Changes in Temporomandibular Joint Disc and Condyle after Rapid Maxillary Expansion Combined with Protraction Facemask Therapy: A Prospective Magnetic Resonance Imaging Study

Protraksiyon Yüz Maskesi ve Hızlı Maksiller Ekspansiyon Sonrası Temporomandibular Eklem Diski ve Kondil Değişiklikleri: Prospektif Manyetik Rezonans Görüntüleme Çalışması

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ABSTRACT

Objective: The aim of this magnetic resonance image (MRI) investigation was to evaluate the effects of rapid maxillary expansion (RME) combined with protraction facemask (FM) appliance therapy on the articular disc–condyle complex.
Subjects and Methods: Twenty-five children displaying a Class III malocclusion were enrolled in the study. The treatment group included 15 patients (5 boys and 10 girls), and a control group included 10 patients (5 boys and 5 girls). The mean age at the beginning of treatment was 10.5 ± 1.03 years for the rapid maxillary expansion with facemask group, 9.33 ± 0.83 years for the control group. MRIs and lateral cephalometric films were obtained at the beginning (T1) and after the RME and FM treatment (T2). Measurements were performed to evaluate the changes in condyle morphology, articular disc position and condyle position in the glenoid fossa. The groups were compared at T1 with independent-t and Mann-Whitney U test, and treatment changes (T1–T2) were evaluated using the paired-t test and Wilcoxon signed-rank test. The statistical significance was considered at P<0.05.
Results: No statistically significant difference was found in any of the MRI and cephalometric measurements between the groups at T1. There were no significant changes seen in disc position between the groups. During the treatment, changes in the alpha angle were reduced (-4.2 ± 6^0) but this change was not significant when compared with the control group. Anterior and posterior joint spaces increased in the treatment group when compared with the control group (P<0.05).
Conclusions: After rapid maxillary expansion combined with protraction facemask therapy, there was no morphological, but a postural change in the condyle as a result of treatment. Further long-term studies are required to determine whether these changes clinically significant and may occur due to rapid maxillary expansion appliance or protraction facemask therapy.

Keywords: Protraction facemask, Rapid maxillary expansion, MRI, Temporomandibular joint, Condyle.

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ÖZET

Amaç: Bu manyetik rezonans görüntüleme (MRI) çalışmasının amacı, hızlı maksiller genişletme (RME) ile birlikte protraksiyon yüz maskesi (FM) tedavisinin, temporomandibular eklem diski ve mandibular kondil üzerindeki etkilerini değerlendirmektir.
Bireyler ve Yöntem: Çalışmaya Sınıf III maloklüzyona sahip 25 çocuk dahil edildi. Tedavi grubu 15 hastadan (5 erkek ve 10 kız) ve kontrol grubu 10 hastadan (5 erkek ve 5 kız) oluşuyordu. Yüz maskesi ile hızlı üst çene genişletmesi (RME/FM) için ortalama tedaviye başlama yaşı 10.5 ± 1.03 yıl, kontrol grubu için 9.33 ± 0.83 yıl idi. MRI'ler ve lateral sefalometrik filmler başlangıçta (T1) ve RME/FM tedavisinden (T2) sonra alındı. Glenoid fossada kondil morfolojisi, artiküler disk pozisyonu ve kondil pozisyonu değişikliklerini değerlendirmek için ölçümler yapıldı. Gruplar T1'de bağımsız-t ve Mann-Whitney U testi ile karşılaştırılırken, tedavi değişiklikleri (T1-T2) eşleştirilmiş t testi ve Wilcoxon signed-rank testi kullanılarak değerlendirildi. İstatistiksel anlamlılık P<0.05 olarak kabul edildi.
Bulgular: T1'de gruplar arasında MRI ve sefalometrik ölçümlerin hiçbirinde istatistiksel olarak anlamlı fark bulunmadı. Gruplar arasında artiküler disk pozisyonunda önemli bir değişiklik görülmedi. Tedavi grubunda alfa açısının azaldığı görüldü (-4.2 ± 6°), ancak bu değişiklik kontrol grubu ile karşılaştırıldığında anlamlı değildi. Kontrol grubu ile karşılaştırıldığında tedavi grubunda ön ve arka temporomandibular eklem boşluklarının arttığı belirlendi (P<0.05).
Sonuçlar: Protraksiyon yüz maskesi tedavisi ile birlikte hızlı maksiller genişletme sonrasında, kondilde morfolojik değişikliklerin olmadığı, ancak postüral bir değişiklik olduğu gözlendi. Bu değişikliklerin klinik olarak anlamlı olup olmadığını ve hızlı maksiller genişletme apareyi veya protraksiyon yüz maskesi tedavisi nedeniyle meydana gelip gelmediğini belirlemek için daha uzun süreli çalışmalara ihtiyaç vardır.

Anahtar Sözcükler: Protraksiyon yüz maskesi, Hızlı maksiller ekspansiyon, MRI, Temporomandibular eklem, Kondil.

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INTRODUCTION

The aetiology of a Class III malocclusion includes a protrusive mandible or mandibular dentition and a retrusive maxilla or maxillary dentition, or a combination of these factors (1). Maxillary deficiency is the underlying aetiology of a Class III malocclusion in an average of 60% of cases (2, 3). A Class III malocclusion with maxillary retrusion is often corrected by rapid maxillary expansion (RME) and maxillary protraction using a facemask (FM) (4). FM combined with RME treatment (RME/FM) has been shown in several studies to be beneficial when used at a young age or to reduce the need for orthognathic surgery (5-7). Furthermore, if the vertical or horizontal discrepancy between centric relation (CR) and maximum occlusal intercuspation (MI) is greater than 2 mm, temporomandibular disorders (TMD) may require consideration (8). FM treatment may also be used to correct the CR–MI relationship (9).

