Effects of Combined Bonded Maxillary Expansion and Face Mask on Dental Arch Length in Patients with Skeletal Class III Malocclusions

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Objective: *To evaluate the effects of combined rapid maxillary expansion (RME) and face mask (FM) therapy during the mixed dentition period on the dental arch length in patients with skeletal Class III malocclusion.* ***Study Design:*** *We evaluated pre- and post-treatment orthodontic models of 52 patients (25 girls, 27 boys) aged 8–12 years with skeletal Class III malocclusion(ANB<0) accompanied by maxillary transverse deficiency and retrognatism treated by bonded RME-FM therapy for a mean duration of 8 months. Palatal rugae, the cusp tips of permanent first molars, deciduous molars/permanent premolars, deciduous canines and the incisal edges of permanent central incisors were marked on orthodontic models, which were then photocopied. Inter-molar, inter-premolar and inter-canine widths; the arch length; the arch depth and molar and incisor sagittal movements were measured on these photocopies. Statistical comparisons were made using paired t-tests.* ***Results:*** *Inter-molar, inter-premolar and inter-canine widths and the arch length showed significant increases after treatment, while the arch depth showed a significant decrease (p<0.001 for all).* ***Conclusions:*** *With the study limitations, our results suggest that combined RME-FM therapy increases the arch length in the mixed dentition of patients with skeletal Class III malocclusion.*

Key words: *Angle Class III, facemask, rapid maxillary expansion, arch length,*

INTRODUCTION

Combined rapid maxillary expansion (RME) and face mask (FM) therapy is a commonly used treatment protocol for patients with Class III malocclusion accompanied by maxillary transverse and sagittal deficiencies during the growth and development period.[1-4] To obtain more successful and stable treatment outcomes, most researchers recommend treatment initiation during the early developmental phase[5], i.e. the mixed dentition period.

The effects of RME[6-8] and FM[9,10] therapy alone and in combination[1,9,11,12] on skeletal and dentoalveolar structures are well documented in the literature. However, research on the effects of combined RME and FM therapy on the arch length is limited.[13] This information is particularly important to foresee arch length need and plan extractions during the treatment of borderline cases. An increase in the arch length can be advantageous in borderline cases for which negative effects of extraction are anticipated. Therefore, awareness of not only skeletal changes (orthopaedic effect) but also transverse and sagittal changes in the dentoalveolar arch can aid in formulating an appropriate orthopaedic and orthodontic treatment plan.

A few studies have evaluated dentoalveolar changes, including those in the arch depth and arch length, induced by combined RME and FM therapy using dental casts.[13-15] . In a study by Lione *et al*.[14] , mesial drift and expansion of second deciduous molars and arch depth changes after use of banded and bonded RME appliances in combination with FM were evaluated and compared. In another study by the same authors[16], only the anterior arch length was evaluated and found to have decreased by the end of treatment.

Total arch length changes induced by combined RME and FM therapy have been evaluated only by Ngan *et al* [13], who used banded RME appliances with FM in a group of subjects who were either in permanent or early mixed dentition stage. Among the subjects whose dental casts were evaluated, only half had crossbite and the duration of RME appliance activation varied from 1 week to 2 weeks. Ngan[13] used an additional

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lingual wire extending to the cingulum of the maxillary incisors, which was expected to prevent incisor retraction. The results revealed a 2.3-mm increase in the inter-molar width and a 0.7-mm decrease in the maxillary arch depth during the treatment period. From the overall insignificant increase of 1.7 mm in the arch length, the authors concluded that this combined treatment cannot create space if crowding is present. The smaller arch length increase can be attributed to the RME protocol; RME was primarily used for disarticulating the maxillary sutures and achieving a smaller amount of expansion.

