eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2023; 57(1): 28-35

Original research

Does the face mask increase the impact of rapid maxillary expansion on sagittal airway dimensions?

Muhsin Cifter[1],
Ozge Ekmen[2],
Asuman Deniz Gumru Celikel[1],
Beyza Tagrikulu[1],
Elif Erbay[2]

Purpose
Airway dimensions associated with the transversal and sagittal position of the maxilla are affected by orthodontic treatment. The objective of this study was to compare the effects of rapid maxillary expansion (RME) and RME followed by face mask (FM) therapies on the airway space and investigate whether application of the FM increases the short-term and long- term impact of RME on sagittal airway dimensions.

Materials and Methods
A total of 26 patients were divided into two groups. Group I included 14 adolescents treated with RME (3 males, 11 females; mean age: 12.2 11 ± 2.1 years), and Group II included 12 adolescents treated with RME followed by FM therapy (7 males, 5 females; mean age: 11.6 ± 1.3 years). Sagittal and vertical skeletal measurements, as well as ten linear cross-sectional airway measurements, were calculated from pretreatment, posttreatment, and postretention cephalometric radiographs.

Results
RME followed by FM resulted in a significant increase in the SNA angle, ANB angle, and Wits parameter by the forward movement of the maxillary bone. A significant increase in the vertical dimensions was also observed. Regarding the airway measurements in both groups, significant oropharyngeal increases were revealed, and these were maintained in the follow-up period. However, there were no other significant differences in the short-term and long-term results obtained for Groups I and II.

Conclusion
The dimensions of the airway were significantly affected by both therapies. However, no additional effect of FM was observed.

Keywords: *Airway, expansion, bonded RME, face mask, long term*

Introduction

Orthodontic procedures that have an impact on facial growth patterns and skeletal structures are likely to affect airway dimensions as well (1). In particular, mandibular advancement, maxillary expansion, and maxillary protraction represent principle interventions that affect the pharyngeal airway (2, 3, 4).

Rapid maxillary expansion (RME) is commonly used for the correction of maxillary constriction and posterior cross-bite. Expansion of the maxilla with RME has been associated with positive effects on the airway and septal deformity, thereby reducing the risk of recurrent ear or nasal infections (5-7). Orthopedic maxillary expansion has also been shown to improve respiratory functions (5, 7, 8-11), while RME is an effective treatment modality for pediatric obstructive sleep apnea (12).

ORCID IDs of the authors: M.C. 0000-0002-6914-0496; O.E. 0000-0002-4407-1631; A.D.G.C. 0000-0003-3450-6643; B.T. 0000-0002-8106-6364; E.E. 0000-0003-3789-7141

[1]Department of Orthodontics, Faculty of Dentistry, Istanbul University, Istanbul, Turkiye

[2]Specialist Orthodontist, Istanbul, Turkiye

Corresponding Author: Asuman Deniz Gümrü Çelikel

E-mail: denizgumru@hotmail.com

Received: 21 November 2021
Revised: 5 March 2022
Accepted: 24 June 2022

DOI: 10.26650/eor.20231133640

How to cite: *Cifter M, Ekmen O, Gumru Celikel AD, Tagrikulu B, Erbay E. Does the face mask increase the impact of rapid maxillary expansion on sagittal airway dimensions? Eur Oral Res 2023; 57(1): 28-35. DOI: 10.26650/eor.20231133640*

Face mask (FM), an extraoral maxillary protraction device, has been used since 1960 to stimulate maxillary growth in the forward direction in growing children (13). The combination of RME and FM therapy can augment the protraction effect of FM therapy on the nasomaxillary complex.

The pharyngeal airway is closely related to the nasomaxillary complex, and the dimensions of the airway space can vary with FM therapy as a result of forward displacement of the maxilla, clockwise rotation of the mandible, and counterclockwise rotation of the palatal plane (14-20). However, while Kılınç *et al* (16) and Oktay and Ulukaya (17) have reported significant dimensional changes after extraoral maxillary protraction, Sayınsu *et al*. (15) and Kaygısız *et al*. (18) have observed significant changes only in the nasopharynx. In contrast, Baccetti *et al*. (21) and Mucedaro *et al*. (19) have reported no significant correlation between skeletal changes and airway changes.

A variety of imaging methods can be used to evaluate airway changes that are associated with these procedures. The most commonly used methods include cephalometric radiographs, traditional computed tomography, and cone-beam computed tomography. In addition to radiographic imaging techniques, medical techniques such as nasal endoscopy and acoustic rhinometry have also been used for this purpose. Each of these methods has their own advantages and limitations (10).

The specific effects of RME therapy with or without FM on airway dimensions has been the subject of considerable discussion in the literature. However, a comparison of these methods with regard to airway dimensions has not been reported. Thus, the purpose of this study was to compare the effect of RME with and without FM on airway dimensions and to investigate the hypothesis that a FM appliance increases both the short-term and long-term impact of RME on sagittal airway dimensions.

