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ORIGINAL ARTICLE

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Effect of modified and conventional facemask therapy on condylar position in Class III patients

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Structured Abstract

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Objectives – To assess the effects of varying force direction of maxillary orthopedic protraction on mandibular condylar position.

Material and Methods – The conventional facemask group (Group 1) comprised 22 patients, 11 girls, and 11 boys (mean age: 9.3 ± 1.3 years); the modified facemask group (Group 2) comprised 22 patients, 12 girls, and 10 boys (mean age: 9.4 ± 1.5 years); and the control group (Group 3) comprised 21 subjects, 11 girls, and 10 boys (mean age: 9.8 ± 1.9 years). Changes in mandibular position indicator (MPI®) measurements of the SAM®3 articulator were evaluated. Treatment and control changes within groups and between groups were analyzed statistically. Intra-group comparisons were tested with the non-parametric Wilcoxon's test and inter-group changes with Kruskal–Wallis. The statistical significance of inter-group differences was further assessed with the Mann–Whitney test for independent samples with Bonferroni's correction.

Results – Antero-posterior positional changes of the left condyle were found higher in the controls than in Group 1 ($p < 0.016$). Superior–inferior positional changes of the left condyle were also found significantly higher in controls than in Group 2 ($p < 0.016$). No other significant changes in condylar position were determined in either group. In the treatment groups, asymmetrical condylar position diminished and became symmetrical with treatment in the antero-posterior direction (Group 1: 13.64%, Group 2: 36.37%) plane. In controls, the antero-posterior change of asymmetry was smaller (antero-posterior change: 7.60%).

Conclusion – These findings generally suggest that modified and conventional facemask therapy with expansion had no adverse effects on the temporomandibular and masticatory system.

Key words: Angle Class III; extraoral traction appliances; malocclusion; mandibular condyle; palatal expansion technique

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Introduction

The Class III malocclusion can exhibit a variety of skeletal and dental components including a large or protrusive mandible, deficient or retrusive maxilla, protrusive mandibular dentition, retrusive maxillary dentition, and combinations of these components (1–3). In most cases, Class III malocclusions are characterized by an average of a 60% maxillary deficiency (3, 4). Protraction of the maxilla with a facemask is a common treatment for Class III malocclusion with maxillary retrusion, especially at early ages. McNamara and Brudon (1) claimed that facemask therapy can produce a correction of CO–CR discrepancy.

Before the adolescence growth period, facemask therapy enables a forward orthopedic effect on the maxilla, often accompanied by a counterclockwise rotation of the maxilla and clockwise rotation of mandible (1). Counterclockwise rotation of maxilla is a benefit in the treatment of low-angle, deep bite Class III patients, but it is not recommended in Class III cases with high-angle skeletal patterns and anterior open bites (5). To eliminate these undesired side effects, some investigators have applied the protraction force nearby the center of resistance of the maxilla with a modified face bow. Investigators showed that modified facebow application method is an effective way to prevent counterclockwise rotation of maxilla (5, 6).

In orthodontic treatment, seated and concentric condyle position is the most favorable position to be established (7). Non-coincidence of seated centric relation (CR) and centric occlusion (CO) can result in occlusal interferences on all teeth in every plane of space and mandibular displacements on closing in all directions (8). Slavicek (9) described the use of the SAM®3 (Great Lakes Orthodontics, Tonawanda, NY, USA) articulator with mandibular position indicator (MPI®, Great Lakes Orthodontics, Tonawanda, NY, USA) to quantify the differences between the joint-dominated recorded condylar position and the tooth-dominated position of maximum intercuspal position (MI). Utt et al. (10) indicated that the SAM®3 articulator and MPI® enable the clinician to determine, record, and compare the positional changes of the condyle between CR and MI in all three spatial planes.

The force of the facemask acting on the chin is similar to the force exerted by the chin cup (11). The magnitude of the force exerted at the chin is approximately 700–750 g for an external protraction force of 1000 g. (12). This type of reactive force produced by the facemask on the chin may result in changes of the mandibular condylar position. Conventional and modified facemasks produce different reactive forces on the chin, which may have a different effect on mandibular condylar position. Splint therapy can be effective in deprogramming of the neuromusculature (13). Bonded rapid maxillary expansion appliances with full occlusal coverage have been introduced, and it is thought that these devices act like a splint. Similarly, it can be assumed that this type of appliance may also result in a change of the mandibular condyle position.