To the best of our knowledge, no study has evaluated changes in the dental arch length induced by bonded RME and FM combination therapy in a group of patients who exhibited maxillary transverse deficiency and retrognatism in mixed dentition stage. Therefore, we conducted this retrospective study to evaluate the effects of bonded RME and FM combination therapy during the mixed dentition period on the dental arch length in patients with skeletal Class III malocclusion The tested hypothesis was that combined RME and FM therapy during the mixed dentition period causes arch length loss in the maxillary dental arch of patients with skeletal Class III malocclusion.

MATERIALS AND METHOD

A total of 52 Caucasian children (27 boys and 25 girls) aged 8–12 years (mean age,10.47±1.41 years) with skeletal Class III malocclusion accompanied by maxillary transverse deficiency and retrognatism treated by bonded RME and FM combination therapy at the Department of Orthodontics in the University of Gazi were included in this retrospective study. Clinical records, pre-treatment lateral and postero anterior cephalograms and pre- and post-treatment dental casts of all patients were evaluated.

The inclusion criteria were as follows: presence of a mixed dentition without permanent canines, pre-pubertal stage of skeletal maturity assessed by the cervical vertebral maturation method (CS1–CS3) [16], presence of skeletal Class III malocclusion(ANB<0, Wits appraisal of −2 mm or greater) with an anterior crossbite or an end-to-end incisor relationship and presence of a Class III molar relationship. In addition, the presence of maxillary skeletal transverse deficiency as determined cephalometrically and clinically by the increased distance (>11.5 mm) of left and right jugal processes to frontal facial plane[17] and by bilateral cross bite in 30 patients and unilateral crossbite with functional shift in 22 patients. Patients with cleft palate and lip, tooth agenesis, supernumerary teeth, craniofacial anomalies, systematic diseases that may affect growth and development and a history of orthodontic treatment were excluded.

The study was conducted in accordance with the ethical principles stated in the Declaration of Helsinki and was approved by the Ethics Committee of Gazi University (25901600-7587).

Treatment protocol

The bonded RME appliance covered the occlusal, vestibular and palatal surfaces of posterior teeth using an acrylic splint (Figure 1).The thickness of the occlusal acrylic surface was limited to the freeway space, and this surface was in contact with all mandibular teeth. The appliance was activated once a day (0.25 mm per activation) until the palatal cusps of the maxillary posterior teeth occluded with the buccal cusps of the mandibular posterior teeth. This corresponded to a mean activation duration of 2.8 weeks which approximately corresponded to 5 mm of screw opening. The same appliance was used as the intraoral part of a Petit FM (Figure 2)[18]. Patients were instructed to wear the FM for at least 16 hours each day. Protraction hooks were placed between the deciduous canine and first premolar, and a protraction force of 400 to 600 g per side was used with an antero-inferior force vector of 15°–30° to the occlusal plane. Elastics were replaced at least once a day. Treatment was considered complete when a positive overjet was achieved. The mean duration of RME and FM combination therapy was 8 months. After removing the bonded RME appliance, residual bonding materials (glass ionomer cement) on the tooth were cleaned, and post treatment impressions were taken on average one week later.

Measurements on photocopies of dental casts

Transverse and sagittal dental changes were determined using dental casts prepared before (T1) and after (T2) combined RME and FM therapy (Figure 3). The median palatal suture, palatal rugae and cusp tips of the maxillary deciduous canine, primary molars/permanent premolars and permanent first molars were marked on the study models using a 0.5-mm pencil, and photocopies of the models were obtained as described by Champagne.[19] 1. inter-canine width: distance between the left and right deciduous canine cusp tips; 2. inter-premolar width: distance between the buccal cusp tips of the right and left first premolars; 3. inter-molar

Figure 1. Bonded rapid maxillary expansion (RME) device for the correction of maxillary deficiency.

Figure 2. Petit face mask for the correction of skeletal Class III malocclusion during the mixed dentition period.