Before puberty, FM treatment has been found to have an orthopaedic effect by moving the maxilla forward (with a counter clock wise rotation) and the mandible back and down (with a backward-downward rotation), as well as correcting a negative overjet and the dental Class III malocclusion (9). The recommended orthopaedic force applied during RME/FM treatment is approximately 1000 gr, and the exerted forces on the chin is approximately 700–750 gr (10). Similar to chin-cup treatment, this reactive force transmitted to the mandible may cause changes in condyle position (11).Splint treatment may be applied in TMD problems to eliminate CR–MI incompatibilities, and this approach may also be effective in reprogramming the neuromuscular system (12).By providing a direct view of the articular disc, magnetic resonance imaging (MRI) is used to assess the temporomandibular joint (TMJ) disc and condyle complex. No soft tissue distortion, clear visualisation, non-invasiveness, multiplanar cross-sectional imaging and no exposure to ionising radiation are significant advantages of using MRI (13). Gokalp and Kurt, in a study evaluating the effect of chin-cup treatment on condyle growth and the temporomandibular disc, stated that chin-cup application could change the growth pattern of the condyles which could be evaluated effectively using MRI (14).

Following a literature review, no direct comparison was found of the effects of rapid maxillary expansion and facemask (RME/FM) appliance treatment on the articular disc–condyle complex position. The aim of this MRI study was to assess to what extent the articular disc–condyle complex was affected by RME/FM appliance treatment. The null hypothesis indicated that there would be no statistically significant differences between the RME/FM and control groups.

METHODS

The sample size was calculated based on a power analysis using G*Power Software version 3.1.9.2 (Universität Düsseldorf, Germany) for posterior angle at alpha error probability of 0.05 and a power of 95% (effect size = 1.741) (14). The power analysis showed that 16 samples were required, totally; the present study was performed on 25 subjects to strengthen the findings of the study. The samples consisted of 25 skeletal Class III maxillary retrusion patients (15 treatment group; 10 control group) who met the following inclusion criteria:

- No congenital anomaly and no clinical symptoms of TMD,
- According to the cervical vertebrae maturation method (CVM), the patients were in the CS 2 or CS 1 stage (prepubertal stage),
- The presence of anterior crossbite and bilateral posterior crossbite,
- Dental Class III molar relationship,
- Skeletal Class III patients (determined by cephalometric films, indicating an ANB angle of 0° or less; and the distance between the Nasion perpendicular to the A-point of 2 mm or less),

The Erciyes University's Regional Ethical Committee on Research authorised ethics approval. The same orthodontic treatment protocol was utilised for all cases in the treatment group. The samples consisted of 25 children displaying a Class III malocclusion. There were 15 patients in the treatment group, comprising ten girls and five boys (mean age: 10.5±1.03 years), and ten patients comprising 5 girls and 5 boys in the control group (mean age: 9.33±0.83 years). At the same time the control group consisted of patients of similar age who had not accepted RME/FM treatment. MRI records of these patients were obtained with the informed consent of their parents.

RME/FM Treatment Design

A Petit type facemask was used in the treatment group (Figure 1) (15). The RME was a bonded full-coverage maxillary acrylic splint expander with embedded vestibular hooks (hooks were located between upper lateral incisors and canines and also 0–15 mm above from the occlusal plane). Heavy elastics (500 gr force on the right and left sides as 1000 gr in total) were applied for RME/FM traction. To reduce open bite during maxillary protraction, the elastics were positioned at -20° angle to the occlusal plane. RME application was performed in such a way that the expansion screw was rotated twice a day for the first week, then once a day until the maxillary and mandibular transverse dimensions were compatible (4). The expansion protocol was modified depending on each patient's individual needs; however, all patients routinely activated the appliance twice a day for a week before the facemask was applied, and then one turn per day for those who required additional expansion. The opening of the midpalatal suture was followed by verifying occlusal films. Figure 2 shows the RME appliance design and occlusal films of a patient. Apart meal time, the patients were instructed to use the FM all the time, and instructions for the use and care of the appliance during treatment were also provided. The facemasks were used for a daily minimum of 18 hours for at least 6 months (mean treatment time 10.5±2.6 months) until a positive overjet was obtained. RME/FM therapy was applied to the treatment group, whereas the control group was observed without orthodontic intervention.

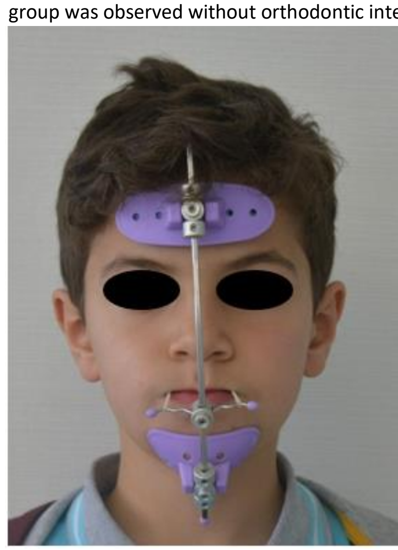

Figure 1. Petit type facemask design used in this study.