To our knowledge, the effects of modified facemask and conventional facemask therapy on mandibular condyle position in a direct comparison with a control group have not been studied earlier. The purpose of this prospective study was to assess the effects of varying force direction on mandibular condylar position changes at maxillary orthopedic protraction compared with control groups. The null hypothesis assumed that there was no statistically significant change in condyle position with conventional and modified facemask–expansion therapy compared to controls.

Materials and methods

This study was approved by the Regional Ethical Committee on Research of the Erciyes University, Faculty of Dentistry. A power analysis established by G*Power Ver. 3.0.10. (Franz Faul, Universität Kiel, Germany) software, based on 1:1 ratio between groups, sample size of 21 patients would give more than 80% power to detect significant differences with 0.40 effect size and at $\alpha = 0.05$ significance level.

The samples consisted of the MPI records of 67 Class III patients with maxillary retrusion. Patients who fulfilled the following inclusion criteria were selected:

- Class III molar relationship,
- An anterior crossbite or edge-to-edge incisal relationship,
- ANB angle of 0° or less; and nasion perpendicular to A-point of 2 mm or less,
- No congenitally missing or extracted teeth,
- No deformity in nasomaxillary complex,
- Mandibular position indicator records of adequate quality available before and at the end of facemask–expansion therapy.

Patients with craniofacial anomalies, psychosocial problems, or skeletal open bite were excluded from the study.

Sixty-seven of 69 (34 girls and 33 boys) who met the inclusion criteria were selected, two patients were discarded because of insufficient cooperation. The conventional facemask treatment group (Group 1) comprised 22 patients, 11 girls, and 11 boys (mean age: 9.3 ± 1.3 years); the modified facemask treatment group (Group 2) 22 patients, 12 girls, and 10 boys (mean age: 9.4 ± 1.5 years); and the control group (Group 3) comprised 21 subjects, 11 girls, and 10 boys (mean age: 9.8 ± 1.9 years).

Mandibular position indicator records were obtained from all subjects at the pre- and post-treatment/control period. For Group 1, the treatment time was between 0.5 and 1.7 years (mean 1.1 ± 0.3 years); for Group 2 between 0.7 and 1.8 years (mean 1.2 ± 0.4 years); and the observation period was between 0.5 and 1.7 years (mean 0.93 ± 0.35 years).

To constitute the control group, MPI records were taken with parental permissions by obtaining informed consent from subjects/parents of those who did not accept treatment at that time.

Group 1 appliance design

In this group, a facemask (14) and a bonded full-coverage maxillary acrylic splint expander with vestibular hooks and heavy elastics (500 g, depending on the distance between the hooks of expansion appliance and the facemask) were used for orthopedic facemask therapy (2). Elastics were connected bilaterally to an adjustable midline crossbow on the Petit-type facemask (14). The protraction elastics were applied to the vestibular hooks attached between the lateral incisor and canine teeth 0–15 mm above the maxillary occlusion plane (Fig. 1) with a downward and forward pull of 20° to avoid bite opening during maxillary protraction (Fig. 2).

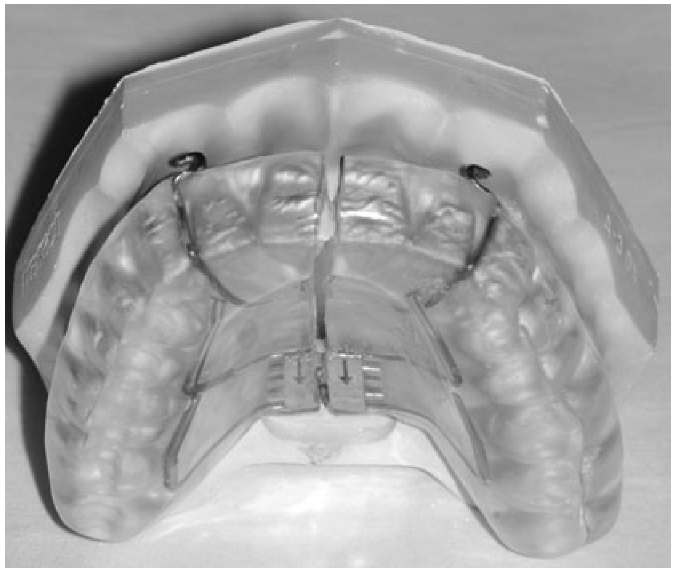

Fig. 1. Conventional bonded, full-coverage maxillary acrylic splint expander with vestibular hooks.