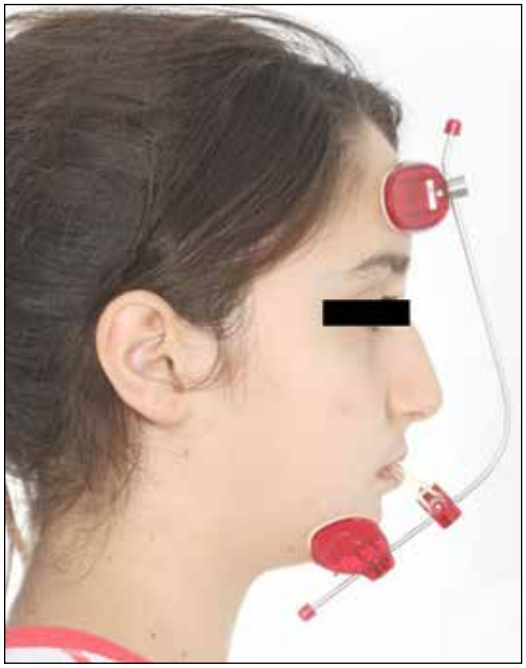
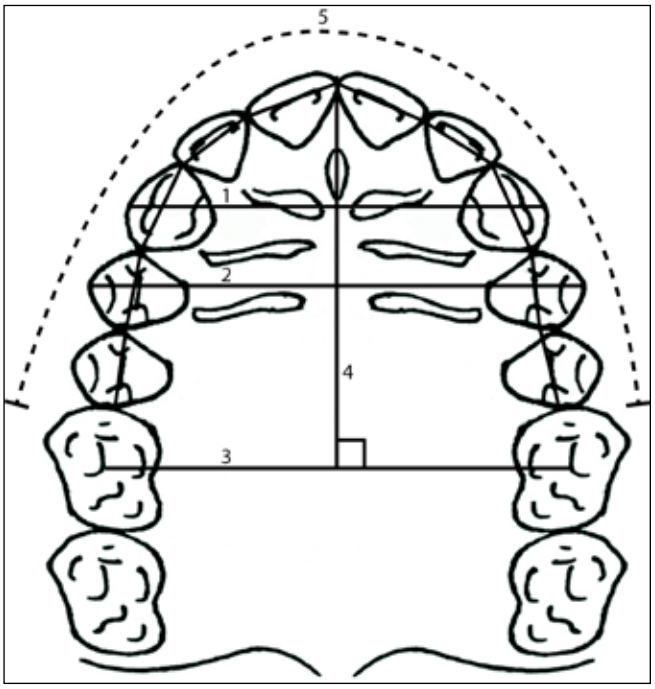


Figure 3. Measurements recorded on photocopies of mixed dentition models: 1. inter-canine width, 2. inter-premolar width, 3. inter-molar width, 4. arch depth, 5. arch length.



width (IMW): distance between the central point on the occlusal surface of the permanent first molars (intersection point of the lines passing through the mesiobuccal–disto-palatal cusps and distobuccal–mesiopalatal cusps tips); 4. arch depth: perpendicular distance from the central incisors to the first molar, measured by a tangent from the most anterior point between the maxillary central incisors to the central point of the IMW line and the 5. arch length were then measured on these photocopies (Figure 3) and compared between the pre- and post-treatment models (Table 1). The arch length was measured from the mesial contact point of the first molar, through the mesial and distal contact points of the posterior teeth and incisal edges of the anterior teeth, to the mesial contact point of the opposite first molar(Figure 3).[20] All models were marked and the measurements were done by the same orthodontist.

The pre- and post-treatment model photocopies were subsequently superimposed to achieve the best fit for the incisive papilla, palatal rugae and palatal raphe. Then, the amount of permanent first molar mesialization and sagittal incisor movements were directly measured on millimetre paper with reference to the median palatal suture (ML) on these superimposed models (Table 2).