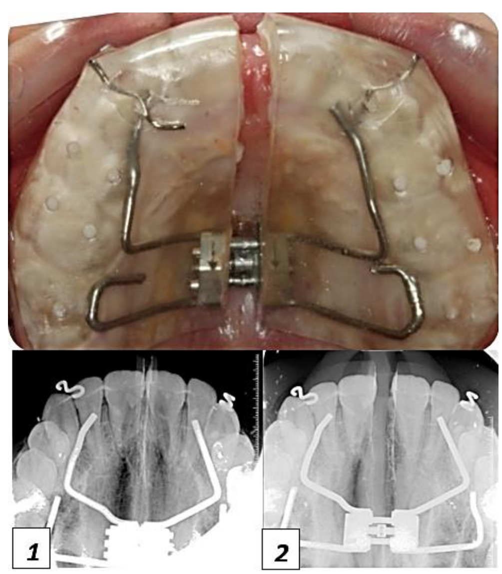

Figure 2. Full coverage acrylic splinted bonded RME appliance design and occlusal films of a patient (1: Before expansion, 2: The opening of the midpalatal suture after expansion).

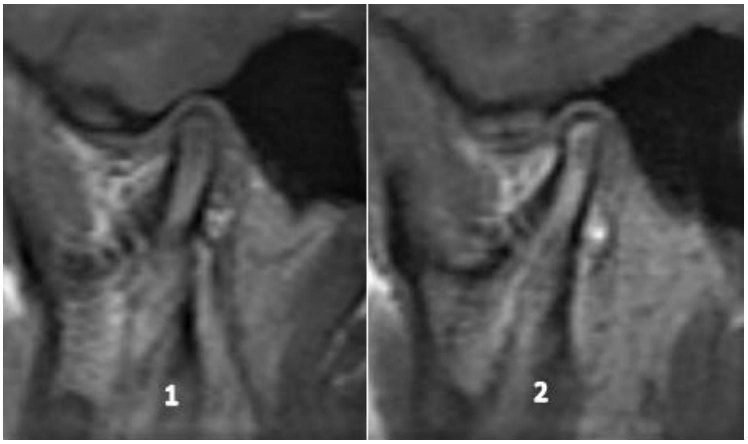

Figure 3. Pre (1) and post-treatment (2) MRI images of a patient's TMJ region in the RME/FM treatment group.

MR Images

A comprehensive MRI examination of each pair of TMJs was performed by using 1.5 T superconductive MR equipment (Philips Gyroscan, Best, the Netherlands). T1-W spin echo (TR, 100; TE, 600), axial T2-W spin echo (TR, 100; TE, 2,000), coronal FLAIR (TR, 100; TE, 4,500), and thin-section inversion recovery images were acquired. The morphology of the condyle, the position of the articular disc's relative to the condyle, and the position of the condyle in the glenoid fossa were all determined. MRIs were obtained at maximum occlusal intercuspation. The mean time between MRI scans in the treatment group was 10.5±2.6 months, and in the control group was 10.8±3.1 months. Pre and post-treatment MRI images of a patient's TMJ region in the RME/FM treatment group are shown in Figure 3.

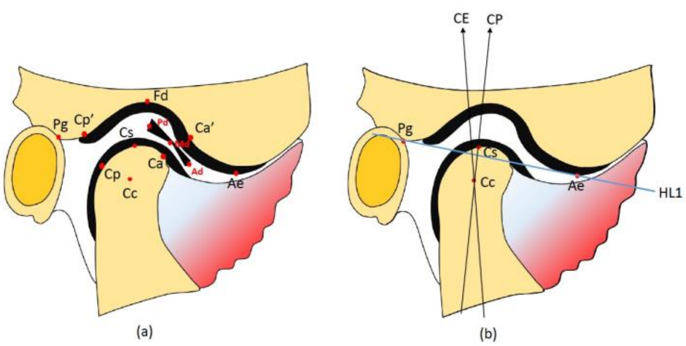

Figure 4. (a): The anatomical landmarks determined on MRIs. Cc: centre of condyle, Cs: superior edge of functional surface of condyle, Ae: the lowest point of the articular eminence, Pg: the lowest point of the postglenoid process , Fd: the deepest point of the glenoid fossa, Pd: the middle of posterior disc band, Md: the middle of intermediate region of disc, Ad: the middle of anterior disc band, Ca: anterior edge of functional surface of condyle, Ca': the projection point where the perpendicular exiting from the Ca point intersects the surface of the glenoid fossa facing the front of the condyle, Cp: point formed by the tangent drawn from the top of the glenoid fossa to the posterior surface of the condyle, Cp': the projection point where the perpendicular exiting from the Cp point intersects the glenoid fossa surface facing the posterior side of the condyle.

(b): Anatomical lines used in this study. Collum Axis (CE): The plane created from the middle of the collum mandible parallel to the posterior margin of the ramus in the sagittal MR image, Condyle Plane (CP): The plane passing through the points Cs and Cc, HL1 line: the line between the Ae and Pg points.

Anatomical Landmarks & Measurements

The following anatomical landmarks, lines and measurements were used to assess changes in condyle morphology, condyle position in the glenoid fossa, and articular disc position according to the condyle:

1. Anatomical landmarks (Figure 4a);
2. The lines used in the study (Figure 4b);
3. Morphological measurements (Figure 5);
4. The angular dimensions of the location of the disc with respect to the condyle (Figure 6);
5. Measurements determining the condyle position in the glenoid fossa (Figure 7);

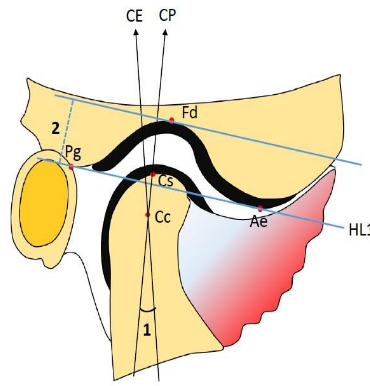

Figure 5. Morphological measurements used in this study: Alpha angle (1); Angle between the condyle plane (CP) and the collum axis (CE) and gives information about the condyle shape so the bending between the condyle head and the condyle neck, Fossa depth (2); The distance between Fd point and the HL1 line and indicates the morphological changes of the glenoid fossa.

