Changes in the oropharyngeal airway of Class II patients treated with the mandibular anterior repositioning appliance

Susan Rizkaa; Valmy Pangrazio Kulbershb; Riyad Al-Qawasmin

ABSTRACT

Objective: To evaluate the effects of functional appliance treatment on the oropharyngeal airway volume, airway dimensions, and anteroposterior hyoid bone position of growing Class II patients.

Materials and Methods: Twenty Class II white patients (mean age, 11.7 ± 1.75 years) treated with the MARA followed by fixed appliances were matched to an untreated control sample by cervical vertebrae maturation stage at pretreatment (T1) and posttreatment (T2) time points. Cone beam computed tomography scans were taken at T1 and T2. Dolphin3D imaging software was used to determine oropharyngeal airway volume, dimensions, and anteroposterior hyoid bone position.

Results: Multivariate ANOVA was used to evaluate changes between T1 and T2. Oropharyngeal airway volume, airway dimensions, and A-P position of the hyoid bone increased significantly with functional appliance treatment. SNA and ANB decreased significantly in the experimental group (P < .05). Changes in SNB and Sn-GoGn failed to reach statistical significance.


KEY WORDS: Class II; Airway; Obstructive sleep apnea; Functional appliance; MARA

INTRODUCTION

The majority of Class II malocclusions can be attributed to mandibular retrognathia rather than maxillary prognathism.1,2 For the growing skeletal Class II patient with mandibular retrognathia, treatment modalities to correct the malocclusion include functional appliances, orthognathic surgery when growth has ceased, and extraction or distalization of maxillary teeth, which may have deleterious effects on the soft tissue profile. Functional appliances, such as the mandibular anterior repositioning appliance (MARA; Ormco, Orange, Calif), are an accepted treatment modality to improve the mandibular position relative to the maxilla while simultaneously improving the profile.3

The incidence of sleep-disordered breathing (SDB) in adolescents has been estimated at 6%, with sufferers being twice as likely as their peers to have excessive daytime sleepiness, poorer grade point average, and attention-deficit/hyperactivity disorder.4 A number of predisposing factors, including asthma, adenotonsillar hypertrophy, allergies, obesity, and craniofacial abnormalities, such as mandibular retrognathism, have been identified for SDB.5 Previous studies have demonstrated the association between mandibular position in relation to the cranial base and oropharyngeal airway (OA) volume.6,7 Specifically, mandibular retrognathia has been associated with a decreased OA volume, which may be due to posterior positioning of the tongue or a posterior position of the hyoid bone.8,9

It has been postulated that advancement of the mandible using anterior posturing appliances immediately enlarges the airway. Such appliances are used for adults with obstructive sleep apnea to prevent upper airway collapse during sleep.10 However, conflicting data exist regarding the long-term effects of functional appliances on oropharyngeal volume, airway dimensions, and hyoid bone position in growing
patients, which may be due to the difficulties in assessing these variables with 2-D analyses.\textsuperscript{11} The aim of the present study was to evaluate changes in hyoid bone position, oropharyngeal volume, and dimensions in the transverse and sagittal planes after treatment of skeletal Class II patients with functional appliances followed by edgewise treatment. This study utilized cone beam computed tomography (CBCT) imaging, which has been shown to be an adequate method for airway analysis.\textsuperscript{12,13}

Null Hypothesis: There is no significant change in antero-posterior (A-P) hyoid bone position, oropharyngeal volume and dimensions after functional appliance treatment.

**MATERIALS AND METHODS**

This retrospective study was approved by the institutional review board (Protocol 1314-64)

**Sample Description**

The experimental group consisted of 20 Class II white patients—13 females and 7 males (mean age, 11.7 ± 1.75 years), treated with the MARA followed by fixed appliances. CBCT scans, using the i-CAT Cone Beam 3D Imaging System (Imaging Sciences International, Hatfield, Pa), were taken prior to the placement of any appliances (T1) and immediately after removal of the fixed edgewise appliances (T2). Scans were done with the patients in centric occlusion with the following radiographic parameters: 120 kVp, 18.54 mAs, 8.9-second scan time, and 0.3-mm voxel dimension. Subjects were seated in a chair and asked to hold their breath and refrain from swallowing while the scans were taken in the natural head position.