Statistical analysis

All statistical analyses were performed using SPSS 16.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics, including means, standard deviations (SDs) and ranges, were computed for the measurements before and after treatment. The data were tested for normality using the Shapiro–Wilk

Table 1. Descriptive statistics and statistical comparisons of values obtained before (T1) and after (T2) combined rapid maxillary expansion (RME) and face mask (FM) therapy

		Before treatment (T1)		After treatment (T2)		Difference (T2–T1)		p
Measurements	n	Mean	SD	Mean	SD	Mean	SD	
1. Inter-molar width	52	45.6	3.0	49.4	2.8	3.82	2.05	0.000
2.Inter-premolar width	39	39.1	3.1	42.3	3.1	3.19	2.46	0.000
3.Inter-caninewidth	25	32.1	2.6	34.3	2.4	2.20	1.99	0.000
4. Arch depth	52	32.1	2.5	31.2	2.5	−0.91	1.36	0.000
5. Arch length	52	69.3	4.6	71.9	4.1	2.60	3.15	0.000

Table 2. Sagittal movements of the maxillary permanent first molars and incisors measured directly on superimpositions of pre- and post-treatment dental casts.

Measure-ment	Mean	Median	Minimum	Maximum	SD
Right molar movement	−0.402	−0.500	−3.000	2.000	1.148
Left molar movement	−0.315	−0.250	−3.500	2.000	1.194
Average molar movement	−0.359	−0.250	−2.500	1.750	1.022
Incisor movement	−0.804	−0.750	−2.500	1.500	0.969

(−) molar mesialization, incisor retraction

(+) molar distalization, incisor protrusion

test. Because the data were normally distributed, paired t-tests were used to evaluate the significance of differences between T1 and T2. A p-value of <0.001 was considered statistically significant.

Forty randomly selected models were marked, photocopies were obtained and measurements were recorded by the same orthodontist after a period of 2 weeks. The method error and intra-observer reliability were determined using Dahlberg's formula[20] and paired t-tests.

Power analysis revealed that 52 patients would achieve a statistical power of 82% at a significance level of 0.05 by considering a mean difference of 0.91 mm and an SD of 1.36 in the arch depth.

RESULTS

The method error did not exceed 0.5 mm for any of the variables investigated, while the duplicated measurements were not significantly different (p>0.05).

There was a significant increase in the inter-molar, inter-premolar and inter-canine widths (3.82±2.05mm, 3.19±2.46mm and 2.20±1.99mm, respectively; p<0.001 for each). In addition, a significant increase in the arch length (2.6±3.15mm) and a significant decrease in the arch depth (0.91±1.36mm) were recorded (p<0.001; Table 1).

The permanent first molars showed an average mesialization of 0.4±1.02 mm, while the permanent central incisors were retracted by 0.8 ± 0.97 mm by the end of combined RME and FM therapy (Table 2).

DISCUSSION

To date, no study has assessed the net effects of maxillary expansion with a bonded RME appliance and FM combination therapy during the mixed dentition period on the arch length in patients with skeletal Class III malocclusion accompanied by maxillary transverse deficiency and retrognatism. The present study assessed this effect using dental casts and found that bonded RME and FM combination therapy did not cause arch length loss in these patients. Therefore, the tested hypothesis was rejected .

The present study included children aged 8–12 years in their early or late mixed dentition periods. Although it has been reported that FM treatment is more effective in patients aged less than 10 years[9], other researchers have found that the changes induced by RME and FM combination therapy in younger children are not significantly different from those in older children. [22] Our study sample included two patients aged 8 years and six patients aged 12 years; the remaining were aged 9–11 years. Thus, our sample can be considered homogeneous, eliminating any gender differences.

The effects of treatment were evaluated on photocopies of dental casts in the present study. Dental changes can be precisely quantified on dental casts, thus resolving the measurement errors caused by the superimposition of bilateral anatomic structures on lateral cephalograms. [14,22] The reliability and reproducibility of measurements obtained from dental cast photocopies have been previously confirmed. [22] Damstra *et al* [23] evaluated the use of palatal rugae as a reference on standardized two-dimensional photographs of patients undergoing expansion, considering only the medial part of the rugae. They concluded that 'the rugae might yet prove to be a stable reference but may need sufficient time to re-establish their original position after RME due to constriction of the stretched fibres in the palatal mucoperiosteum'. In the present study, we superimposed pre- and post-treatment dental cast (model) photocopies to achieve the best fit for the incisive papilla, palatal rugae and palatal raphe.