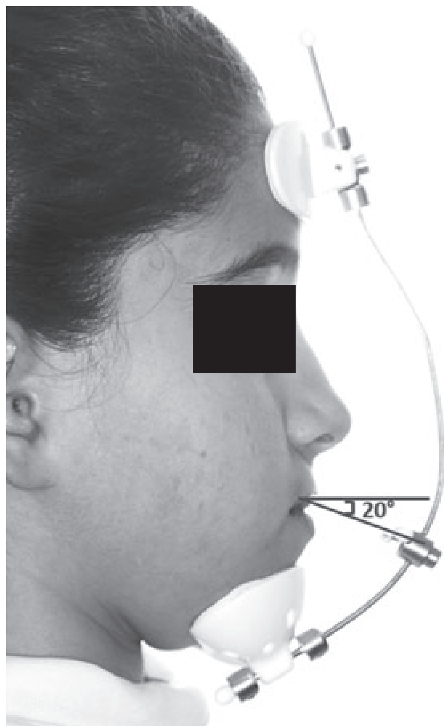

Fig. 2. Conventional facemask appliance and force direction used in the present study.

Group 2 appliance design

A modified bonded rapid maxillary expansion appliance with full occlusal coverage, a specially designed facebow, a facemask and heavy elastics (500 g, depending on the distance between the modified facebow hooks and the facemask) were used for orthopedic facemask therapy. The bonded expansion appliance was modified by adding two tubes (Activator Tubes, Dentaurum, Ispringen, Germany,) on the buccal side of the acrylic in the premolar area (Fig. 3). The purpose of these tubes was to accommodate the inner bows of the specially designed face bow. The facebow was constructed from an adjustable facebow (Std Ss Facebow, G&H Wire Company, Franklin, IN, USA). Intra-orally, the inner bows of the facebow had a special U-shape bend to enter the buccal tubes from the distal, and thus be able to retain the facebow, when an anterior pull was applied. The outer bow was bent upward 90 degrees to

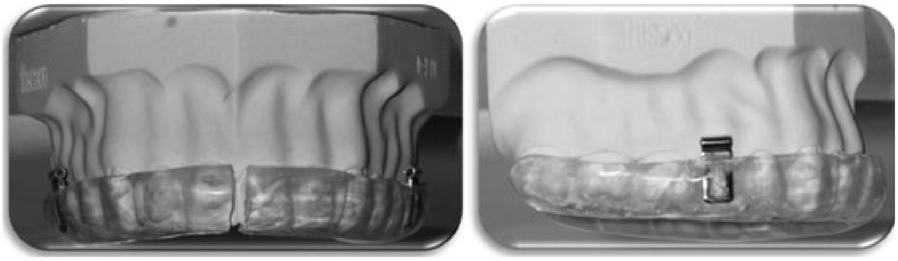

Fig. 3. Modified bonded, full-coverage maxillary acrylic splint expander with tubes.

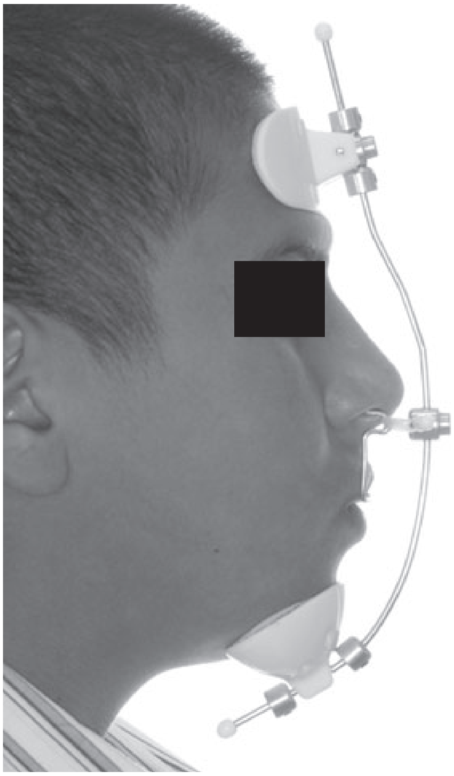

Fig. 4. Modified facemask appliance used in the present study.

provide a point of force application at the level of the dentomaxillary center of resistance and also to apply parallel forces at both sides (Fig. 4).