Material and Methods

Subjects

Lateral cephalograms were obtained from the records of 26 adolescents (16 girls, 10 boys) that were treated at the Department of Orthodontics, Faculty of Dentistry, Istanbul University, Turkey. The patients were subsequently allocated into two groups: Group 1 (RME) included 14 adolescents (3 boys, 11 girls) with a mean age of 12.2 ± 2.1 years. These patients presented with maxillary constriction and a bilateral or unilateral cross bite. This group received RME therapy with a bonded-type Hyrax appliance (Fig. 1). The activation protocol was two times a day for two weeks until the palatal cusps of the upper posterior teeth achieved an edge-to-edge position with the buccal cusps of the lower posterior teeth. Group 2 (RME + FM) included 12 adolescents (7 boys, 5 girls) with a mean age of 11.6 ± 1.3 years. These patients presented with skeletal Cl III deficiency with maxillary constriction. Treatment included a bonded-type Hyrax appliance in combination with a Petit-type FM appliance (Fig. 2). The FM appliance applied 6–7 N of force bilaterally for at least 16 h a day, with a direction of 40 degrees below the occlusal plane. This treatment was applied until a dental Angle Cl I canine and molar relationship was achieved.

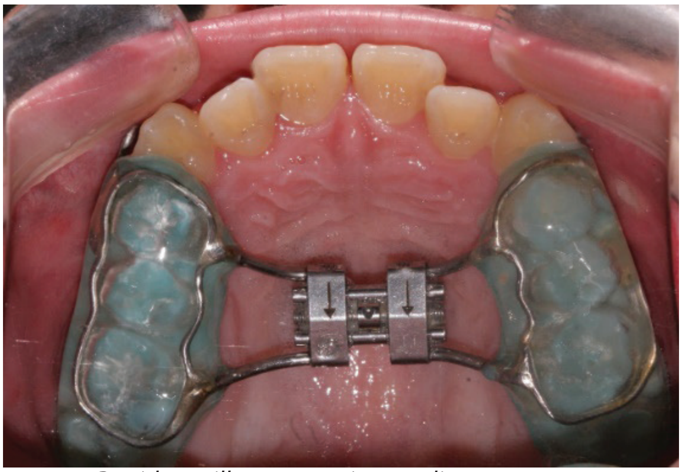

Figure 1. *Rapid maxillary expansion appliance.*

Figure 2. *Face mask appliance.*

Cephalometric analyses

Lateral cephalograms were obtained at three different time-points: before treatment (T1), after treatment (T2), and during the observation period after treatment (T3). For Group I, the total duration of the T1-T2 treatment period performed in two stages was 37.66 ± 14.29 months and the duration of the T3 period was 32.72 ± 14.98 months. For Group II, the total duration of the T1-T2 treatment period performed in two stages was 41.87 ± 11.93 months and the duration of the T3 period was 39.25 ± 20.22 months.

Skeletal measurements

Skeletal changes were evaluated by using sagittal and vertical measurements (Fig. 3).

Airway measurements

The reference lines and points used for the cephalometric tracings are shown in Figure 4. Two reference lines were constructed for the measurements as follows: S0 line passing through the anterior nasal spine and the posterior nasal spine; and N line, perpendicular to the S0 line and passing through the nasion. The airway was then divided into eleven cross-sections of equal thickness through lines parallel to S0 (S1-S10) from the superior level of the velopharynx to the level of the base of the epiglottis. To evaluate alterations in the airway space, linear distances from eleven different points on the N line to the posterior and anterior walls of the airway were measured and the differences between the posterior and anterior walls were assessed relative to the airway (22, 23).

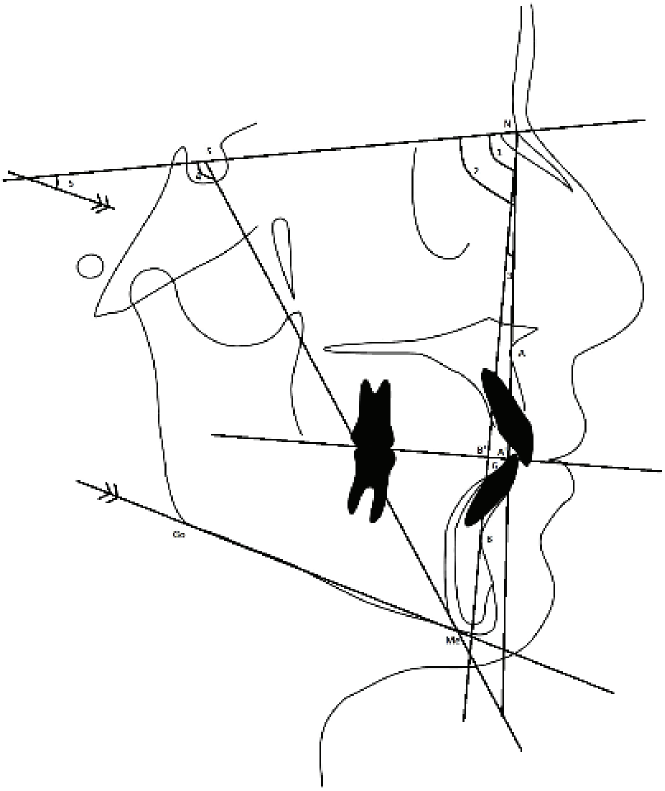

Figure 3. *Skeletal measurements: 1. SNB angle, 2. SNA angle, 3. ANB angle, 4. NSMe (Y) angle, 5. SN-GoMe angle, 6. Wits appraisal.*

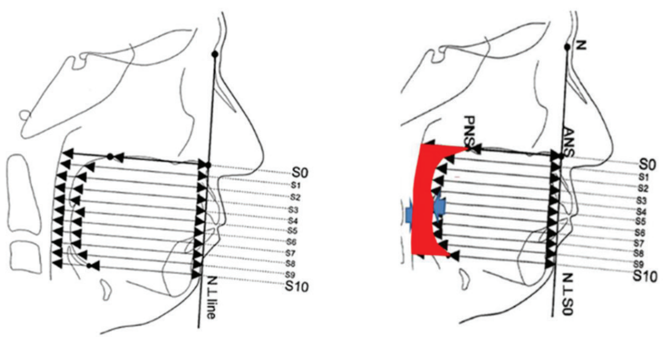

Figure 4. Airway measurements.