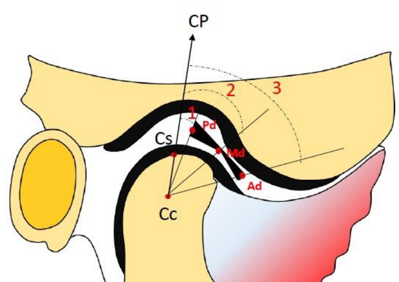

Figure 6. Angular measurements determining the position of the TMJ disc relative to the condyle: Posterior angle between Cs, Cc and Pd points (1), Medial angle between Cc, Cs and Md points (2), Anterior angle between Cc, Cs and Ad points (3).

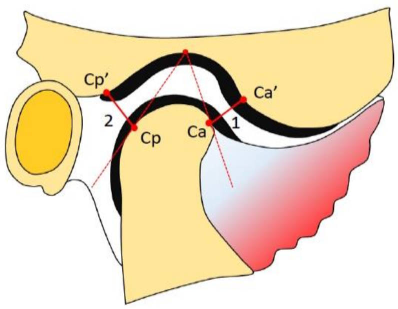

Figure 7. Measurements determining the position of the condyle in the glenoid fossa: Anterior joint space; perpendicular distance between Ca and Ca' points (1), Posterior joint space; perpendicular distance between Cp and Cp' points (2).

Statistical methods

The right and the left TMJ sides were compared with the Wilcoxon signed-rank test and since there was no determined difference, the data were pooled. The groups were compared at T1 with a Mann-Whitney U test, and treatment changes (T1–T2) were evaluated with a Wilcoxon signed-rank test. The statistical significance was established at P<0.05. All measurements were performed by the same researcher and measurements were made by numbering MRI images and lateral cephalograms (without individual, study group and timing information). For the purpose of determining method error, all material was re-evaluated three weeks after the completion of all drawings and measurements. The ICC (intraclass correlation coefficient) was used to determine the method error of the measured values, and correlation coefficients 'rs' were calculated by comparing the first and second measurements with each other. The ICC determined for all measurements was close to 1.00 (0.846–1.00).

RESULTS

At the beginning (T1) and end (T2) of the treatment, the comparison of MRI measurements between the treatment and control groups are shown in Table 1. The comparison of the T1–T2 differences of the MRI measurements between the groups are provided in Table 2. A comparison of cephalometric measurements between groups in the T1 period are shown in Table 3. Lateral cephalometric changes (T2-T1) in RME/FM and control groups are shown in Table 4 and a comparison of lateral cephalometric measurement changes (T2-T1) between the groups are shown in Table 5.

Table 1. Measurements in treatment and control groups at T1 and T2.

Table 1. Measurements in treatment and control groups at T1 and T2.

Measurements	RME/FM Group					Control Group				
	Pre-treatment (T1)		Post-treatment (T2)		P value*	Pre-treatment (T1)		Post-treatment (T2)		P value*
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Alpha Angle	18.70	6.93	14.47	9.76	0.016	17.72	10.02	18.44	6.06	0.760
Posterior Angle	25.40	9.61	21.20	5.54	0.216	23.06	12.37	23.78	8.47	0.810
Medial Angle	20.60	10.42	23.77	10.98	0.420	22.50	10.19	16.89	8.96	0.146
Anterior Angle	71.46	13.55	73.67	15.95	0.617	64.61	19.28	65.72	17.01	0.817
Anterior Joint Space	2.26	0.52	2.80	0.57	0.000	2.69	0.40	2.72	0.49	0.838
Posterior Joint Space	2.23	0.42	2.75	0.57	0.004	2.85	0.37	2.75	0.33	0.616
Fossae Depth	4.97	0.67	5.33	0.73	0.028	4.66	0.79	5.02	0.68	0.077

SD, Standard Deviation.

Table 2. Statistical comparison of the group differences.

Measurements	RME/FM Group		Control Group		P value* (RME/FM-Control)
	Mean	SD	Mean	SD	
Alpha Angle	-4.23	6.01	0.72	6.85	0.060
Posterior Angle	-4.20	12.55	0.72	8.74	0.233
Medial Angle	3.17	14.75	-5.61	10.45	0.152
Anterior Angle	2.20	16.67	1.11	13.96	0.633
Anterior Joint Space	0.53	0.42	0.03	0.47	0.008**
Posterior Joint Space	0.51	0.57	-0.10	0.58	0.032*
Fossae Depth	0.36	0.56	0.36	0.53	0.720

SD, Standard Deviation.

Table 3. Comparison of initial (T1) lateral cephalometric measurements between groups.

Measurement	RME/FM		Control Group		P Value
	Mean	(SD)	Mean	(SD)	
Skeletal Measurements					
Upper Face Height (N-ANS)* (mm)	45.07	(1.95)	45.81	(3.62)	0.511[x]
Anterior Facial Height (ANS-Me) (mm)	55.25	(4.42)	55.65	(4.62)	0.828[x]
SNA (º)	77.20	(2.69)	77.32	(2.57)	0.331[y]
SNB (º)	79.29	(2.85)	79.56	(2.73)	0.813[x]
ANB (º)	-2.10	(1.43)	-2.24	(1.76)	0.829[x]
MP - SN (º)	34.95	(2.71)	34.51	(2.43)	0.657[y]
Wits Appraisal (mm)	-5.91	(2.98)	-6.61	(2.60)	0.374[y]
Convexity (NA-APo) (º)	-4.50	(3.91)	-5.38	(4.40)	0.605[x]
Dental Measurements					
Overjet (mm)	-2.63	(1.24)	-1.86	(1.32)	0.150[x]
Overbite (mm)	1.22	(1.95)	2.25	(3.02)	0.309[x]
Interincisal Angle (U1-L1) (º)	131.74	(10.83)	135.29	(10.37)	0.423[x]
U1 - SN (º)	101.93	(7.41)	103.36	(9.04)	0.668[x]
IMPA (L1-MP) (º)	91.37	(5.77)	86.84	(5.03)	0.055[x]
Soft Tissue Measurements					
Nasolabial Angle (Col-Sn'-ULA) (º)	113.47	(8.36)	107.04	(14.44)	0.171[x]
Soft Tissue Convexity (º)	136.23	(4.53)	135.65	(2.96)	0.727[x]

