Effects of modified and conventional facemask therapies with expansion on dynamic measurement of natural head position in Class III patients

Ahmet Yagci,a Tancan Uysal,b Serdar Usumez,c and Metin Orhand
Kayseri, Izmir, Gaziantep, and Ankara, Turkey

Introduction: The aim of this prospective clinical trial was to assess the effects of varying force directions on the dynamic measurement of natural head position and orofacial airway dimensions of Class III patients during maxillary orthopedic protraction compared with an untreated control group. Methods: The conventional facemask group comprised 15 patients (8 girls, 7 boys; mean age, 9.6 ± 1.3 years), the modified facemask group comprised 15 patients (7 girls, 8 boys; mean age, 9.5 ± 1.5 years), and the control group comprised 15 subjects (7 girls, 8 boys; mean age, 9.8 ± 1.6 years). Natural head position measurements and cephalometric records were obtained from all subjects before and after treatment or the control period (approximately 1 year). An inclinometer and a portable data logger were used to collect the dynamic natural head position data. For statistical comparisons, paired samples t tests, analysis of variance (ANOVA), and post-hoc Tukey tests were used at the P < 0.05 level. Results: Both treatment groups showed statistically significant changes in the sagittal (pitch) measurements of natural head position and upper pharynx, aerial, and total area of airway measurements during the treatment period. In the control group, the only statistically significant change was an increased upper pharynx measurement (P = 0.020). According to the intergroup comparisons, statistically significant natural head position differences were found in the conventional (6° flexion) and the modified (5.7° flexion) facemask groups when compared with the controls. The modified facemask group also showed significant changes in aerial (P = 0.003) and total (P < 0.001) areas of the airway measurements compared with the control group. No statistically significant differences were observed between the 2 treatment groups. Conclusions: These findings suggest that modified and conventional facemask therapy with expansion have significant cranial flexion effects on the dynamic measurements of natural head position. Additionally, the modified facemask procedure showed significant effects on the orofacial airway dimensions compared with the initial values and the values of the untreated controls. (Am J Orthod Dentofacial Orthop 2011;140:e223-e231)

Facemask and palatal expansion therapy has become a common technique for the correction of developing Class III malocclusions in recent years. Studies have documented that facemask treatment before adolescence produces an orthopedic effect to bring the maxilla forward (with counterclockwise rotation), often accompanied by a downward-backward rotation of the mandible and favorable dental changes for correction of reverse overjet and Class III malocclusion.1 Counterclockwise rotation of the maxilla is a benefit in the treatment of low-angle, deepbite Class III patients, but it is not recommended in Class III patients with high-angle skeletal patterns and anterior open bites.2 To eliminate these undesired side effects, some investigators have applied the protraction force close to the center of resistance of the maxilla with a modified face-bow. Investigators showed that a modified facemask application method with a face-bow is an effective way to prevent counterclockwise rotation of the maxilla.2,3
Profitt and Fields\textsuperscript{4} claimed that rapid maxillary expansion (RME) had to be done before protraction of the maxilla. Other studies in the literature support the concept that RME treatment releases the maxilla’s sutures with the surrounding bones and enhances the protraction procedure.\textsuperscript{5,6} RME can also cause a total increase in the nasal cavity’s volume, since its lateral walls are displaced apart. A possible hypothesis about the role of facemask and palatal expansion therapy in postural changes might be that the increased palatal diameter results in the consequent enlargement of the pharyngeal airway space. This enlargement leads to improvement in respiratory function and consequent flexion of the head on the cervical column with an increase of the cervical lordosis angle and a decrease of the cranio cervical angulations.\textsuperscript{7}

Various methods can obtain natural head position.\textsuperscript{8-10} Some authors accept natural head position as the most relaxed position of the head when the subject is not guided by any outer reference (self-balanced position).\textsuperscript{11-13} Others believe that natural head position is the position of the head when the subject’s visual axis is parallel to the ground.\textsuperscript{8} Orhan and Goyenc\textsuperscript{14} produced natural head position by the “target on the mirror” technique with high reproducibility but stated that it was an unnatural, forced, and static position. In addition, natural head position is described not as a single angular measurement but as a small range of angles around the natural head position.\textsuperscript{14,15} Thus, this position is dynamic and should be recorded as such.

