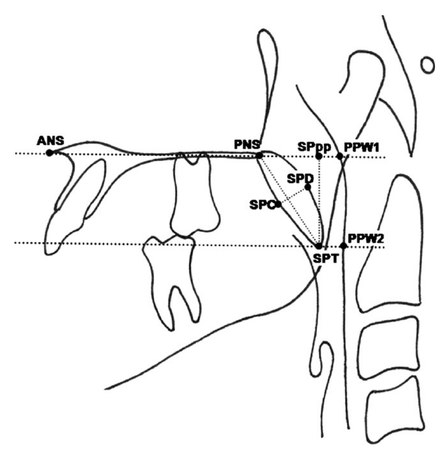

FIGURE 3. Soft palate and nasopharyngeal airway landmarks: ANS (anterior nasal spine), PNS (posterior nasal spine), SPT (soft-palate tip), SPC (soft-palate center), SPD (soft-palate dorsum), SPpp (intersection point of the perpendicular line drawn from the SPT to the palatal plane [ANS-PNS]), PPW1 (posterior pharyngeal wall 1—intersection point of the palatal plane at the posterior pharyngeal wall), PPW2 (posterior pharyngeal wall 2—intersection point of the plane parallel to the palatal plane drawn from the SPT to the posterior pharyngeal wall).

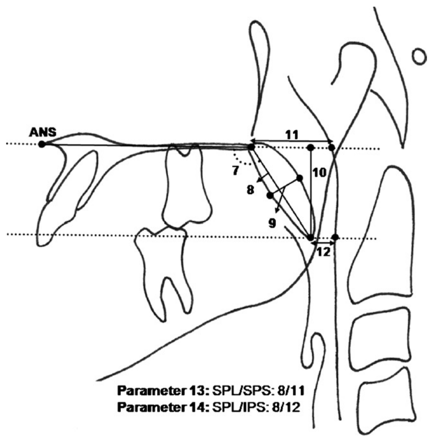

FIGURE 4. Soft palate and nasopharyngeal airway measurements: 7: ANS.PNS.SPT (soft-palate angulation); 8: PNS-SPT (SPL-soft palate length); 9:SPC-SPD (soft-palate thickness); 10: SPT-SPpp (soft-palate height); 11: PNS-PPW1 (SPS-superior pharyngeal space); 12: SPT-PPW2 (IPS-inferior pharyngeal space); 13: SPL/SPS (ratio between soft-palate length and superior pharyngeal space); 14: SPL/IPS (ratio between soft-palate length and inferior pharyngeal space).

obtained from all patients. Occlusal films were also obtained from patients in the expansion groups and were used to supplement information from hand-wrist films to place patients into the appropriate study group. Craniofacial (Fig. 2) and nasopharyngeal (Figs. 3 and 4) measurements were performed on lateral cephalometric radiographs at T_1 and T_2 for all patients.

Statistics

Mean values and SEs were calculated and used to compare linear changes both within and among groups. Analysis of variance was used to compare measurements at T_1 among groups (Table 2), paired *t*-tests were performed to evaluate changes from T_1 toT_2 within each group (Table 3), and Duncan tests were performed to compare changes among groups from T_1 toT_2 (Table 3).

Error Study

All cephalograms were traced and retraced 1 month later by the same examiner. No significant differences between the 2 series were found, and the reliability coefficients (*r*) ranged between 0.93 and 0.98.

RESULTS

Differences in preexpansion/precontrol values among SARME, RME, and control groups are presented in Table 2.

Preexpansion Versus Postexpansion (T_1 and T_2): SARME Group

A significant decrease was observed in SNB (−0.93 degrees; $P < 0.05$), possibly related to the significant increase observed in SN/GoGn (0.77 degrees; $P < 0.05$) (Table 3).