SD, Standard Deviation; [x]Results of independent-t test; [y]Results of Mann Whitney U test.

Table 4. Lateral cephalometric changes (T2-T1) in RME/FM and Control groups.

Measurements	RME/FM Group T1 Mean (SD)	RME/FM Group T2 Mean (SD)	P Value	Control Group T1 Mean (SD)	Control Group T2 Mean (SD)	P Value
Skeletal Measurements						
Upper Face Height (N-ANS)	45.07 (1.95)	47.47 (2.27)	<0.001ˣ	45.81 (3.62)	47.18 (3.26)	0.022ˣ
Anterior Facial Height (ANS-Me)	55.25 (4.42)	61.95 (5.42)	<0.001ˣ	55.65 (4.62)	56.66 (4.37)	0.136ˣ
SNA (º)	77.20 (2.69)	80.62 (3.70)	0.001ˣ	77.32 (2.57)	78.01 (2.84)	0.168ʸ
SNB (º)	79.29 (2.85)	77.73 (2.93)	0.016ˣ	79.56 (2.73)	80.72 (3.34)	0.008ˣ
ANB (º)	-2.10 (1.43)	2.89 (2.07)	0.001ʸ	-2.24 (1.76)	-2.70 (1.76)	0.181ˣ
MP - SN (º)	34.95 (2.71)	38.77 (5.00)	0.001ʸ	34.51 (2.43)	33.65 (2.76)	0.356ˣ
Wits Appraisal (mm)	-5.91 (2.98)	-2.98 (1.50)	0.004ʸ	-6.61 (2.60)	-7.51 (2.58)	0.057ˣ
Convexity (NA-APo) (º)	-4.50 (3.91)	6.63 (5.44)	<0.001ˣ	-5.38 (4.40)	-6.01 (4.38)	0.396ˣ
Dental Measurements						
Overjet (mm)	-2.63 (1.24)	2.31 (1.52)	<0.001ˣ	-1.86 (1.32)	-1.75 (1.61)	0.822ˣ
Overbite (mm)	1.22 (1.95)	0.47 (1.86)	0.169ˣ	2.25 (3.02)	2.45 (2.49)	0.704ˣ
Interincisal Angle (U1-L1) (º)	131.74 (10.83)	130.95 (9.27)	0.684ˣ	135.29 (10.37)	135.97 (7.17)	0.752ˣ
U1 - SN (º)	101.93 (7.41)	101.87 (4.80)	0.975ˣ	103.36 (9.04)	104.79 (6.70)	0.398ˣ
IMPA (L1-MP) (º)	91.37 (5.77)	88.41 (6.69)	0.095ˣ	86.84 (5.03)	85.60 (5.13)	0.478ˣ
Soft Tissue Measurements						
Nasolabial Angle (Col-Sn'-ULA)	113.47 (8.36)	110.81 (10.61)	0.304ˣ	107.04 (14.44)	112.27 (9.52)	0.158ˣ
Soft Tissue Convexity (º)	136.23 (4.53)	131.95 (4.33)	0.001ˣ	135.65 (2.96)	137.26 (2.90)	0.039ˣ

Table 5. Comparison of lateral cephalometric parameters changes (T2-T1) between groups.

Measurements	RME/FM Group Mean	RME/FM Group (SD)	Control Group Mean	Control Group (SD)	P Value
Skeletal Measurements					
Upper Face Height * (mm)	2.41	(1.94)	1.37	(1.57)	0.173ˣ
Anterior Facial Height (mm)	6.70	(3.84)	1.01	(1.95)	<0.001ˣ
SNA (º)	3.42	(3.15)	0.69	(1.35)	0.007ˣ
SNB (º)	-1.56	(2.20)	1.16	(1.09)	0.008ʸ
ANB (º)	4.99	(2.62)	-0.46	(1.00)	<0.001ˣ
MP - SN (º)	3.81	(3.33)	-0.86	(2.79)	0.001ˣ
Wits Appraisal (mm)	2.93	(2.95)	-0.90	(1.31)	<0.001ˣ
Convexity (NA-APo) (º)	11.13	(5.72)	-0.63	(2.24)	<0.001ˣ
Dental Measurements					
Overjet (mm)	4.94	(1.86)	0.11	(1.50)	<0.001ˣ
Overbite (mm)	-0.75	(2.01)	0.20	(1.61)	0.223ˣ
Interincisal Angle (U1-L1) (º)	-0.79	(7.40)	0.68	(6.60)	0.616ˣ
U1 - SN (º)	-0.05	(6.51)	1.43	(5.09)	0.550ˣ
IMPA (L1-MP) (º)	-2.96	(6.39)	-1.24	(5.30)	0.489ˣ
Soft Tissue Measurements					
Nasolabial Angle (º)	-2.66	(9.66)	5.23	(10.75)	0.068ˣ
Soft Tissue Convexity (º)	-4.27	(3.80)	1.61	(2.11)	<0.001ˣ

SD, Standard Deviation; ˣResults of Independent-t test; ʸResults of Mann Whitney U test.