This study was approved by the Clinical Research Ethical Committee of Istanbul University, Faculty of Dentistry (19.10.2021/560).

Statistical analysis

For the statistical assessment of the study data, SPSS (Statistical Package for Social Sciences) 15.0 (SPSS Inc., Chicago, IL, USA) for Windows for Windows software was used. Conformity of the parameters to the normal distribution was assessed by the Kolmogorov–Smirnov test. In addition to descriptive statistical methods (mean, standard deviation), within-group and between-group comparisons of quantitative data were done. Analysis of variance for repeated measurements was used for within-group comparisons of parameters with normal distribution and Bonferroni test was used for the determination of the group responsible for the observed difference. For parameters without normal distribution, Friedman test was used for within-group comparisons and Wilcoxon sign test was used for the determination of the group causing the difference. Student t test and Mann-Whitney U tests were used for between-group comparisons of parameters with or without normal distribution, respectively. Significance was evaluated at a level of $p<0.05$.

Results

For Groups I and II, the mean skeletal and airway measurements for each group are listed in Tables 1–4. Comparisons of the treatment changes for both groups are listed in Table 5 and Table 6.

In Group 1, there were no significant changes in the skeletal measurements before and after treatment. However, the airway measurements significantly differed after treatment at levels S0, S2, S3, S4, S7, and S10. In Group 2, significant changes were observed in all of the skeletal measurements after treatment, except for the SNB angle. In addition, the airway measurements significantly differed at levels S0, S1, and S2 after treatment.

A comparison of the two groups identified significant changes in the skeletal measurements obtained. For Group I, only a statistically significant decrease in the SNA angle was observed during the retention period (T2-T3). However, for Group II, a statistically significant increase in the SNA angle was observed after treatment (T1-T2), while a statistically significant decrease in the SNA angle was observed during the retention period (T2-T3). The ANB angle and WITS parameter for Group II also exhibited statistically significant increases after treatment (T1-T2).

For the airway measurements, the only significant change observed after treatment (T1-T2) was at level S7. For Groups I and II, an increase versus a decrease at level S7 were observed, respectively.

Discussion

It is hypothesized that orthodontic treatments that enlarge the oral cavity and change the position of the tongue affect pharyngeal airway dimensions. For the therapeutic management of snoring and obstructive sleep apnea by orthodontists (12, 24, 25), the oropharyngeal airway is thought to be the most affected region. In the present study, cephalometric parameters were evaluated to examine skeletal and oropharyngeal airway changes in adolescents treated with RME or RME followed by FM therapy. Comparisons between these groups were also made to determine whether a FM induces any additional effects on airway dimensions.

RME is a commonly used method for maxillary constriction and is also a recommended procedure for

Table 1: *Skeletal measurements in RME group.*

RME	Skeletal T1 Mean±SD	Skeletal T2 Mean±SD	Skeletal T3 Mean±SD	+p	*T1-T2 ++p*	*T1-T3 ++p*	*T2-T3 ++p*
SNA	79,10±3,36	79,89±3,92	80,43±2,90	***0,416***	*1,000*	*0,534*	*1,000*
SNB	77,57±4,75	77,46±4,36	78,46±3,80	***0,254***	*1,000*	*1,000*	*0,272*
ANB	1,82±3,59	2,42±1,94	2,10±2,43	**0,621**	*1,000*	*1,000*	*1,000*
Wits	0,46±2,76 (1)	0,82±1,96 (1,5)	0,71±2,12 (1)	**•0,850**	*••0,929*	*••0,964*	*••0,564*
SN/GoMe	39,14±6,43	40,28±7,47	39,21±7,24	**0,177**	*0,885*	*1,000*	*0,178*
Y	71,03±5,26	72,14±5,05	72,07±5,03	**0,386**	*0,562*	*0,565*	*1,000*

*+ Repeated measures analysis of variance; ++ Bonferroni test; ·Friedman Test; •• Wilcoxon sign test; * p<0.05; ** p<0.01*

Table 2: *Airway measurements in RME group.*

RME	Airway T1 Mean±SD	Airway T2 Mean±SD	Airway T3 Mean±SD	+p	*T1-T2 ++p*	*T1-T3 ++p*	*T2-T3 ++p*
S0	18,00±4,09	20,60±4,26	20,71±4,35	**0,009****	*0,007***	*0,022**	*1,000*
S1	11,96±2,85	13,89±3,28	13,39±3,96	**0,082**	*0,071*	*0,451*	*1,000*
S2	9,14±2,66	10,35±2,69	10,03±2,89	**0,047***	*0,044**	*0,469*	*1,000*
S3	7,82±3,06	9,25±3,12	8,67±2,71	**0,025***	*0,018**	*0,328*	*0,864*
S4	8,28±4,27	9,71±4,65	9,10±5,03	**0,043***	*0,033**	*0,470*	*0,605*
S5	10,64±4,42	11,32±4,39	10,28±4,47	**0,058**	*0,056*	*1,000*	*0,415*
S6	9,71±4,25	11,00±4,42	9,92±4,25	**0,224**	*0,237*	*1,000*	*0,416*
S7	9,07±4,14	10,32±4,01	9,42±4,29	**0,023***	*0,015**	*1,000*	*0,588*
S8	9,75±3,61	10,35±3,88	9,25±3,98	**0,125**	*0,596*	*1,000*	*0,203*
S9	10,82±4,18	11,35±4,21	10,78±3,70	**0,646**	*1,000*	*1,000*	*1,000*
S10	14,35±4,93	15,67±4,77	15,82±5,00	**0,003****	*0,004***	*0,006***	*1,000*