In both treatment groups, the midline expansion screw of the bonded maxillary expander was activated twice a day for the first week and once a day until the desired change (the lingual cusps of the upper posterior teeth approximating the buccal cusps of the lower posterior teeth) in the transverse dimension was achieved. Although the rate and amount of expansion depended on the individual need of each patient, patients received expansion twice a day for 7 days prior to facemask delivery, followed by one turn per day if additional expansion was necessary. Patients were instructed to wear the facemask full time except during meals. The appliance was used in both treatment groups until a positive overjet was accomplished.

MPI® records

The condylar position records were taken with the SAM®3 articulator (Great Lakes Orthodontics, Tonawanda, NY, USA) and the Mandibular Position Indicator (MPI®, Great Lakes Orthodontics). The technique of bimanual manipulation, described by Dawson, was used to locate the CR position (15). The operator guided the mandible, applying chin point pressure at pogonion to prevent protrusion, supporting the angles of the mandible in a superior direction, and asking the patient to relax and close slowly. The patient continued to close slowly until the lower anterior teeth were indexed and there was a 2 -mm posterior interarch vertical separation at the probable first contact. The wax section was cooled with the air syringe, removed, and placed in cold water to harden. The registration was inspected to ensure no cusp penetration through the wax. The wax registration was trimmed with a sharp scalpel to remove undercuts, soft tissue contacts, interproximal areas, and occlusal surfaces, while maintaining indexing of cusp tips and incisal edges. A MI wax bite registration was made with a single layer of dead-soft pink bite registration wax.

The maxillary stone cast was mounted on the upper member of the SAM®3 articulator with the anatomic facebow transfer. The mandibular cast was mounted on the articulator using the CR record. Condylar inclination was set at average values of 35°, and Bennett angulation was set at 0° to prevent any lateral movement of the condyles during mounting. The CR and MI MPI® markings were made on self-adhesive grid paper flags (9). The magnitude and direction between the CR and MI markings were measured and recorded for both sides. The transverse shift was measured with the dial gauge on the MPI® assembly. MPI® records used in the study are presented and defined in the Table 1. The ΔY value is negative when the MI position is on the left of the CR position. The ΔY value is positive when the MI position is on the right of the CR position. The ΔX

Table 1. **Condylar measurements used in the present study**

MPI measurements
ΔY: Condyle position distance between CR and CO in transverse plane
Left ΔX: Condyle position distance between CR and CO in horizontal plane for left side
Right ΔX: Condyle position distance between CR and CO in horizontal plane for right side
Left ΔZ: Condyle position distance between CR and CO in vertical plane for left side
Right ΔZ: Condyle position distance between CR and CO in vertical plane for right side

MPI, mandibular position indicator; CR, centric relation; CO, centric occlusion.

value is positive when the MI position is located anterior of the CR position. The ΔX value is negative when the MI position is posterior of the CR position. The ΔZ value is positive when the MI position is located inferior to the CR position. The ΔZ value is negative when the MI position is superior to the CR position.

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). Arithmetic mean and standard deviation values were calculated for all cephalometric measurements. The normality test of Shapiro–Wilks and Levene's variance homogeneity test were applied to the data. The data were found not normally distributed, and there was no homogeneity of variance between the groups. Intra-group comparisons were evaluated by using non-parametric Wilcoxon's test, and inter-group changes were analyzed with Kruskal–Wallis. The statistical significance of inter-group differences was further assessed with the Mann–Whitney test for independent samples with Bonferroni's correction ($p < 0.016$).

To determine the errors associated with MPI® measurements, 10 MPI® records were selected randomly. Their measurements were repeated 8 weeks after the first measurement. A Bland and Altman plot was applied to assess the repeatability. It was found that the difference between the first and second measurements was insignificant (Table 2).