The results of the present study revealed an average arch depth change of 0.9 mm, although RME provided an expansion of approximately 4 mm in the posterior region, with a resultant 2.6-mm increase in the arch length.

We faced some limitations in direct comparisons of our study findings with those of previous studies[1-4,11,14,15] because of differences in subject characteristics (ethnicity, age, sex), methods (design of RME or FM, activation of the screw, location of the extraoral force, duration of treatment, total time, criteria for ending treatment, direction and amount of applied force), materials used to evaluate treatment effects (lateral cephalograms, three-dimensional images of dental casts),methodological differences in measurements (anatomical landmarks, reference points, superimposition methods) and statistical methods.

In the present study, RME resulted in significant increases of 3.82 ± 2.05, 3.19 ± 2.46 and 2.20 ± 1.99 mm in inter-molar, inter-premolar and inter-canine widths, respectively. A greater increase in the inter-canine width is expected after RME, because it was reported that opening of the midpalatal suture is greater in the anterior region than in the posterior region.[24,25] However, in the present study, the inter-canine width showed a smaller increase than the inter-molar width. This result is not consistent with those of other studies. [20,24]In support of our findings, Phatouros and Goonewardene [26] applied a bonded RME appliance in the mixed dentition and reported average expansion amounts of4.8 and 3.9 mm in the permanent first molar and canine regions, respectively. Although the defined amounts of expansion were greater than

those in our study, the results are similar to ours in that the inter-canine width increase was smaller than the inter-molar width increase.

Lione *et al* [16] reported similar increases in inter-canine and inter-molar widths. These conflicting results may be due to differences in the appliance design and the dentition stage between our study and their study. Lione used a bonded RME appliance anchored on deciduous molars and canines and did not include the permanent first molars.

As observed in previous studies, [20,26] the acrylic part of the RME appliance used in our study did not cover the canines; therefore, a large increase in the inter-canine width was not expected. From another perspective, perioral soft tissues may play a role in preventing a larger increase in the inter-canine width. [26] However, Garret et al. [25] reported that skeletal expansion with an RME appliance was wedge shaped, with the wide base at the anterior maxilla and the orthopaedic and skeletal expansion decreasing from the anterior to the posterior region (55% of the total expansion at the first premolar, 45% at the second premolar and 38% at the first molar). On the other hand, alveolar bending and dental tipping increased from the anterior to the posterior region. In the present study also, alveolar bending and dental tipping was greater in the posterior than in the anterior region.

The general effects of conventional FM therapy on the dentition include mesial movement of the maxillary molars and proclination of the maxillary incisors, while the addition of RME induces incisor retraction.[8,9] Proclination of the maxillary incisors may be limited because of the space created by the expansion appliance.[9] The expected net effect of combined RME and FM therapy is a decrease in the arch depth.

In the present study, the permanent first molars showed an average mesialization of 0.4 mm and the incisors showed an average retraction of 0.9 mm at the end of 8 months of combined RME and FM therapy.

The results of the present study are similar to those of Kulbersh *et al*. [27] who observed uprighting of the maxillary incisors (decrease in the 1/SN angle) and 5 mm of molar mesialization with bonded RME and FM combination therapy, while Halicioğlu *et al*[11] reported that the maxillary incisors were more proclined in the FM group than in the RME+FM group. However, our results oppose those of other studies that showed forward movement of both maxillary molars and incisors.[1, ,28] Williams *et al*. [28] recorded a 2.73-mm incisor protrusion with bonded RME and FM combination therapy, while Kapust *et al* [1] observed a mean maxillary molar mesialization of 2.4 mm and maxillary incisor forward movement of 1.8 mm with RME and FM therapy.