*+ Repeated measures analysis of variance; ++ Bonferroni test; * p<0.05; ** p<0.01*

Table 3: *Skeletal measurements in RME&FM group.*

RME&FM	Skeletal T1 Mean±SD	Skeletal T2 Mean±SD	Skeletal T3 Mean±SD	+p	*T1-T2 ++p*	*T1-T3 ++p*	*T2-T3 ++p*
SNA	75,29±3,04	77,75±3,58	76,58±3,98	***0,001****	*0,001***	*0,313*	*0,151*
SNB	77,87±3,54	77,37±3,69	77,66±4,31	***0,451***	*0,939*	*1,000*	*1,000*
ANB	-2,58±2,97	0,37±1,49	-1,08±2,39	**0,001****	*0,001***	*0,461*	*0,067*
Wits	-4,25±2,92 (-3,5)	-1,25±2,59 (-0,5)	-2,25±2,70 (-1)	**•0,001****	*••0,002***	*••0,058*	*••0,136*
SN-GoMe	39,91±5,57	41,87±5,44	41,25±6,09	**0,015***	*0,012**	*0,468*	*1,000*
Y	70,33±3,17	72,75±3,96	72,16±4,40	**0,006****	*0,009***	*0,096*	*1,000*

*+ Repeated measures analysis of variance; ++ Bonferroni test; ·Friedman Test; •• Wilcoxon sign test; * p<0.05; ** p<0.01*

Table 4: *Airway measurements in RME&FM group.*

RME&FM	Airway T1	Airway T2	Airway T3	+p	*T1-T2 ++p*	*T1-T3 ++p*	*T2-T3 ++p*
	Mean±SD	Mean±SD	Mean±SD				
S0	15,29±4,20	19,54±4,37	20,50±3,63	**0,003****	*0,001***	*0,006***	*0,674*
S1	12,12±2,94	14,20±2,27	14,20±2,57	**0,018***	*0,013**	*0,030**	*1,000*
S2	10,33±2,37	12,29±2,22	11,83±1,980	**0,024***	*0,020**	*0,028**	*0,879*
S3	10,25±2,90	11,83±3,06	10,75±1,99	**0,059**	*0,056*	*0,890*	*0,336*
S4	10,20±2,78	12,95±3,45	12,25±2,93	**0,087**	*0,072*	*0,221*	*0,872*
S5	12,33±4,45	12,91±4,75	11,54±3,92	**0,379**	*1,000*	*1,000*	*0,465*
S6	11,75±3,95	11,25±4,45	10,41±4,56	**0,324**	*1,000*	*0,443*	*0,802*
S7	10,66±4,00	9,79±3,85	10,16±5,14	**0,365**	*0,897*	*1,000*	*1,000*
S8	10,83±5,05	10,29±3,74	10,16±4,97	**0,894**	*1,000*	*1,000*	*1,000*
S9	10,91±5,12	11,54±4,95	10,83±5,00	**0,558**	*1,000*	*1,000*	*0,852*
S10	15,29±6,13	15,83±6,93	16,33±7,64	**0,567**	*1,000*	*0,863*	*1,000*

*+ Repeated measures analysis of variance; ++ Bonferroni test; * p<0.05; ** p<0.01*

Table 5: *Comparision of the groups by skeletal measurements.*

		RME	RME&FM	+p
		Mean±SD	Mean±SD	
SNA	**T1-T2**	0,78±2,94 (0,75)	2,46±1,48 (2,75)	**0,046***
	T2-T3	0,53±2,25 (0)	-1,16±1,83 (-1)	**0,045***
	T1-T3	1,32±3,47 (0,5)	1,29±2,52 (0,75)	**0,917**
SNB	**T1-T2**	-0,10±3,02 (0,5)	-0,50±1,63 (-0,5)	**0,351**
	T2-T3	1,00±2,04 (0,5)	0,29±1,91 (0,75)	**0,714**
	T1-T3	0,89±3,53 (0,5)	-0,21±2,86 (0,25)	**0,437**
ANB	**T1-T2**	0,60±2,78 (0)	2,95±1,99 (2,5)	**0,011***
	T2-T3	-0,32±1,38 (0)	-1,45±1,90 (-2)	**0,064**
	T1-T3	0,28±2,68 (0)	1,50±3,39 (0,5)	**0,437**
Wits	**T1-T2**	0,35±2,70 (0)	3,00±1,75 (2)	**0,001****
	T2-T3	-0,10±0,65 (0)	-1,00±2,04 (-1)	**0,062**
	T1-T3	0,25±2,44 (0)	2,00±3,13 (1,5)	**0,091**
SN-GoMe	**T1-T2**	1,14±3,91 (1)	1,95±1,87 (2)	**0,380**
	T2-T3	-1,07±1,94 (-1)	-0,62±2,28 (-0,5)	**0,814**
	T1-T3	0,07±3,60 (1)	1,33±3,03 (0,5)	**0,587**
Y	**T1-T2**	1,10±2,97 (0)	2,41±2,20 (2)	**0,103**
	T2-T3	-0,07±2,12 (0)	-0,58±3,35 (-0,25)	**0,775**
	T1-T3	1,03±2,79 (0,75)	1,83±2,58 (2)	**0,621**