Table 2. **Bland and Altman plot to assess the repeatability**

Measurements	Correlation	Bias	95% CI	SE	SD of differences
ΔY	0.10	0.20	0.2 to 0.9	0.43	0.90
Right ΔX	0.30	0.30	−0.2 to 0.5	0.40	0.60
Left ΔX	0.20	0.40	−0.3 to 0.3	0.48	0.70
Right ΔZ	0.20	0.50	0.3 to 0.8	0.29	0.80
Left ΔZ	0.40	0.30	−0.1 to 0.6	0.34	0.70

Results

At the beginning and end of treatment/control, symmetrical condylar movement percentages in treatment and control groups were shown in Table 3.

Pre-treatment symmetrical condylar movement

Asymmetric condylar position was determined in most of the subjects (mediolateral: 77.28%; antero-posterior: 77.28%; supero-inferior: 72.28%) in Group 1 and (mediolateral: 71.40%; antero-posterior: 83.70%; supero-inferior: 80.90%) in the control group at the beginning. Half of the Group 2 showed a symmetrical condylar movement in mediolateral direction at the beginning of the treatment. However, in the antero-posterior (77.28%) or supero-inferior (68.19%) planes, asymmetric condylar position was determined commonly in Group 2 patients, at the beginning.

Pre- and post-treatment and pre- and post-control symmetrical condylar movement changes

In Group 1, condylar movements became more symmetrical with the therapy. In Group 2, symmetrical condylar movements got worse in the mediolateral plane and asymmetrical condylar movement percentage increased during treatment. However, in the antero-posterior direction, condylar movements became symmetrical (T2–T1: 36.37%) with the modified face-mask/expansion therapy. During the observation period, asymmetrical condyle movements in controls were changed symmetrically in antero-posterior and supero-inferior directions.

Pre-treatment and pre-control inter-group comparisons

Pre-treatment/control descriptive statistical values of MPI measurements and statistical comparisons are presented in Table 4.

Table 3. **Determination of symmetrical condylar movement percentages in treatment and control groups**

Symmetrical movement in condyle	Group 1		Group 2		Group 3		Total	
	T1 (%)	T2 (%)	T1 (%)	T2 (%)	T1 (%)	T2 (%)	T1 (%)	T2 (%)
Transvers	22.72	40.90	50.00	40.90	28.60	28.60	33.85	36.92
Antero-posterior	22.72	36.36	22.72	59.09	16.30	23.90	20.64	40.02
Supero-inferior	27.72	40.90	31.81	36.36	19.10	28.60	26.31	35.38

Table 4. **Pre-treatment/control values and standard deviations of measurements and statistical comparisons**

Measurements	Group 1 pre-treatment (T1)		Group 2 pre-treatment (T1)		Group 3 pre-control (T1)		
	Mean	SD	Mean	SD	Mean	SD	*p*
ΔY	−0.05	1.21	−0.30	1.22	−0.09	1.46	NS
Right ΔX	0.45	1.55	1.21	1.53	0.21	2.15	NS
Left ΔX	−0.85	1.02	−0.60	1.13	−0.02	1.91	NS
Right ΔZ	0.80	1.80	0.30	1.85	0.02	1.77	NS
Left ΔZ	0.35	1.92	0.35	1.80	−1.07	2.54	0.04

NS, not significant.

At the start of this study, Left ΔZ measurements were statistically different ($p < 0.05$), and other MPI measurements were similar, and no statistically significant differences were determined ($p > 0.05$).

Pre- and post-treatment and pre- and post-control intra-group comparisons

Pre- and post-treatment/control descriptive statistical values and comparisons are presented in Table 5.

During the study period, no statistically significant positional changes were observed in both treated groups. However, post-control measurements showed significant changes in Left ΔZ measurement ($p < 0.05$).

Treatment and control changes between group comparisons

Antero-posterior positional changes for the left condyle were found higher in the control group than in Group 1, and this difference was statistically significant ($p < 0.016$). The left condyle in Group 1 came closer to CR in antero-posterior plane.

Supero-inferior position changes for the left condyle were found higher in the control group than in Group 2, and this difference was found statistically significant ($p < 0.016$). The left condyle in Group 2 came closer to CR in supero-inferior plane. No other significant changes in condylar position were determined in either group.