To our knowledge, the effects of modified and conventional facemask therapies with expansion on the dynamic measurements of natural head position and orofacial airway dimensions compared with a control group have not been studied. The aim of this prospective clinical trial was to assess the effects of varying force directions on natural head position and orofacial airway changes with maxillary orthopedic protraction compared with a control group. The null hypothesis assumed that there were no statistically significant changes in natural head position and orofacial airway dimensions after treatment with conventional and modified facemasks and expansion therapy compared with the controls.

**MATERIAL AND METHODS**

This study was approved by the Regional Ethical Committee on Research of the Erciyes University in Turkey.

A power analysis established by G*Power software (version 3.0.10; Franz Faul, Universität Kiel, Kiel, Germany), based on a 1:1 ratio between groups and a sample size of 15 patients, would give more than 75% power to detect significant differences with an effect size of 0.30 and \( \alpha = 0.05 \) significance level.

Our sample consisted of the dynamic natural head position records of 45 Class III patients with maxillary retrusion. Patients who satisfied the following inclusion criteria were selected: (1) Class III molar relationship, (2) anterior crossbite or edge-to-edge incisal relationship, (3) ANB angle of 0° or less and nasion perpendicular to A-point of 2 mm or less, (4) no congenitally missing or extracted teeth, and (5) no deformity in the nasomaxillary complex.

Patients with craniofacial abnormality, psychosocial impairment, craniofacial anomaly, skeletal openbite, nasal allergic conditions, airway obstructions due to adenoids, or previous orthodontic treatment were excluded from the study.

The conventional facemask group comprised 15 patients (8 girls, 7 boys; mean age, 9.6 ± 1.3 years), the modified facemask group comprised 15 patients (7 girls, 8 boys; mean age, 9.5 ± 1.5 years), and the control group comprised 15 subjects (7 girls, 8 boys; mean age, 9.8 ± 1.6 years). Treatment times in group 1 were between 0.6 and 1.5 years (mean, 1.12 ± 0.24 years); treatment times in group 2 were between 0.7 and 1.7 years (mean, 1.24 ± 0.4 years); and the observation period in the control group was between 0.5 and 1.6 years (mean, 0.97 ± 0.32 years).

To constitute the control group, dynamic records of natural head position were taken with parental permission by obtaining informed consent from subjects or parents who did not accept treatment with an extraoral appliance at that time.

In the conventional facemask group, a facemask\textsuperscript{16} 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 the expansion appliance and the facemask) were used for orthopedic therapy.\textsuperscript{1}

Elastics were connected bilaterally to the adjustable midline crossbow on the Petit-type facemask.\textsuperscript{16} The protraction elastics were applied to the vestibular hooks attached between the lateral incisors and the canines above 10 to 15 mm to the maxillary occlusion plane, with a downward and forward pull of 20° to prevent bite opening during maxillary protraction.

In the modified facemask group, a modified bonded RME appliance with full occlusal coverage, a specially designed facebow, a facemask, and heavy elastics (500 g, depending on the distance between the modified face-bow hook parts and the facemask) were used for orthopedic facemask therapy.

The bonded expansion appliance was modified by adding 2 tubes (Activator tubes; Dentaurum, Ispringen,
Germany) on the buccal side of the acrylic in the premolar area. The purpose of these tubes was to accommodate the inner bows of the specially designed face-bow. The face-bow was constructed from an adjustable face-bow (standard stainless steel, G&H Wire, Franklin, Ind). The inner bows of the face-bow end went in the mouth with a special U-shape bend to enter the buccal tubes from the distal aspect and thus to retain it when an anterior pull was applied. The outer bow was bent upward at 90° to provide a point of force application at the level of the dentomaxillary center of resistance and also to apply the parallel forces in both sides (Fig 1).

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 in the transverse dimension was achieved. The patients were instructed to wear the facemask full time except during meals. We told the patients to keep track of their wearing time on the scorecard and to bring the card to each visit. The appliance was used in both treatment groups until a positive overjet was accomplished.