*+ Mann Whitney U test ; * p<0.05; ** p<0.01*

airway volume augmentation in the nasopharyngeal area (26). In a study by Cistulli *et al*. (27), RME improved obstructive sleep apnea due to maxillary constriction in 9/10 patients. Correspondingly, the apnea-hipopnea index value for these patients decreased from 19 to 7 per hour, and the total expansion achieved was 12.1 mm (27). In another study of 38 children that underwent maxillary expansion, Felippe *et al*. (8) observed an increase in both the palatal and nasal area and volume, concomitant with a decrease in nasal resistance. Similarly, Iwasaki *et al.* found a decrease in pharyngeal airway pressure during inspiration with the reduction of nasal resistance by the RME (28).

Measurements of the nasopharyngeal region have been reported. However, there are few studies that have investigated the effects of RME on the oropharyngeal region. Using three-dimensional measurements with computed tomography, Smith *et al*. (4) observed an increase in the volume of nasal cavity and nasopharynx, and a decrease in the volume of the oropharynx, following rapid maxillary expansion. In the present study, the dimensions of the superior oropharyngeal region increased at levels S0, S2, S3, and S4, and also increased in the inferior oropharyngeal region at levels S7 and S10, with RME. Moreover, these changes maintained in the long-term. The factors that may have contributed to the observed increase in the oropharyngeal dimensions include repositioning of the tongue and mandible due to expansion of the maxilla. Ribeiro *et al*. (11) also noted a significant change in the oropharynx after RME. However, there were inconsistencies in the acquisition of the measurements reported due to tongue posture, head inclination, and breathing and swallowing movements that were not standardized between patients (11).

Forward displacement of the maxilla and clockwise rotation of the mandible have been commonly reported after FM treatments (21, 29, 30). Examinations of pharyngeal airway changes after FM treatments have reported similar skeletal changes (16-18). The present results are consistent with both sets of findings, as statistically significant increases were observed in all of the skeletal parameters examined, except the SNB angle. Moreover, although long-term relapse was observed, it was not statistically significant.

Concerning the relationship between application of a FM and pharyngeal airway dimensions, varying results have been published. For example, Kaygısız *et al*. (18) reported an improvement in nasopharyngeal airway dimensions that was maintained over an extended period of time following

Table 6: *Comparision of the groups by airway measuraments.*

		RME	RME&FM	+p
		Mean±SD	Mean±SD	
S0	T1-T2	2,60±2,57 (1,75)	4,25±2,98 (4)	**0,147**
	T2-T3	0,10±1,33 (0)	0,95±2,58 (0)	**0,671**
	T1-T3	2,71±3,19 (1)	5,20±4,50 (4,5)	**0,097**
S1	T1-T2	1,92±2,82 (1)	2,08±2,00 (1,5)	**0,479**
	T2-T3	-0,50±2,48 (0)	0,00±1,70 (0)	**0,979**
	T1-T3	1,43±3,49 (1,5)	2,08±2,32 (2)	**0,586**
S2	T1-T2	1,21±1,61 (1)	1,95±2,03 (1,5)	**0,358**
	T2-T3	-0,32±1,99 (0)	-0,45±1,43 (-1)	**0,479**
	T1-T3	0,89±2,22 (1)	1,50±1,65 (1,75)	**0,421**
S3	T1-T2	1,43±1,62 (1,5)	1,58±1,91 (0,5)	**0,693**
	T2-T3	-0,57±1,93 (0)	-1,08±2,17 (0,75)	**0,466**
	T1-T3	0,86±1,86 (1)	0,50±1,58 (0)	**0,418**
S4	T1-T2	1,43±1,80 (1)	2,75±3,64 (2)	**0,272**
	T2-T3	-0,61±1,68 (0)	-0,70±2,21 (-1)	**0,450**
	T1-T3	0,82±2,04 (1)	2,04±3,57 (1)	**0,550**
S5	T1-T2	0,68±0,91 (0)	0,58±3,13 (0,25)	**0,654**
	T2-T3	-1,03±2,45 (0)	-1,37±3,12 (-1)	**0,716**
	T1-T3	-0,36±2,19 (0)	-0,79±3,10 (0)	**0,735**
S6	T1-T2	1,28±2,52 (0,25)	-0,50±3,00 (0)	**0,208**
	T2-T3	-1,07±2,54 (-0,5)	-0,83±2,47 (-0,5)	**0,917**
	T1-T3	0,21±1,23 (0)	-1,33±2,96 (0)	**0,244**
S7	T1-T2	1,25±1,38 (1,25)	-0,87±2,78 (0)	**0,047***
	T2-T3	-0,89±2,45 (0)	0,37±1,74 (0)	**0,250**
	T1-T3	0,35±2,29 (0,25)	-0,50±3,70 (0)	**0,660**
S8	T1-T2	0,60±1,68 (0,25)	-0,54±3,89 (0,25)	**0,659**
	T2-T3	-1,11±2,07 (0,25)	-0,12±2,24 (0)	**0,260**
	T1-T3	-0,50±2,55 (0)	-0,67±4,73 (-0,5)	**0,917**
S9	T1-T2	0,53±2,13 (0)	0,62±3,39 (0)	**0,936**
	T2-T3	-0,57±2,52 (0)	-0,71±2,17 (0)	**1,000**
	T1-T3	-0,03±2,00 (0)	-0,08±3,42 (0,5)	**0,677**
S10	T1-T2	1,32±1,23 (1)	0,54±2,82 (1)	**0,635**
	T2-T3	0,14±1,36 (0)	0,50±2,16 (0,25)	**0,715**
	T1-T3	1,46±1,42 (1,5)	1,04±3,22 (1,75)	**1,000**