TABLE 2. Comparison of SARME, RME, and Control Groups at T_1 (Preexpansion/Precontrol) by Analysis of Variance and Duncan Tests

Parameters		SARME D	SARME SD	RME D	RME SD	Control D	Control SD	Test	SARME vs RME	RME vs Control	SARME vs Control
Maxilla											
SNA	deg	75.28	0.94	74.57	0.96	80.77	3.32	*		*	*
Mandible											
SNB	deg	75.20	1.32	77.56	1.07	77.97	2.36				
Maxillomandibular relations											
ANB	deg	0.08	0.67	−2.98	1.30	2.80	1.94	†	†	†	†
SN/GoGn	deg	42.80	1.32	41.90	1.08	31.46	3.58	‡		‡	‡
Overjet	mm	1.92	0.82	−1.82	1.67	3.01	1.64	†	†	†	
Overbite	mm	−1.61	1.48	1.15	0.52	1.85	1.98	†	†		†
Soft palate											
ANS-PNS/SPT	deg	123.69	9.59	128.22	5.02	129.27	5.68				
PNS-SPT	mm	33.18	4.24	33.12	2.41	33.30	5.17				
SPC-SPD	mm	8.65	2.79	8.57	1.37	8.01	1.38				
Nasopharyngeal airway											
SPT-SPpp	mm	27.13	4.52	25.71	2.35	25.36	3.99				
PNS-PPW1	mm	20.69	7.28	20.11	5.11	23.31	2.86				
SPT-PPW2	mm	12.25	3.36	10.55	2.06	9.02	2.56	*			*
SPL/SPS	%	1.86	0.85	1.78	0.57	1.43	0.15				
SPL/IPS	%	2.95	1.09	3.30	0.89	4.24	2.32				

*$P < 0.05$.
†$P < 0.01$.
‡$P < 0.001$.
D indicates of differences; deg, degrees; SPL, soft-palate length; IPS, inferior pharyngeal space.

TABLE 3. Comparison of the Changes Occurred in SARME, RME, and Control Groups by During Expansion/Observation Periods by Analysis of Variance and Duncan Tests

		SARME		RME		Control			SARME vs RME	RME vs Control	SARME vs Control
Parameters		**D**	**SD**	**D**	**SD**	**D**	**SD**	**Test**			
Maxilla											
SNA	deg	0.18	0.36	2.18*	0.67	0.56	1.61	*	*	*	
Mandible											
SNB	deg	−0.93*	0.34	0.52	0.34	0.67	1.38	*	*		*
Maxillomandibular relations											
ANB	deg	1.11	0.59	1.66*	0.50	−0.11	0.77				
SN/GoGn	deg	0.77*	1.58	0.32	1.63	−0.79	1.84				
Overjet	mm	0.26	0.42	1.64*	0.56	−0.38	0.72	†		†	
Overbite	mm	1.51	1.07	0.42	0.60	−0.14	1.12				
Soft palate											
ANS-PNS/SPT	deg	3.41	7.54	−0.84	6.44	−0.08	4.28				
PNS-SPT	mm	−0.85	7.12	−1.20	3.03	1.57	3.52				
SPC-SPD	mm	0.07	2.05	−0.03	1.24	0.32	1.40				
Nasopharyngeal airway											
SPT-SPpp	mm	−1.09	5.79	−0.71	3.16	1.37	3.97				
PNS-PPW1	mm	2.36	4.06	−0.56	2.93	0.55	2.68				
SPT-PPW2	mm	1.07	4.69	0.65	1.28	−0.32	2.41				
SPL/SPS	%	0.41	0.72	0.01	0.26	0.04	0.20				
SPL/IPS	%	−0.26	1.17	−0.32	0.70	0.06	1.67				

Paired *t*-tests were also performed to analyze changes within the groups.
*$P < 0.05$.
†$P < 0.01$.
D indicates of differences; deg, degrees.

Preexpansion Versus Postexpansion (T_1 and T_2): RME Group

Significant increases were observed in SNA (2.18 degrees; $P < 0.05$) and ANB (1.66 degrees; $P < 0.05$). Overjet (initially negative) increased significantly (1.64 mm; $P < 0.05$) (Table 3).

Precontrol Versus Postcontrol (T_1 and T_2): Control Group

No statistically significant changes were observed in any of the parameters in the control group during the observation period (Table 3).