At T1, no statistically significant differences were found between the groups in any of the MRI and cephalometric measurements parameters.Anterior, posterior and medial angles were used to determine disc position. The absence of a significant change in these angles indicated that the articular disc position was preserved in both the control and treatment groups (Table 1). No significant changes were seen in disc position between the groups.

In the treatment group, the alpha angle reduced by -4.2 ± 6^0, and this change was statistically significant (P=0.02). However, the change was not significant when compared with the control group (P=0.06). Only anterior and posterior joint spaces changed significantly when compared to the control group. Therefore the null hypothesis was rejected. The anterior joint space increased by 0.5 ± 0.4 mm, and the posterior joint space increased by 0.5 ± 0.5 mm (P<0.05) in the treatment group. However, in the control group there was no statistically significant change in these parameters. The fossa depth indicating morphological changes in the glenoid fossa, increased significantly in the treatment group (P<0.05), whereas no significant change was observed in the control group.A statistically significant difference was observed in the alpha angle, fossa depth, anterior and posterior joint space parameters in the treatment group, while the increase in the anterior and posterior joint spaces was significant when the treatment group was compared with the control group.

When the cephalometric measurements were evaluated, in the RME/FM group at T1 time ANB angle was -2.10±1.43°, while it increased to 2.89±2.07° after the treatment (P=0.001). In the control group, ANB angle decreased from -2.24±1.76° to -2.70±1.76° (P=0.181). The mandibular plane angle (MP-SN) increased by an average of 3.81±3.33° in the treatment group which was significant when compared to the control group (P=0.001). This increase in mandibular plane angle is thought to be associated with a clockwise posterior rotation of the mandible after RME/FM treatment. While the soft tissue convexity angle decreased by an average of -4.27±3.80° in the RME/FM group, a significant increase was observed by 1.61±2.11° in the control group (P<0.001).

DISCUSSION

It has been reported that the use of the chin as an anchorage point by various appliances used in the early treatment of skeletal Class III malocclusion, affects the TMJ. A FM that applies pressure to the maxilla by receiving support from the chin transfers around 75% of the force to the TMJ (16). Although earlier studies have reported that the retractive forces applied to the mandible do not create an inflammatory response in the retroarticular region (17, 18), some studies have noted a disruption in the relationship between the components of the TMJ (14).

There was an attempt to match the chronological/skeletal age and cephalometric features of the control group with the treatment group. The control group was comprised of Class III cases who rejected treatment, but who consented to being examined for inclusion as a Class III control group (19). There are inconsistent reports in the literature identifying the optimal age for FM treatment. Takada et al. (20) studied maxillary protraction and chin cup therapy and reported that both in the prepubertal and midpubertal groups, the maxilla was more anteriorly displaced than expected by natural growth. Similarly, Baik (21) concluded from statistical comparisons that RME/FM treatment in younger children was not significantly different from that seen in older children. Contrarily, Baccetti et al. (22) found more forward movement of A-point in the early treatment group (age 7 years and 7 months) than in the late treatment group (age 8 years and 8 months). In addition, Sarangal et al. (23) stated that the ideal age for facemask therapy is 6–8 years, and it can be started as soon as the patient can accept the appliance and comply with instructions. In the present study, the mean age was 10.5±1.03 years for the treatment group. Although FM therapy is more effective at an early age, it can also provide a viable option for older children (24). Further studies are recommended to determine the changes in the TMJ following RME/FM therapy in younger age groups.

RME treatment affects the articulations of the maxillary sutures, which facilitates the maxillary protraction (25). According to the results of a previous meta-analysis, similar skeletal changes were noted in the group in which RME was applied with a facemask and a group in which only a facemask was applied. The treatment time was unaffected by the existence of deciduous, early- or late-mixed dentition (19). In the present study, facemask application was initiated seven days after RME activation in the treatment group. The RME/FM expansion continued with until each patient's transverse dimension was corrected by the full-coverage, bonded and acrylic splint device.

Cannavale et al. (26) stated in their meta-analysis, that although the RME is the best treatment option in individuals with a bilateral crossbite, the effects of symmetrical expansion on facial asymmetry and the TMJ should be well evaluated in unilateral crossbite and facial asymmetry cases. Since all patients included in the present study had a bilateral posterior crossbite, the RME appliance was considered as the correct treatment approach. However, in cases of craniofacial asymmetry, sutural involvement during the course of RME treatment, especially when followed by FM, has the risk of worsening the skeletal asymmetry. Although it was concluded that FM and RME/FM treatments may not be effective in the long term in correcting maxillary sagittal retrusion in growing patients, future studies are needed to evaluate the skeletal benefits of RME/FM treatment on the maxilla in the sagittal, vertical and transversal dimensions (4).

The effects of RME/FM therapy were investigated using MRI to assess the location of the disc and condyle in the glenoid fossa, as well as the morphology of the condyle, disc and the fossa. MRI is an effective imaging method used for detailed examination of the temporal bone and temporomandibular joint area (27). Furthermore, cone beam computed tomography (CBCT) is another effective diagnostic method for TMJ bone components. With CBCT imaging, data can be obtained about the shape of the articular surfaces, the condyle head, and the width of the joint spaces in the TMJ region, but the biggest disadvantage of CBCT compared to MRI is the high-dose radiation (28).

In the present study; the posterior angle, between the condylar plane and the posterior band of the disc was assessed, to determine the disc–condyle relationship and the position of the disc relative to the condyle as a result of the treatment. Because there were no statistically significant changes in other angles (medial, anterior angles) determining the disc position, it was concluded that the RME/FM treatment did not significantly alter the disc position.