*+ Mann Whitney U test; * p<0.05*

FM therapy. An increase in the oropharyngeal airway area was also observed, although the increase was not statistically significant at the end of treatment, yet a significant increase occurred during the follow-up period (18). Sayınsu *et al.* (15) and Cakırer *et al.* (31) also observed an increase in nasopharyngeal airway dimensions, yet an increase in the oropharyngeal dimensions were not observed. In the present study, only an increase in the superior oropharyngeal airway was observed at the level of S0, S1, and S2 in the RME + FM group, similar to the short-term findings reported by Kaygısız *et al.* (18) However, in contrast with the findings of Kaygısız *et al.* (18), the oropharyngeal measurements in the present study were maintained over the long-term interval monitored.

Between-group comparisons of skeletal measurements revealed statistically significant differences in the SNA angle, the ANB angle, and Wits appraisal. The vertical measurements also increased for the RME + FM group, yet the increase was not statistically significant. In terms of airway dimensions, the only statistically significant difference between the two groups was associated with level S7. However, while an increase was observed at level S7 for the RME group, a decrease after treatment was observed for the RME + FM group. It is possible that the latter observation is due to clockwise rotation of the mandible. For example, Akcam *et al.* (32) observed a decrease in airway space in patients with clockwise rotation of the mandible. Furthermore, according to Ceylan and Oktay (33), pharyngeal airway size may be influenced by changes in the ANB angle, and oropharyngeal dimensions may be diminished in subjects with an increased ANB angle.

The present results suggest that treatments of RME and RME followed by FM therapy have similar effects, and the FM appliance has no additional effect on oropharyngeal airway dimensions. Previously, no relationship between changes in craniofacial morphology and upper-airway dimensions after maxillary protraction were observed in a study by Hiyama *et al.* (14). These results were attributed to an increase in the superior-airway dimension relative to the anterior position of the tongue, and to the increased volume of the oral cavity and head posture (14). Mucedero *et al.* (19) also analyzed changes in oropharyngeal and nasopharyngeal airway dimensions in the sagittal plane following orthopedic therapy of Cl III malocclusion with FM or FM plus RME. Compared to subjects with untreated Cl III malocclusion, there were no significant changes observed in the treatment groups. Changes in the sagittal airway dimensions induced by orthopedic therapy or physiological growth also exhibited greater inter-individual variability in subjects with Cl III malocclusion (19). Similarly, Baccetti *et al.* (21) found no significant short-term or long-term changes in sagittal oropharyngeal and nasopharyngeal airway dimensions induced by maxillary protraction in subjects with Cl III malocclusion compared with an untreated control group. The authors also emphasized the importance of considering age-related 266 physiological changes of the posterior pharyngeal lymphoid tissue (21).

Due to the difficulty in finding untreated children with the type of malocclusion treated in the present study, no control group was included for ethical reasons. Changes that occur in the dimensions of the upper-airway during natural growth are also important to consider in order to determine whether the observed increase in upper-airway dimensions following treatment were directly related to maxillary expansion. Özbek *et al.* (2), previously reported that 15 untreated patients (mean age: 11.3 years) exhibited only negligible changes in the upper-airway dimensions over a 1.8-year observation period. These results support the observation of the present study that maxillary expansion is responsible for the increase in oropharyngeal airway dimensions that was achieved.

In the present study, two-dimensional measurements of airway dimensions were obtained from cephalometric radiographs. Despite the reported use of a variety of methods for the measurement of nasal airway dimensions, cephalometric radiography continues to represent a widely available and cost-effective method for obtaining quantitative information on changes in the nasopharyngeal area (34,35). Nevertheless, it is important to remember that soft tissue components of the airway are susceptible to atrophy or hypertrophy, and this can have a marked impact on measured airway dimensions. An assessment of airway changes induced by orthodontic therapy also requires a multidisciplinary approach. Thus, future prospective studies should incorporate different measurement modalities in order to obtain a more comprehensive evaluation of the airway changes that may occur. Moreover, considering the significant variability observed between patients in the present study, the unpredictability of the present results, and the controversial results from previous studies, RME or RME combined with FM should not be considered as a treatment option for improving airway space without an orthodontic indication (36).

Conclusion

In conclusion, RME and RME followed by FM therapy resulted in an increase in sagittal airway dimensions, particularly in the superior oropharyngeal region. However, there were no statistically significant differences observed at the sagittal plane following these two treatment approaches in terms of pharyngeal airway dimensions. In addition, no additional effect of FM therapy was observed.