When both treatment groups compared, there were no statistically significant differences determined ($p > 0.05$).

Table 5. **Pre- and post-treatment, pre- and post-control values and standard deviations of measurements and statistical comparisons**

Measurements	Group 1 pre-treatment (T1)		Group 1 post-treatment (T2)			Group 2 pre-treatment (T1)		Group 2 post-treatment (T2)			Group 3 pre-control (T1)		Group 3 post-control (T2)			*p*		
	Mean	SD	Mean	SD	*p*	Mean	SD	Mean	SD	*p*	Mean	SD	Mean	SD	*p*	(1–2)	(1–3)	(2–3)
ΔY	−0.05	1.21	−0.02	1.63	NS	−0.30	1.22	0.20	1.80	NS	−0.09	1.46	−0.11	1.44	NS	0.235	0.267	0.291
Right ΔX	0.45	1.55	0.60	1.52	NS	1.21	1.53	0.60	1.35	NS	0.21	2.15	0.74	1.50	NS	0.143	0.231	0.168
Left ΔX	−0.85	1.02	−0.15	1.21	NS	−0.60	1.13	−0.35	1.37	NS	−0.02	1.91	−1.10	1.78	NS	0.197	0.009	0.114
Right ΔZ	0.80	1.80	0.14	2.12	NS	0.30	1.85	0.80	1.67	NS	0.02	1.77	0.57	2.21	NS	0.186	0.291	0.324
Left ΔZ	0.35	1.92	0.07	1.74	NS	0.35	1.80	0.15	1.75	NS	−1.07	2.54	0.55	2.22	0.012	0.061	0.239	0.008

NS, not significant.

Discussion

CR splint therapy can be effective in deprogramming the neuromusculature and correcting the mandibular condyle position (13). A full-coverage bonded maxillary expander acts like a CR splint, so it may affect and change the condylar position. Additionally, the reactive force of the facemask appliance on the chin may affect the mandibular condylar position. Modified and conventional facemasks have a different force acting on the chin and therefore may have different effects on mandibular condylar position.

Centric relation is a three-dimensional relationship; so it must be assessed with a three-dimensional measuring device and not with two-dimensional X-ray films (10). The accuracy and reliability of the MPI instruments have been documented in previous studies (10, 13). Girardot (16) observed that measurements obtained with the MPI were different from those obtained with oriented tomograms even though the same condyles were being measured. He concluded that the MPI instrumentation is a more reliable method to assess changes in condylar position than tracings of oriented tomograms.

The average age of the patients in our study group was 9.35 years. A review of the literature revealed that greater skeletal changes with the use of the maxillary protraction appliance are to be expected in young patients (17, 18). However, Baik (19) found no age-effect for the treatment effect. Similarly, Yuksel et al. (20) compared the treatment outcomes in two different chronological age groups and found no significant difference in the orthodontic and orthopedic effects.

RME treatment releases the maxillary sutures with the surrounding bones and enhances the protraction procedure (21). In the present concept, treatment was started on the seventh day of RME in both treatment groups after mobilizing the maxillary surrounding sutures. Beside this, expansion was continued together with facemask therapy until the desired change in the transverse dimension was achieved. During the protraction procedure, rigid appliances are needed to withstand the heavy forces (22). In the current study, a full-coverage maxillary acrylic splint expander appliance was used in both treatment groups, to increase the rigidity of the appliance, to prevent the occlusal interferences, to apply homogeneous force, and to maximize the skeletal effect of the protraction headgear.

Non-concentric condyle-fossa relationships have been associated with abnormal temporomandibular joint function (23). In comparison, asymptomatic subjects have been characterized by more concentric positions (24). But many investigators held that more than half of the population has a discrepancy between CR and the MI jaw position (25, 26). Similar results were found by MPI records in the present study. In Class III patients, CR-MI difference in condylar position was determined in almost all investigated subjects at the beginning of treatment/control. Also, a wide range of condylar position changes was noted during the study period.