An inclinometer (linear tilt sensor, SX-070DLIN; Advanced Orientation Systems, Linden, NJ) and a portable data logger (XR440; Pace Scientific, Mooresville, NC) were used to collect the dynamic head posture data as described previously (Figs 2 and 3). The inclinometers were placed on the eyeglasses’ arms, and cables from the inclinometers to the data logger were positioned not to obstruct the subject’s field of view. The right sensor was positioned parallel to the sagittal plane to determine changes in pitch, and the left sensor was positioned vertical to the sagittal plane to determine changes in roll. Analog data were used to record the dynamic changes in head position, and the data were stored in a portable data logger. The sampling rate of the data logger was adjusted to 1 sample every 2 seconds for a recording period of 6 minutes. The mean dynamic natural head posture...
position was calculated for each subject by using the collected data. When the head is tipped forward in the sagittal plane relative to the true vertical, the value measured by the inclinometers is positive. A negative value shows backward tipping.

The natural head position recordings were collected at the initial stage of the appliance placement and at the end of the facemask and palatal expansion therapy (mean treatment periods, 1.12 ± 0.24 years for the conventional facemask group and 1.24 ± 0.40 years for the modified facemask group). Natural head position records from the control group were taken approximately 1 year after the initial records, similar to the treatment group (mean observation period, 0.97 years ± 0.32 months). All natural head position recordings in the study groups were taken from the patients without the RME and facemask appliances in situ.

Lateral cephalometric radiographs were taken with a cephalometer (Ortoceph OC100, Instrumentarium, Tuusula, Finland). All subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of the x-rays, the Frankfort plane was parallel to the horizontal, the teeth were in centric occlusion, and the lips were lightly closed.

All radiographs were traced manually, and whole measurements were recorded by an author (A.Y.) and reviewed twice by another investigator (T.U.) for accurate landmark identification.

The following cephalometric measurements were made (Fig 4): (1) McNamara’s upper pharynx dimension: the minimum distance between the upper soft palate and the nearest point on the posterior pharynx wall; (2) McNamara’s lower pharynx dimension: the minimum distance between the point where the posterior tongue contour crosses the mandible and the nearest point on the posterior pharynx wall; and (3) total, adenoidal, and aerial areas by using the method of Handelman and Osborne. This method takes as references the

![Fig 4. Cephalometric measurements used in the study.](image_url)
basion-nasion plane, the bispinal plane, and 2 perpendicular lines to the bispinal plane—1 crosses the more anterior point at the atlas vertebra and other crosses the posterior nasal spine. The resulting trapezoid is divided into 2 spaces (aerial and adenoid). Total area is the sum of adenoidal and aerial areas.

Statistical analysis

All statistical analyses were performed by using the Statistical Package for the Social Sciences (version 13.0 for Windows; SPSS, Chicago, Ill). The normality test of Shapiro-Wilks and the Levene variance homogeneity were applied to the data. The data were distributed normally, and there was homogeneity of variance between the groups. Descriptive statistics were given as mean and standard deviation. Intragroup comparisons were evaluated by using the paired samples t test, and intergroup changes were analyzed with analysis of variance (ANOVA). Post-hoc multiple comparisons were done by the Tukey honestly significant difference test. When the P value was less than 0.05, the statistical test was determined to be significant.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).

In both facemask and expansion groups, changes in the sagittal mean values of the dynamic natural head position measurements and statistical comparisons are presented in Table II. Pretreatment and posttreatment and control descriptive statistical values and comparisons are given in Table III. Mean difference and standard deviations of the measurements and the post-hoc statistical comparisons are presented in Table IV.

To determine whether the 3 groups of subjects were matched, ANOVA was performed on the means of the pretreatment measurements. It was found that the 3 groups were equally matched because the totality of the measurements was not significantly different (Table II).

In the conventional facemask group, statistically significant changes were found in sagittal natural head position measurements (P = 0.009), and upper pharynx (P = 0.005), aerial area (P = 0.003), and total area (P = 0.030) measurements of the airway during the treatment period. In the modified facemask group, the posttreatment measurements showed significant differences in sagittal measurements of natural head position (P = 0.017) and upper pharynx (P = 0.005), aerial area (P < 0.001), and total area (P < 0.001) of the airway measurements. In the control group, the only statistically significant change was in the upper pharynx measurement (P = 0.020) (Table III).
position measurement were statistically significant when compared with the control group (conventional face-mask vs control, \( P = 0.016 \); modified facemask vs control, \( P = 0.033 \)). The modified facemask group also showed significant changes in aerial (\( P = 0.003 \)) and total (\( P < 0.001 \)) areas of the airway measurements compared with the control group. When both treatment groups were compared, no statistically significant differences were found in any measurements.