The amount of molar mesialization (0.4 mm) recorded in the present study was lesser than that reported in other studies, which reported an amount of 1.6–2.4 mm using cephalometric analyses.[1,3,4, 27,29] These discrepancies in results can be attributed to differences in the analysis method (cephalometric analyses, dental casts) and the treatment protocol (duration of treatment, appliance activation, etc.) between studies.

In the present study, the decrease in the arch depth (0.9mm) appeared to be related to the amounts of molar mesialization and incisor retraction. The values obtained in our study are very similar to those reported by Lione *et al* [14] who showed deciduous second molar mesialization of 1.5 mm and an arch depth decrease of 0.7 mm in the bonded RME group. However, they did not evaluate incisor movements. Similarly, Ngan *et al* [13] reported a decrease of 0.7 mm in the maxillary arch depth during treatment with banded RME and FM combination therapy.

In the present study, we observed that, although the arch depth decreased to cause space deficiency, a total expansion of 4 mm by the RME appliance resulted in an arch length increase of 2.6 mm. This finding is concomitant with the findings of two previous studies[8, 20] reporting that a gain in the dental arch perimeter can be practically predicted to be 0.7 and 0.65 times the amount of posterior expansion, respectively.

Only two previous studies have evaluated total arch length changes after combined RME and FM therapy.[13, 15] Lione*l* [15] concluded that bonded RME and FM combination therapy during the deciduous or early mixed dentition stage produced significant expansion of the maxillary arch and mesialization of the posterior teeth, with a decrease in the arch depth and anterior arch length. They also reported that mesialization of deciduous canines and molars determined a space loss in the anterior maxillary region in the RME and FM treatment group, but not in the control group. Unfortunately, these findings cannot be compared with our findings because they did not include total arch length measurements. In another study, Ngan *et al*.[13] found no net significant increase in the dental arch length after 8 months of banded RME and FM combination therapy. This was not consistent with the findings in our study, probably because of differences in treatment protocols. Ngan *et al*[13] activated the RME appliance twice a day for 7 days, and expansion was used for disarticulating the sutures rather than correcting the posterior crossbite. Therefore, the magnitudes of expansion and space gain were smaller than those in the present study.

The results of this study did not support the tested hypothesis, as combined RME and FM therapy for skeletal Class III malocclusion during the mixed dentition period did not cause arch length loss in fact increases the dental arch length These results are clinically important, particularly with regard to decisions regarding extraction in borderline cases.

We observed that dental changes induced by RME and FM combined therapy during the mixed dentition period were small. This result is supported by the findings of Kim *et al*.[9] who mentioned that larger skeletal changes and smaller dental changes are induced with combined RME and FM therapy, although larger dental changes are induced by treatment without expansion. In agreement with Ngan [30], we can say that the amount of molar mesialization and incisor retraction were clinically negligible, thus confirming that overjet correction should be ascribed mainly to skeletal changes induced by combined RME and FM therapy.

This study has some limitations. First, antero posterior and lateral cephalometric measurements to assess the amount of molar and incisor transverse and sagittal movements and the skeletal response were not obtained. Second, a matched control group for comparison of the treatment outcomes was not included, which did not allow us to differentiate treatment effects from normal growth. Finally, patients were not followed for a long interval after using the appliances to observe any relapse issues. Further studies are necessary to overcome these limitations and further clarify our findings.

CONCLUSION

With the study limitations, our results suggest that combined RME and FM therapy increases the arch length in the mixed dentition of patients with skeletal Class III malocclusion.

Clinically; it seems that this combined therapy doesn't cause any space problems for permanent canine eruption without any suplementary anchorage control mechanics such as a wire exdended to the cingulum of incisors.

This information is particularly important with regard to decisions regarding extraction in borderline cases. An increase in the arch length can be advantageous in borderline cases for which negative effects of extraction are anticipated. Therefore, awareness of not only skeletal changes (orthopaedic effect) but also transverse and sagittal changes in the dentoalveolar arch can aid in formulating an appropriate orthopaedic and orthodontic treatment plan.

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