When analyzing the Class III patients at the start of the present study, asymmetrical antero-posterior and supero-inferior condylar movement was determined in 79.36% and 73.69% of subjects, respectively. Also, left condyle supero-inferior position (Left ΔZ) was statistically different between treated and control groups at the beginning. Hoffman et al. (27) noted an antero-posterior asymmetry of at least 0.1 mm in 77% and supero-inferior asymmetry of 0.1 mm or greater in 75% of the subjects studied. Rosner and Goldberg (28) found a remarkable absence of symmetrical condylar movement between CR and MI; only one of the 75 persons showed equal movement in the antero-posterior direction. One might expect a higher correlation because of an expected morphological similarity with the rigid mandible connecting the condyles; however, flexure of the mandible has been described by Burch (29). It should be considered that the joints are at the far end of the mandible with similar but separate, and perhaps, asymmetric environments (10).

When Group 1 and Group 3 were compared, only a statistically significant difference was found in the antero-posterior positional changes in the left condyle. Control subjects' changes were found higher in the control group than in the treated patients. Left condyle antero-posterior position (Left ΔX) in Group 1 became closer to CR. When Group 2 and Group 3 were compared concerning superior or inferior deflection of the condyle, it was found that the greatest movement occurred to the inferior in the control group. Left condylar supero-inferior position

(Left ΔZ) was changed during treatment, and the difference between Group 2 and Group 3 was found statistically significant. The left condyle in Group 2 became closer to CR in the supero-inferior plane. These results support Roth's (30) concept of a molar fulcrum and may be important since posterior displacement of the condyle away from the eminence would theoretically compromise joint stability and/or function.

We determined mediolateral asymmetry in 77.78% of the subjects at the beginning and 59.10% of subjects at the end of treatment in Group 1. Major improvements were observed in condylar movement in Group 1 (18.18% changed asymmetry to symmetry). However, no statistically significant condylar change was determined in any of the planes. Nevertheless, we determined mediolateral asymmetry in 50% of the subjects at the beginning and 59.10% of subjects at the end of treatment in Group 2. For symmetrical condylar movement evaluation, only undesired changes were observed in mediolateral dimension for Group 2. Symmetrical movements became asymmetric in more patients after the treatment period in Group 2. Modified facemask therapy may have some detrimental effects on the condylar position. We thought that this negative effect is explained by the asymmetric reactive force on mandibular condyle that is delivered from flexible facebow of the modified facemask appliance.

The magnitudes of mediolateral displacement determined in the current study were similar to previous reports. We found no statistically significant condyle changes in transversal plane. Rosner and Goldberg (28) reported nearly half of those studied had less than 0.3 -mm mediolateral displacement, 38% were displaced 0.3–0.6 mm, and 12% displaced more than 0.6 mm. They reported a mean mediolateral displacement of 0.34 + 0.24 mm.

Clinical reports describe not only forward and downward maxillary movement, but also a clockwise rotation of the mandible as the means of correction (31). The facemask appliance has a potential to change the mandibular condyle antero-posterior position by this effect. In treatment groups, asymmetrical condyle position decreased and became symmetrical with treatment in antero-posterior (Group 1: 13.64%, Group 2: 36.37%) plane. This decrease in asymmetrical condyle percentage was found lower in control subjects (antero-posterior change: 7.60%).

There is no evidence that orthodontic treatment outcomes are better when articulators are used in terms of improved patient temporomandibular disorder status and stomatognathic health. Using an articulator system for evaluation of the condylar position is a controversial issue. The function of an articulator is based on the average mandibular slope and average condyle structure and therefore can only provide an estimation of the individual condylar position(s). Thus, all results obtained in the current study should be interpreted carefully.

Conclusion

To our knowledge, this study is the first to analyze the relationship between condylar position changes and modified facemask therapy (protraction force applied with a modified facebow extraorally) in comparison with conventional facemask therapy and an untreated control group, all in one study. The null hypothesis was rejected because the facemask–expansion therapy did affect the position of mandibular condyle. The findings generally suggest that modified and conventional facemask therapy with expansion had no adverse effects on the temporomandibular and masticatory system.

Clinical relevance

This study was to assess the effects of varying force direction on mandibular condyle position during maxillary orthopedic protraction. The findings generally suggest that modified and conventional facemask therapy with maxillary expansion has no adverse effects on the temporomandibular and masticatory system.