Türkçe özet: *Yüz Maskesi Hizli Üst Çene Genişletmesinin Sagital Havayolu Boyutlari Üzerine Etkisini Arttirir Mi? Giriş ve Amaç: Üst çenenin transversal ve sagittal konumundan etkilenen havayolu boyutları ortodontik tedavilerden etkilenmektedir. Bu çalışmanın amacı; sadece üst çene hızlı genişletme prosedürü uygulanmış olgular ile hızlı genişletme sonrası yüz maskesi uygulanmış olguların havayolu boyutlarında meydana gelen değişimlerin karşılaştırılması ve yüz maskesi 40 apareyinin kısa ve uzun dönemde genişletme ile meydana gelen değişimleri etkileyip 41 etkilemediğinin araştırılmasıdır. Gereç ve Yöntem: Çalışmada toplam 78 sefalometrik film incelenmiştir. Olgular iki gruba ayrılmıştır. I. grupta hızlı üst çene genişletmesi uygulanan 14 olgu (3 erkek, 11 kız; ortalama 44 yaş: 12.2 ± 2.1 yıl), II. grupta hızlı üst çene genişletmesi sonrası yüz maskesi uygulanan 12 olgu (7 erkek, 5 kız; ortalama yaş: 11.6 ± 1.3 yıl) yer almaktadır. Tedavi öncesi, tedavi sonrası ve pekiştirme sonrası üç dönemde alınan sefalometrik filmler üzerinde sagittal ve vertikal ölçümlerle birlikte 10 kesitsel havayolu ölçümü yapılmıştır. Bulgular: Genişletme sonrası yüz maskesi uygulanan grupta üst çenenin öne gelmesiyle birlikte SNA, SNB açıları ve Wits ölçümünde anlamlı artış meydana gelmiştir. Vertikal yönde de anlamlı artış gözlemlenmiştir. Havayolu ölçümleri incelendiğinde hem kısa hem de uzun dönemde orofarengeal bölgede anlamlı artış meydana gelmiştir. Gruplar arasında her iki 53 dönemde anlamlı bir farklılık meydana gelmemiştir. Sonuç: Her iki tedavi yöntemi ile havayolu boyutlarında önemli değişiklikler meydana gelmiş olmakla birlikte yüz maskesi apareyinin havayolu boyutlarına ilave bir etkisi olduğu tespit edilememiştir. Anahtar Kelimeler: havayolu, genişletme, bonded RPE, yüz maskesi, uzun dönem.*

Ethics Committee Approval: This study was approved by the Clinical Research Ethical Committee of Istanbul University, Faculty of Dentistry (19.10.2021/560).

Informed Consent: The participants provided informed consent.

Peer-review: Externally peer-reviewed.

Author contributions: MC, OE, ADGC, BT, EE participated in designing the study. MC, OE, ADGC, BT, EE participated in generating the data for the study. MC, OE, ADGC, BT participated in gathering the data for the study. OE participated in the analysis of the data. MC, OE wrote the majority of the original draft of the paper. MC, OE, ADGC, BT participated in writing the paper. MC, OE, ADGC, BT, EE have had access to all of the raw data of the study. MC, EE have reviewed the pertinent raw data on which the results and conclusions of this study are based. MC, OE, ADGC, BT, EE have approved the final version of this paper. ADGC guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: : The authors had no conflict of interest to declare.

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

References

1. Wertz RA. Changes in nasal airflow incident to rapid maxillary expansion. The Angle Orthodontist 1968;38:1-11.
2. Özbek M, Toygar Mamikoglu T, Gögen H, Lowe AA, Baspinar E. Oropharyngeal airway dimensions and functional-orthopedic treatment in skeletal Class II cases. The Angle Orthodontist 1998;68:327-36.
3. Di Carlo G, Saccucci M, Ierardo G, Luzzi V, Occasi F, Zicari AM, Duse M, Polimeni A. Rapid maxillary expansion and upper airway morphology: A systematic review on the role of cone beam computed tomography. Biomed Res Int 2017; Article ID 5460429:1-10. [CrossRef]
4. Smith T, Ghoneima A, Stewart K, Liu S, Eckert G, Halum S, *et al*. Three-dimensional computed tomography analysis of airway volume changes after rapid maxillary expansion. American Journal of Orthodontics and Dentofacial Orthopedics 2012;141:618-26. [CrossRef]
5. Timms D. Some medical aspects of rapid maxillary expansion. British Journal of Orthodontics 1974;1:127-32. [CrossRef]
6. Timms D. Rapid maxillary expansion in the treatment of nasal obstruction and respiratory disease. Ear, Nose, & Throat Journal 1987;66:242-7.
7. Gray LP. Results of 310 cases of rapid maxillary expansion selected for medical reasons. The Journal of Laryngology & Otology 1975;89:601-14. [CrossRef]
8. Oliveira De Felippe NL, Da Silveira AC, Viana G, Kusnoto B, Smith B, Evans CA. Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: short-and long-term effects. American Journal of Orthodontics and Dentofacial Orthopedics 2008;134:370-82. [CrossRef]
9. Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. American Journal of Orthodontics and Dentofacial Orthopedics 2010;137:71-8. [CrossRef]
10. Baratieri C, Alves Jr M, de Souza MMG, de Souza Araújo MT, Maia LC. Does rapid maxillary expansion have long-term effects on airway dimensions and breathing? American Journal of Orthodontics and Dentofacial Orthopedics 2011;140:146-56. [CrossRef]
11. Ribeiro ANC, De Paiva JB, Rino-Neto J, Illipronti-Filho E, Trivino T, Fantini SM. Upper airway expansion after rapid maxillary expansion evaluated with cone beam computed tomography. The Angle Orthodontist 2011;82:458-63. [CrossRef]
12. Villa MP, Malagola C, Pagani J, Montesano M, Rizzoli A, Guilleminault C, *et al*. Rapid maxillary expansion in children with obstructive sleep apnea syndrome: 12-month follow-up. Sleep Medicine 2007;8:128-34. [CrossRef]
13. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral forces. American Journal of Orthodontics 1978;74:121-41. [CrossRef]
14. Hiyama S, Suda N, Ishii-Suzuki M, Tsuiki S, Ogawa M, Suzuki S, *et al*. Effects of maxillary protraction on craniofacial structures and upper-airway dimension. The Angle Orthodontist 2002;72:43-7.