The alpha angle, which provides information about the angulation between the condyle head and the neck, and about condylar shape, reduced, and the change was statistically significant. A relationship between mechanical stresses and bone remodelling has been previously reported (29). Gokalp and Kurt (14) stated after investigating the efficacy of chin-cup application on TMJ that the retractive forces applied to the mandible increased the activity of the lateral pterygoid muscle; therefore, the tension created by the distal pole of the lateral pterygoid muscle adhering to the anterior face of the condylar head increased osteoclastic activity in the region and, an angulation change occurred in the condyle neck. Depending on the retractive effect of the facemask and although there was a significant decrease in the alpha angle in the treatment group (P=0.02), the difference was not statistically significant when compared to the control group (P=0.06). Accordingly, it is likely that some of the changes seen in condyle morphology following RME/FM therapy are the result of growth and development.

The glenoid fossa and the mandibular condyle have a strong relationship in positional and dimensional metrics in patients with normal and abnormal facial profiles (30). Pullinger et al. (31) stated that the position of the condyle in the glenoid fossa can be evaluated with a ratio obtained as a percentage of the anterior-posterior joint spaces divided by the sum of their differences. In the present study, a statistically significant increase was observed in the anterior-posterior joint space distances in the treatment group. When this change was compared with the control group, it was also determined to be statistically significant. As a result, the condylar position in the glenoid fossa changed in the treatment group. The increase in anterior-posterior joint space may be related to the altered occlusal relationship and improvement of the anterior crossbite after RME/FM treatment. Huqh et al. (32) stated that the effects of an active skeletonised sutural distractor (ASSD) appliance on TMJ morphology in Class III malocclusion patients, caused significant alterations in joint spaces and condylar position. According to the findings of the present study, changes in the anterior-posterior joint spaces and in the condyle position, can be related to the type of RME applied. A full-coverage acrylic type RME appliance was used that caused an increase in the inter-occlusal distance, which may be a reason for the increase in the joint spaces. Further studies using different appliances such as a Hyrax type or mini-screw-supported RME that will not affect the inter-occlusal distance may be beneficial in making a definitive determination.

In order to determine the therapeutic effect of RME/FM therapy, it is important to evaluate the positional and morphological changes in the TMJ. In the present study, the fossa depth was measured and increased significantly in the treatment group (P=0.03). However, when compared with the control group, this change was not statistically different. Mimura and Deguchi (33) observed no change in fossa depth as a result of chin-cup therapy when compared with a control group, although Deguchi and McNamara (34) found an increase in the depth of the glenoid fossa due to the chin-cup treatment of Class III patients.

There were some limitations identified in the present study. Although the number of individuals was compatible with similar studies, it would be beneficial to incorporate a greater number of individuals of matching genders. Although MRI is an effective method for imaging the soft tissues in the TMJ region, it may be insufficient for measurements made of hard tissue regions such as the alpha angle. An additional limitation was that difficulties in determining which appliance was responsible for the significant changes in the TMJ. MRI images were taken at maximum dental intercuspation and immediately after the end of treatment. RME/FM treatment changes the occlusal relationships, which may also affect the TMJ findings immediately, and so it would be useful to conduct studies evaluating the long-term TMJ changes of RME/FM therapy.

In the present study, treatment effects produced by the RME/FM appliances on the TMJ disc and condyle were evaluated. The major findings were:

1. RME/FM treatment, which was applied during early growth and development stages and by applying protraction forces within physiological limits, did not cause positional and morphological changes in the articular disc.
2. RME/FM treatment caused a statistically significant increase in the anterior-posterior joint spaces, indicating the position of the condyle in the glenoid fossa had changed.
3. The clinical significance of the change in the position of the condyle was uncertain. Further long-term studies are required to determine whether the changes are clinically significant and are produced by the RME appliance or FM therapy.

Conflict of interest

No conflict of interest was declared by the authors.

REFERENCES

1. Toffol LD, Pavoni C, Baccetti T, Franchi L, Cozza P. Orthopedic treatment outcomes in Class III malocclusion: A systematic review. Angle Orthod. 2008, 78(3), 561–73.

2. Guyer EC, Ellis EE, McNamara JA Jr, Behrents RG. Components of Class III malocclusion in juveniles and adolescents. Angle Orthod. 1986;56:7–30.

3. Al Dayeh A, Williams RA, Trojan TM, Claro WI. Deformation of the zygomaticomaxillary and nasofrontal sutures during bone-anchored maxillary protraction and reverse-pull headgear treatments: An ex-vivo study. Am J Orthod Dentofacial Orthop. 2019;156(6):745–57.

4. Lee WC, Shieh YS, Liao YF, Lee CH, Huang CS. Long-term maxillary three dimensional changes following maxillary protraction with or without expansion: A systematic review and meta-analysis. J Dent Sci. 2021;16(1):168–77.

5. Nevzatoğlu S, Küçükkeleş N. Long-term results of surgically assisted maxillary protraction vs regular facemask. Angle Orthod. 2014, 84(6), 1002–9.

6. Cordasco G, Matarese G, Rustico L, Fastuca S, Caprioglio A, Lindauer SJ, Nucera R. Efficacy of orthopedic treatment with protraction facemask on skeletal Class III malocclusion: A systematic review and meta-analysis. Orthod Craniofac Res. 2014, 17(3), 133–43.

7. Mandall N, Cousley R, DiBiase A, Dyer F, Littlewood S, Mattick R, Worthington HV. Early Class III protraction facemask treatment reduces the need for orthognathic surgery: A multi-centre, two-arm parallel randomized, controlled trial. J Orthod. 2016, 43(3), 164–75.