Comparison of Changes Among SARME, RME, and Control Groups

A comparison of changes occurring over the expansion/observation periods among the RME, SARME and control groups is presented in Table 3. No statistically significant differences in measurements related to soft-palate morphology or nasopharyngeal dimensions were observed among the SARME, RME, and control groups; however, increases in soft-palate angulation (anterior nasal spine [ANS]–posterior nasal spine [PNS]/soft-palate tip [SPT]) and in superior (PNS–posterior pharyngeal wall 1 [intersection point of the palatal plane at the posterior pharyngeal wall, PPW1]) and inferior (SPT–posterior pharyngeal wall 2 [intersection point of the plane parallel to the palatal plane drawn from the SPT to the posterior pharyngeal wall, PPW2]) pharyngeal areas were greater in the SARME group than in the RME and control groups.

When craniofacial descriptive measurements were examined, significant differences were found in the changes in SNA, SNB, and overjet among the 3 groups as a result of the significant increase in SNA in the RME group (2.18 degrees; $P < 0.05$) and the significant decrease in SNB in the SARME group (−0.93 degrees; $P < 0.05$). A statistically significant difference was observed between the RME and control groups ($P < 0.01$) in the amount of change in overjet, which increased significantly in the RME group (1.64 mm; $P < 0.05$) and decreased significantly (−0.38 mm) in the control group.

DISCUSSION

Most long-faced individuals possess craniofacial characteristics that include excessive anterior face height, incompetent lip posture, posterior crossbite, increased vertical dimensions, a steep mandibular plane and narrow external nares caused by postural habits, and oral breathing secondary to obstruction of the nasal airway or damage to the central or peripheral nervous system.[8] It has been suggested that long-faced individuals experience nasal airflow resistance and are candidates for respiratory disturbances.[8,9] Although the retrospective nature of the current study precluded the possibility of determining whether the subjects were oral breathers or experienced respiratory disturbances, patients in both RME and SARME treatment groups had 2 significant features: posterior crossbites and increased SN/GoGn values (RME: 41.90 degrees, SARME: 42.80 degrees; Table 2).

It has previously been suggested that maxillary constriction leads to nasal valve narrowing and increased nasal resistance.[10] It has also been shown that, in cases with severe maxillary constriction, the space required to accommodate the tongue close to the roof of the palate is inadequate and tongue posture is lower than desirable.[11] Individuals with a combination of such significant findings are likely to experience a paradigm called "soft-tissue stretching" hypothesis, which leads to increased facial height.[3]

The relationship between nasal airway resistance and the use of RME appliances remains controversial. Most studies have found decreases in nasal airway resistance after treatment with expansion appliances; however, individual variations in treatment response[7] and the unpredictability of treatment results have also been noted.[12] Surgically assisted RME, which offers greater expansion of the maxillary halves, may be superior to RME in increasing nasopharyngeal airway dimensions, which may in turn decrease nasal resistance. Therefore, the current study aimed to evaluate the increases in nasopharyngeal airway dimensions after RME and SARME.

A number of different methods have been used to monitor and record soft-palate function and development. Radiographic cephalometry has proved to be a common and cost-effective method for obtaining quantitative information related to the changes in the soft-palate and nasopharyngeal area following any therapeutic approach.[13] In the current study, lateral cephalometric radiographs were used to evaluate changes in soft-palate morphology and nasopharyngeal airway dimensions.

In their study investigating nasal airway changes after SARME using a series of transnasal acoustic measurements, Kunkel et al[14] recorded striking improvements in nasal patency in 6 of 8 patients after expansion. The authors also reported a significant widening of the posterior nasal cavity and translational pattern of maxillary movement, even without separation of the pterygomaxillary junction.