15. Sayınsu K, Isik F, Arun T. Sagittal airway dimensions following maxillary protraction: a pilot study. The European Journal of Orthodontics 2006;28:184-9. [CrossRef]
16. Kilinç AS, Arslan SG, Kama JD, Özer T, Dari O. Effects on the sagittal pharyngeal dimensions of protraction and rapid palatal expansion in Class III malocclusion subjects. The European Journal of Orthodontics 2008;30:61-6. [CrossRef]
17. Oktay H, Ulukaya E. Maxillary protraction appliance effect on the size of the upper airway passage. The Angle Orthodontist 2008;78:209-14. [CrossRef]
18. Kaygisiz E, Tuncer BB, Yüksel S, Tuncer C, Yildiz C. Effects of maxillary protraction and fixed appliance therapy on the pharyngeal airway. The Angle Orthodontist 2009;79:660-7. [CrossRef]
19. Mucedero M, Baccetti T, Franchi L, Cozza P. Effects of maxillary protraction with or without expansion on the sagittal pharyngeal dimensions in Class III subjects. American Journal of Orthodontics and Dentofacial Orthopedics 2009;135:777-81. [CrossRef]
20. Lee J-W, Park K-H, Kim S-H, Park Y-G, Kim S-J. Correlation between skeletal changes by maxillary protraction and upper airway dimensions. The Angle Orthodontist 2011;81:426-32. [CrossRef]
21. Baccetti T, Franchi L, Mucedero M, Cozza P. Treatment and post-treatment effects of facemask therapy on the sagittal pharyngeal dimensions in Class III subjects. The European Journal of Orthodontics 2009;32:346-50. [CrossRef]
22. Tsuiki S, Almeida FR, Bhalla PS, Lowe AA, Fleetham JA. Supine-dependent changes in upper airway size in awake obstructive sleep apnea patients. Sleep and Breathing 2003;7:43-50. [CrossRef]
23. Tsuiki S, Lowe AA, Almeida FR, Fleetham JA. Effects of an anteriorly titrated mandibular position on awake airway and obstructive sleep apnea severity. American Journal of Orthodontics and Dentofacial Orthopedics 2004;125:548-55. [CrossRef]
24. Pirelli P, Saponara M, Guilleminault C. Rapid maxillary expansion in children with obstructive sleep apnea syndrome. Sleep 2004;27:761-6. [CrossRef]
25. Guilleminault C, Li KK. Maxillomandibular Expansion for the Treatment of Sleep-Disordered Breathing: Preliminary Result. The Laryngoscope 2004;114:893-6. [CrossRef]
26. Kiliç N, Oktay H. Effects of rapid maxillary expansion on nasal breathing and some naso-respiratory and breathing problems in growing children: a literature review. International Journal of Pediatric Otorhinolaryngology 2008;72:1595-601. [CrossRef]
27. Cistulli PA, Palmisano RG, Poole MD. Treatment of obstructive sleep apnea syndrome by rapid maxillary expansion. Sleep 1998;21:831-5. [CrossRef]
28. Iwasaki T, Takemoto Y, Inada E, Sato H, Suga H, Saitoh I, Kakuno E, Kanomi R, Yamasaki Y. The effect of rapid maxillary expansion on pharyngeal airway pressure during inspiration evaluated using computational fluid dynamics. International Journal of Pediatric Otorhinolaryngology 2014;78:1258-64. [CrossRef]
29. Ngan PW, Hagg U, Yiu C, Wei SH. Treatment response and long-term dentofacial adaptations to maxillary expansion and protraction. Seminars in Orthodontics 1997;3:255-64. [CrossRef]
30. Gallagher R, Miranda F, Buschang P. Maxillary protraction: treatment and posttreatment effects. American Journal of Orthodontics and Dentofacial Orthopedics 1998;113:612-9. [CrossRef]
31. Cakirer B, Kucukkeles N, Nevzatoglu S, Koldas T. Sagittal airway changes: rapid palatal expansion versus Le Fort I osteotomy during maxillary protraction. The European Journal of Orthodontics 2012;34:381-9. [CrossRef]
32. Akcam MO, Toygar TU, Wada T. Longitudinal investigation of soft palate and nasopharyngeal airway relations in different rotation types. The Angle Orthodontist 2002;72:521-6.
33. Ceylan İ, Oktay H. A study on the pharyngeal size in different skeletal patterns. American Journal of Orthodontics and Dentofacial Orthopedics 1995;108:69-75. [CrossRef]
34. Jakhi S, Karjodkar F. Use of cephalometry in diagnosing resonance disorders. American Journal of Orthodontics and Dentofacial Orthopedics 1990;98:323-32. [CrossRef]
35. Duan H, Xia L, He W, Lin Y, Lu Z, Lan Q. Accuracy of lateral cephalogram for diagnosis of adenoid hypertrophy and posterior upper airway obstruction: a meta-analysis. Int J Pediatr Otorhinolaryngol 2019;119:1–9. [CrossRef]
36. Gordon JM, Rosenblatt M, Witmans M, Carey JP, Heo G, Major PW, *et al*. Rapid palatal expansion effects on nasal airway dimensions as measured by acoustic rhinometry: a systematic review. The Angle Orthodontist 2009;79:1000-7. [CrossRef]