### DISCUSSION

In this study, we used an inclinometer system to assess the effects of varying force directions on head position changes with maxillary orthopedic protraction compared with a control group. Significant natural head position differences were found in the conventional (6.4° flexion) and modified (5.7° flexion) facemask groups when compared with the control group. The modified facemask group also showed significant changes in aerial and total areas of the airway measurements compared with the control group. According to our findings, the null hypothesis was thus rejected.

Accurate registration of head position should be done with a measuring device that can make dynamic recordings. Recording head posture should be possible during swallowing and mastication. Ideally, this device should be easy to use and should not affect head position. At the same time, measurements should be reproducible over long periods, and the accuracy of the recordings should not depend entirely on operator skill. Murphy et al\(^{20}\) constructed such a device by using a contactless, precision potentiometer capable of measuring single-axis angles. They found that the device could make continuous and accurate recordings of cranial posture. Preston et al\(^{21}\) used the same device for comparing head positions in standing and walking subjects, and suggested that the system could be used for positioning patients, as in taking natural head position cephalometric radiographs. Another smaller and lighter device, introduced by Usumez and Orhan,\(^{17}\) was shown to be effective in measurement and transfer of head posture. However, wearing the inclinometer apparatus might have an effect on natural head position. The head portion of the instrument used in this study was kept as light and small as possible to avoid affecting natural head position. The cranial portion of the instrument weighed only 21.6 g. Furthermore, Murphy et al\(^{20}\) demonstrated that the inclinometer apparatus did not have a significant effect on the wearer’s head posture.

It was shown that both sagittal and transversal natural head positions were reproducible after 2 years.\(^{22}\) Differential growth or local soft-tissue changes in the bridge of the nose and the superior auricular fornx (where the spectacles that carry the inclinometers rest) could change the seat of the spectacles for growing subjects. This might lead to overinterpretation or underinterpretation of the reproducibility of natural head position. However, many researchers confirmed that natural head position was reproducible for a relatively short term.\(^{10,13,22,23}\) In this study, the sample comprised 45 patients, 9.6 ± 1.4 years of age, who were treated or observed for about 1 year.

Cervical posture and the anatomy of the first cervical vertebra have been related to factors such as nasorespiratory function\(^{24,25}\) and orthodontic therapy.\(^{26}\) The anatomy and position of the cervical curvature in space have been related to different factors concerning general aspects of the body, ethnicity,\(^{27}\) sex,\(^{27}\) and age.\(^{28}\) Despite that, some researchers who investigated natural head position found insignificant sex differences.\(^{22,29}\) Therefore, sex differences were not determined in this study.

A review of the literature showed that greater skeletal changes with maxillary protraction appliances are possible in young patients.\(^{30}\) On the other hand, Yuksel et al\(^{31}\)

| Table III. Values and standard deviations of the measurements and statistical comparisons |
|----------------------------------|-----------------|-----------------|-----------------|
| Measurement                      | Pretreatment    | Posttreatment   | P value*        |
|                                  | CFM group       | MFM group       |                 |
|                                  | Mean  | SD   | Mean  | SD   | Mean  | SD   |
| Transversal (roll) (°)           | 9.24  | 2.13 | 6.51  | 7.51 | 0.229 |
| Sagittal (pitch) (°)             | -6.31 | 6.44 | 7.25  | 18.85 | 0.009 |
| Lower pharynx (mm)              | 7.58  | 2.90 | 9.73  | -2.71 | 0.095 |
| Upper pharynx (mm)              | 10.69 | 2.98 | 10.50 | 2.20  | 0.813 |
| Adenoidal area (mm²)            | 311.82| 154.11| 303.27| 149.20| 0.712 |
| Aerial area (mm²)               | 478.83| 132.76| 604.95| 157.76| 0.003 |
| Total area (mm²)                | 790.65| 244.88| 908.22| 183.38| 0.030 |

*Paired samples t test.