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References

1. McNamara JA Jr, Brudon WL. *Orthodontics and Dentofacial Orthopedics*. Ann Arbor: Needham Press; 2001.
2. McNamara JA Jr, Brudon WL. *Orthodontic and Orthopedic Treatment in the Mixed Dentition*. Ann Arbor: Needham Press; 1993.
3. Guyer EC, Ellis EE, McNamara JA Jr, Behrents RG. Components of Class III malocclusion in juveniles and adolescents. *Angle Orthod* 1986;56:7–30.
4. Ellis E, McNamara JA Jr. Components of adult Class III malocclusion. *J Oral Maxillofac Surg* 1984;42:295–305.
5. Keles A, Tokmak EC, Erverdi N, Nanda R. Effect of varying the force direction on maxillary orthopedic protraction. *Angle Orthod* 2002;72:387–96.
6. Göyenç Y, Ersoy S. The effect of a modified reverse headgear force applied with a facebow on the dentofacial structures. *Eur J Orthod* 2004;26:51–7.
7. Bennett JC, McLaughlin RP. *Orthodontic Treatment Mechanics and the Preadjusted Appliance*. Aylesburg: Wolfe Publishing; 1993.
8. Cordray FE. Centric relation treatment and articulator mountings in orthodontics. *Angle Orthod* 1996;66:153–8.
9. Slavicek R. Part 4 instrumental analysis of mandibular casts using the mandibular position indicator. *J Clin Orthod.* 1988;22:566–75.
10. Utt TW, Meyers CE Jr, Wierzba TF, Hondrum SO. A three-dimensional comparison of condylar position changes between centric relation and centric occlusion using the mandibular position indicator. *Am J Orthod Dentofacial Orthop* 1995;107:298–308.
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. 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.
13. Karl PJ, Foley TF. The use of a deprogramming appliance to obtain centric relation records. *Angle Orthod* 1999;69:117–25.
14. 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.
15. Dawson PE. *Diagnosis and Treatment of Occlusal Problems*. St. Louis: CV Mosby Co; 1974.
16. Girardot A. The nature of condylar displacement in patients with temporomandibular pain-dysfunction. *Orthod Rev* 1987;1:16–23.
17. 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.
18. 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;113:204–12.
19. Baik HS. Clinical results of the maxillary protraction in Korean children. *Am J Orthod Dentofacial Orthop* 1995;108:583–92.
20. Yüksel S, Uçem TT, Keykubat A. Early and late facemask therapy. *Eur J Orthod* 2001;23:559–68.
21. Nanda R. Biomechanical and clinical considerations of a protraction headgear. *Am J Orthod* 1980;78:125–39.
22. Alcan T, Keles A, Erverdi N. The effects of a modified protraction headgear on maxilla. *Am J Orthod* 2000;117:27–38.
23. Pullinger AG, Solberg WK, Hollender L, Guichet D. Tomographic analysis of mandibular condyle position in diagnostic subgroups of temporomandibular disorders. *J Prosthet Dent* 1986;55:723–9.
24. Pullinger AG, Hollender L, Solberg WK, Petersson A. A tomographic study of mandibular condyle position in an asymptomatic population. *J Prosthet Dent* 1985;53:706–13.
25. Agerberg G, Sandstrom R. Frequency of occlusal interferences: a clinical study in teenagers and young adults. *J Prosthet Dent* 1988;59:212–7.
26. Howat AP, Capp NJ, Barrett NVJ. *Occlusion and Malocclusion*. St. Louis: CV Mosby; 1991.
27. Hoffman PJ, Silverman SI, Garfinkel L. Comparison of condylar position in centric relation and in centric occlusion in dentulous patients. *J Prosthet Dent* 1973;30:582–8.
28. Rosner D, Goldberg G. Condylar retruded contact position and intercuspal position correlation in dentulous patients part 1: three-dimensional analysis of condylar registrations. *J Prosthet Dent* 1986;56:230–7.
29. Burch JG. Patterns of change in human mandibular arch width during jaw excursions. *Arch Oral Biol* 1972;17:623–31.
30. Roth RH. Functional occlusion for the orthodontist. Part III. *J Clin Orthod* 1981;15:174–98.
31. Nartallo-Turley PE, Turley PK. Cephalometric effects of combined palatal expansion and facemask therapy on Class III malocclusion. *Angle Orthod* 1998;68:217–24.