In the current study, SNA and ANB showed statistically significant increases in the RME group and slight increases in the SARME group (Table 3). Repositioning of the maxilla, as indicated here by the change in SNA, is an important indicator of changes in the superior pharyngeal space (PNS-PPW1). Haas,[2] Davis and Kronman,[15] and Chung et al[16] reported that point A moved forward in all cases where midpalatal expansion was applied. Biederman[17] offered 2 possible explanations for the biomechanics of RPE in the horizontal plane. On the one hand, if the center of rotation of the maxillary halves is located anywhere along the midline, the halves would move laterally and posteriorly, which would require resorption of the posterior margins of the maxillary halves. As a part of this hypothesis, point A would also show posterior movement. On the other hand, if the center of rotation is located at the posterior-lateral part of the maxillary halves, the separated halves would be pushed forward, which would also result in the advancement of Point A. The second hypothesis is in accordance with the RPE findings of the current study. In the sagittal dimensions, point A moved forward significantly, whereas the correlated forward movement of the posterior nasal spina (PNS) was overshadowed by the rotation of the maxillary halves (Table 3), resulting in a slight decrease in the superior nasopharyngeal space (−0.56 mm; PNS-PPW1). In contrast, in the SARME group, the SNA remained almost unchanged, and the superior nasopharyngeal space increased (2.36 mm; PNS-PPW1). This finding could be explained by a less rotational and more favorable lateral movement of the maxillary halves that may have occurred as a result of the surgical procedure.[9]

In their evaluation of oropharynx soft-tissue growth, Taylor et al[18] observed an increase in PNS-PPW1 with growth. They also found 2 periods of accelerated change (6–9 and 12–15 years) and 2 periods of quiescence (9–12 and 15–18 years) in pharyngeal soft tissue. In the current study, no statistically significant changes were observed in superior nasopharyngeal airway space (PNS-PPW1) or inferior nasopharyngeal airway space (SPT-PPW2) for either the RME or SARME group; however, the increase in nasopharyngeal airway space was greater in the SARME group. In both groups, the amount of change varied significantly among individual patients (Table 3; SDs).

Soft-palate dimensions and their dynamic relationship with the pharyngeal airway space play an important role in swallowing, respiration, phonation, and velopharyngeal closure. The velopharyngeal closure mechanism functions to control nasal airflow, and disorders in that mechanism may cause phonation problems.[19,20] Stellzig-Eisenhauer[21] reported that the ratio of the soft palate to sagittal depth of the nasopharyngeal airway plays a very important role in the resonance of speech. Subtelny[22] described the ratio of the soft palate to pharyngeal space as the "need ratio." In the current study, there were no significant changes in positional and linear measurements of the soft palate (ANS-PNS/SPT, PNS-SPT, soft-palate center [SPC]–SPD [soft-palate dorsum], and SPT-SPpp) after expansion in either the RME or SARME group. Akcam et al[19] emphasized the importance of the stability of the ratio of the soft palate to pharyngeal space in preventing speech disorders, and the authors recommended avoiding any treatment plan that might disturb this balance.[22]

In the current study, the mean ANB in the RME group was −2.98 ± 1.30, indicating skeletal class III malocclusion, whereas the ANB in the SARME group was 0.08 ± 0.67, indicating a class III tendency. Articulatory speech disorders are frequently observed in severe skeletal class III patients.[23] To avoid posttreatment speech problems, the dimensions of the soft palate and its functional relations with surrounding structures should be examined in detail during treatment planning of skeletal class III patients, particularly in the case of orthopedic treatment involving the maxilla.[19] The present study did not show any statistically significant changes in soft-palate dimensions after either RME or SARME, suggesting that both procedures are appropriate for maxillary expansion in class III patients.

CONCLUSIONS

No statistically significant differences were found between changes in the nasopharyngeal airway after RME and SARME. Increases in superior (PNS-PPW1) and inferior (SPT-PPW2) pharyngeal spaces were greater in the SARME group when compared with the RME and control groups. This could be due to a reduction in resistance of the nasomaxillary and pterygomaxillary complexes as a result of the surgical intervention in the SARME patients. Although SARME seems to be beneficial in patients with respiratory disturbances, variations between patients and unpredictability of results need to be taken into consideration.

Changes in airflow are not significant enough to warrant the use of maxillary expansion for the primary purpose of improving airflow. Neither RME nor SARME was found to have a significant effect onsoft-palate dimensions, which suggests that neither procedure is likely to result in speech problems.

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