CFM, Conventional facemask; MFM, modified facemask.
compared the treatment outcomes in 2 chronologic age
groups and found no significant difference in the ortho-
dontic and orthopedic effects. According to Merwin
et al.,32 there was no difference between the age groups
of 5 to 8 and 8 to 12 years from the point of protraction
of the maxilla. Taylor et al.33 concluded that greater rates
of change in the soft-tissue measurements of the posterior
pharyngeal wall occurred between 6 to 9 years and 12 to
15 years, and that growth increments were small between
9 and 12 years. Because the mean age of the subjects in
our study was 9.6 years and the mean treatment time
was about 1 year, it was thought that the changes in
pharyngeal measurements related to normal growth
were negligible.

The breathing pattern might influence the development
of the transverse relationship, resulting in the develop-
ment of posterior crossbite.34 Ceylan and Oktay35 re-
ported that the pharyngeal airway size was influenced
by the changes in ANB angle. Hiyama et al.36 found that
maxillary growth induced by protraction treatment had
a significant positive effect on the superior upper airway
dimension. Oktay and Ulukaya37 found that maxillary
protraction increased the distances and increments in
the upper part of the airway space. Saynsu et al.38 inves-
tigated the effects of RME and a protraction appliance
on the sagittal airway, and found an increase in naso-
pharyngeal width. Similarly, Kilinc et al.39 demon-
strated that maxillary expansion together with protraction
of the maxilla improved nasopharyngeal and oropharyn-
geal airway dimensions. Kaygısız et al.40 evaluated the
long-term outcomes of treatment with reverse headgear
in patients with skeletal Class III malocclusion. They
found that the nasopharyngeal airway dimensions
were improved after treatment, and favorable effects
of the treatment remained over the posttreatment period
of 4 years. Similarly, in our study, both treatment groups
showed increases in the aerial and total areas of the air-
way during the treatment period. However, according to
intergroup comparisons, significant differences were ob-
served only in the modified facemask and expansion
group compared with the control group. A different ro-
tational pattern of the maxilla during the protraction
procedure might explain the differences in airway
changes.

Table III. Continued

<table>
<thead>
<tr>
<th>Measurement</th>
<th>CFM group</th>
<th>MFM group</th>
<th>Control group</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transversal (roll) (°)</td>
<td>−2.73</td>
<td>1.62</td>
<td>3.56</td>
<td>(CFM-MFM) NS</td>
</tr>
<tr>
<td>Sagittal (pitch) (°)</td>
<td>13.56</td>
<td>15.01</td>
<td>−0.51</td>
<td>(CFM-control) NS</td>
</tr>
<tr>
<td>Upper pharynx (mm)</td>
<td>2.15</td>
<td>1.94</td>
<td>1.92</td>
<td>(MFM-control) NS</td>
</tr>
<tr>
<td>Lower pharynx (mm)</td>
<td>−0.19</td>
<td>0.21</td>
<td>−0.42</td>
<td></td>
</tr>
<tr>
<td>Adenoidal area (mm²)</td>
<td>−8.55</td>
<td>38.76</td>
<td>−18.00</td>
<td></td>
</tr>
<tr>
<td>Aerial area (mm²)</td>
<td>126.12</td>
<td>179.04</td>
<td>36.86</td>
<td></td>
</tr>
<tr>
<td>Total area (mm²)</td>
<td>117.57</td>
<td>217.80</td>
<td>217.80</td>
<td></td>
</tr>
</tbody>
</table>

CFM, Conventional facemask; MFM, modified facemask; MD, mean difference; NS, not significant.
On the other hand, Mucedero et al. analyzed the effects of RME and facemask, or facemask therapy, on sagittal pharyngeal dimensions in Class III subjects with or without RME. They found that the favorable skeletal maxillary and mandibular changes produced by maxillary protraction with or without RME were not associated with significant changes in sagittal oropharyngeal and nasopharyngeal airway dimensions, and orthopedic treatment of Class III malocclusion did not produce a significant increase in airway dimensions in the short term. Bacetti et al. found no significant short-term or long-term changes in sagittal oropharyngeal and nasopharyngeal airway dimensions induced by maxillary protraction in subjects with a Class III malocclusion when compared with untreated control group. When compared with the control group, only the modified facemask group showed statistically significant differences in cranial and total area measurements in this study.