8. Lim WH, et al. Dentofacial characteristics in orthodontic patients with centric relation–maximum intercuspation discrepancy. Angle Orthod, 2014, 84.6: 939–45..

9. McNamara JA Jr, Brudon WL. Orthodontics and Dentofacial Orthopedics. Ann Arbor: Needham Press; 2001, 256-262.

10. Grandori F, Merlini C, Amelotti C, Piasente M, Tadini G, Ravazzani P. A mathematical model for the computation of the forces exerted by the facial orthopedic mask. Am J Orthod Dentofacial Orthop. 1992;101:441–8.

11. Mitani H, Fukazawa H. Effects of chincap forces on the timing and amount of mandibular growth associated with anterior reversed occlusion (Class III malocclusion) during puberty. Am J Orthod Dentofacial Orthod. 1986;90:454–63.

12. Karl PJ, Foley TF. The use of a deprogramming appliance to obtain centric relation records. Angle Orthod. 1999;69:117–25.

13. Jung WS, et al. Magnetic resonance imaging-verified temporomandibular joint disc displacement in relation to sagittal and vertical jaw deformities. Int J Oral Maxillofac Surg. 2013, 42.9: 1108–15.

14. Gokalp H, Kurt G. Magnetic resonance imaging of the condylar growth pattern and disc position after chin cup therapy: a preliminary study. Angle Orthod. 2005, 75.4: 568–75.

15. Petit H. Adaptations following accelerated facial mask therapy. In: McNamara JA, Ribbens KA, Howe RP, editors. Clinical Alteration of the Growing Face. Monograph no:14. Craniofacial Growth Series. Ann Arbor: Center for Human Growth and Development, University of Michigan; 1983. p. 14.

16. Deguchi T, Uematsu S, Kawahara Y, Mimura H. Clinical evaluation of TMJ in patients treated with chin-cup. Angle Orthod. 1998;68(1):91–4.

17. Gokalp H; Arat M; Erden I. The changes in temporomandibular joint disc position and configuration in early orthognathic treatment: a magnetic resonance imaging evaluation. Eur J Orthod. 2000, 22.3: 217–24.

18. Yagci A, Uysal T. Effect of modified and conventional facemask therapy on condylar position in Class III patients. Orthod Craniofac Res. 2010;13:246–54.

19. Zhang W, Qu HC, Yu M, Zhang Y. The Effects of Maxillary Protraction with or without Rapid Maxillary Expansion and Age Factors in Treating Class III Malocclusion: A Meta-Analysis. PLoS One. 2015; 11;10(6).

20. Takada K, Petdachai S, Sakuda M. Changes in dentofacial morphology in skeletal Class III children treated by a modified maxillary protraction headgear and a chin cup: a longitudinal cephalometric appraisal. Eur J Orthod. 1993;15; 211-21.

21. Baik HS. Clinical results of the maxillary protraction in Korean children. Am J Orthod Dentofac Orthop. 1995;108; 583-92.

22. Baccetti T, Franchi L, McNamara Jr JA. Treatment and posttreatment craniofacial changes after rapid maxillary expansion and facemask therapy. Am J Orthod Dentofacial Orthop. 2000; 118(4), 404-13.

23. Sarangal H, Namdev R, Garg S, Saini N, Singhal P. Treatment Modalities for Early Management of Class III Skeletal Malocclusion: A Case Series. Contemp Clin Dent. 2020;11(1):91-6.

24. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion therapy in Class III children: a comparison of three age groups. Am J Orthod Dentofacial Orthop. 1998;113(2):204-12.

25. Nanda R. Biomechanical and clinical considerations of a protraction headgear. Am J Orthod. 1980;78:125–39.

26. Cannavale R, Chiodini P, Perillo L, Piancino MG. Rapid palatal expansion (RPE): Meta-analysis of long-term effects. Orthod Craniofac Res. 2018;21(4):225-35.

27. Kim JY, Kim D, Jeon KJ, Kim H, Huh JK. Using deep learning to predict temporomandibular joint disc perforation based on magnetic resonance imaging. Sci Rep. 2021; 23,11(1):6680. **28.** Derwich M, Mitus-Kenig M, Pawlowska E. Temporomandibular Joints' Morphology and Osteoarthritic Changes in Cone-Beam Computed Tomography Images in Patients with and without Reciprocal Clicking-A Case Control Study. Int J Environ Res Public Health. 2020;14;17(10):3428.

29. Tanne K, Sakuda M. Biomechanical and clinical changes of the craniofacial complex from orthopedic maxillary protraction. Angle Orthod. 1991;61:145–52.

30. Almashraqi AA. Dimensional and Positional Associations between the Mandibular Condyle and Glenoid Fossa: A Three-dimensional Cone-beam Computed Tomography-based Study. J Contemp Dent Pract. 2020;21(10):1075–83.

31. Pullinger A, Solberg W, Hollender L. Tomographic analysis of mandibular condyle position in diagnostic subgroups of TMD. J Prosthet Dent. 1986;55:723–9.

32. Huqh MZU, Hassan R, Rahman RA, Yusof A, Narmada IB, Ahmad WMAW. The Short-Term Effect of Active Skeletonized Sutural Distractor Appliance on Temporomandibular Joint Morphology of Class III Malocclusion Subjects. Eur J Dent. 2021 Feb 23.

33. Mimura H, Deguchi T. Morphological adaptation of TMJ after chin-cup therapy. Am J Orthod Dentofacial Orthop. 1996;110:541–6.

34. Deguchi T, McNamara JA. Craniofacial adaptations induced by chin-cup therapy in Class III patients. Am J Orthod Dentofacial Orthop. 1999;115:175–82.