Respiratory airway function influences facial morphology and craniofacial functions. It has been commonly accepted that there is a relationship between head posture and upper airway size. Upper airway enlargement leads to improvement in respiratory function and consequent flexion of the head. In our study, in the modified facemask group, there was no statistically significant increase in airway increases during expansion and protraction of the maxilla, statistically significant amounts of cranial flexion of the head, and the area measurements in both treatment groups (6.4° flexion in the conventional facemask group and 5.7° flexion in the modified facemask group).

In the modified facemask group, pharyngeal airway space was increased with protraction and expansion therapy, and natural head posture was changed comparably. Although a significant flexion of head posture was determined (mean, 6.4°) in the conventional facemask group, no statistically significant changes were found in pharyngeal airway space compared with the untreated control group. Changes in body posture have been shown to elicit activity from muscles that could affect the mandibular rest position. This circumstance might be the result of relationships between natural head position and mandibular rest position.

**CONCLUSIONS**

Within the limitations of this study, these findings suggest that modified and conventional facemask therapy with expansion had significant cranial flexion effects on the dynamic measurements of natural head position. Additionally, the modified facemask procedure showed significant effects on oro-facial airway dimensions compared with the initial values and the values of the untreated controls.

**REFERENCES**

21. Preston CB, Evans WG, Todres JI. The relationship between ortho
head posture and head posture measured during walking. Am J
22. Usumez S, Orhan M. Reproducibility of natural head position mea-
123:451-4.
23. Lundström A, Forsberg CM, Westergren H, Lundström F. A com-
parison between estimated and registered natural head posture.
24. Kyåmarkula S, Huggare JAV. Morphology of the first cervical verte-
25. Huggare JAV, Raustia A. Head posture and cervicovertebral and
craniofacial morphology in patients with craniofacial dys-
Evaluation of cervical spine posture after functional therapy with
27. Cooke MS, Wei SHY. Intersex differences in craniofacial mor-
phology and posture in southern Chinese and British Caucasians.
lordosis and thoracic kyphosis in 8, 11 and 15-year-old children.
29. Peng L, Cooke MS. Fifteen-year reproducibility of natural head
1999;116:82-5.
30. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face
mask/expansion therapy in Class III children: a comparison of three
31. Yuksel S, Uçem TT, Keykubat A. Early and late facemask therapy.
Eur J Orthod 2001;23:559-68.
application of anteriorly directed orthodontic force to the maxilla.
33. Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue
34. Hartsook JT. Mouth breathing as a primary etiologic factor in the
35. Ceylan I, Oktay H. A study of the pharyngeal size in different
69-75.
Effects of maxillary protraction on craniofacial structures and up-
37. Oktay H, Ulukaya E. Maxillary protraction appliance effect on the
38. Saymus K, Işık F, Arun T. Sagittal airway dimensions following
39. Kılıç AS, Arslan SG, Kama JD, Ozer T, Dari O. Effects on the sag-
ittal pharyngeal dimensions of protraction and rapid palatal ex-
pansion in Class III malocclusion subjects. Eur J Orthod 2008;
30:61-6.
40. Kaygısız E, Tuncer BB, Yuksel S, Tuncer C, Yıldız C. Effects of max-
illary protraction and fixed appliance therapy on the pharyngeal
41. Mucedero M, Baccetti T, Franchi L, Cozza P. Effects of maxillary
protraction with or without expansion on the sagittal pharyngeal
dimensions in Class III subjects. Am J Orthod Dentofacial Orthop
42. Baccetti T, Franchi L, Mucedero M, Cozza P. Treatment and
post-treatment effects of facemask therapy on the sagittal pharyn-
geal dimensions in Class III subjects. Eur J Orthod 2010;32:
346-50.
43. Gungor AY, Turkkahraman H. Effects of airway problems on
44. Pae EK, Lowe AA, Sasaki K, Price C, Tsuchiya M, Fleetham JA. A
cephalometric and electromyographic study of upper airway struc-
tures in the upright and supine positions. Am J Orthod Dentofacial
45. Odeh M, Schanall R, Gavriel Y, Oliven A. Dependency of upper air-
way patency on head position: the effect of muscle contraction.
Respir Physiol 1995;100:239-44.