The control group consisted of 73 untreated skeletal Class II white subjects, who had CBCT scans taken with the same parameters as did the experimental group. Controls were selected with the inclusion criteria of SN-GoGn ≥ 27 and ≤ 37, SNB ≤ 77, and ANB ≥ 4.5, as well as cervical vertebrae maturation stage (CVMS), as described by Baccetti,\textsuperscript{14} to match the experimental group.

**Exclusion Criteria**

All subjects were nonsyndromal. Patients with a CVMS of 5 or greater at the pretreatment time point were excluded due to a lack of remaining growth.\textsuperscript{14} Subjects were excluded if, upon visual inspection of the CBCT scan, they were found to be swallowing or having a hyperextended head position while the scan was taken. All subjects who were found to have a nonconcentric condylar position upon visualization of the CBCT-formatted TMJ tomograms were also excluded from the sample.

**Oropharyngeal Airway Analysis**

Dolphin3D (Dolphin Imaging and Management Solutions, Chatsworth, Calif) was used for all data collection by one investigator (S.R.). The A-P and transverse dimensions of the oropharynx were measured at the level of its narrowest A-P dimension in the midsagittal plane (Figure 1).

A volumetric analysis was performed using Dolphin's Airway Module. The oropharyngeal airway (OA) space was defined by two horizontal planes paralleling Frankfort horizontal (FH). The superior limit was the horizontal line connecting the posterior nasal spine and the posterior wall of the pharynx. The inferior limit was that spanning the A-P dimension of the airway, passing through the tip of the epiglottis (Figure 2). The airway sensitivity setting, which controls the program's ability to find differences in gray-scale resolution, was standardized at 45 to best recognize the airway and calculate the volume in mm\textsuperscript{3}.

**Cephalometric Analysis**

The CBCT scans were formatted to produce lateral cephalograms oriented according to FH without magnification, digitized, and traced. A custom analysis was created to determine SNA, SNB, ANB, SN-GoGn, and a linear measurement of the A-P position of the hyoid bone. Hyoid bone position was defined by the line from the anterior aspect of the hyoid bone to the posterior pharyngeal wall, paralleling FH, as seen in Figure 3.

**Statistical Analysis**

All variables were remeasured for five randomly selected patients. The intraclass correlation coefficient was calculated for all measurements and repeated measurements to determine the accuracy of data collection. The accuracy of measurements was calculated as 99.9% for airway volume, 97.2% for hyoid bone position, 90.4% and 99.7% for A-P and transverse airway dimensions (respectively), 97.4% for SNA, 99.6% for SNB, 99.4% for ANB, and 99.5% for SN-GoGn, indicating a high level of agreement.

Power calculations were done for this study using the following parameters: the level of significance was \( \alpha = .05 \) and the power of the test was 80%. It was found that a sample of 11 individuals was need to detect a difference of at least 1400 mm\textsuperscript{3} with standard deviation of 1650 mm\textsuperscript{3} as found by our preliminary studies (unpublished data). Multivariate ANOVA was used to evaluate the effect of functional appliances on the experimental variables when controlling for CVMS as previously described. Comparison of the starting forms for the experimental and control groups was also done.
Figure 1. Measurement of OA A-P and transverse dimensions.

Figure 2. Measurement of OA volume.
RESULTS

The mean length of functional appliance treatment was 10.6 months. The average length of time from functional appliance removal to debond was 16.8 months.

Descriptive statistics for the experimental group at T1 and T2 are listed in Table 1. Table 2 shows the descriptive statistics for the control groups at each CVMS. Comparison of mean changes from T1–T2 for experimental and control samples is shown in Table 3.

When the MARA and control groups were evaluated at T1 (comparison of starting forms), no statistically significant differences were found between the experimental and control groups in OA volume, transverse airway dimension, SNA, SNB, ANB, or SN-GoGn. There was a significant difference, however, in the narrowest A-P airway dimension, whereby this variable was significantly smaller initially in the experimental group than in the control group ($P = .023$).

Statistical analysis showed that the airway volume, A-P hyoid bone position, and A-P and transverse airway dimensions were significantly increased in the experimental group compared with the control group ($P = .005, .000, .000, .000$, respectively). SNA and ANB decreased significantly in the experimental group compared with controls ($P = .000$ and .026). Although SNB increased in the experimental group from T1 to T2, this change did not reach statistical significance ($P = .063$). There was no significant change in SN-GoGn ($P = .43$). Upon visual inspection of TMJ tomograms at T2, we found no patients with condylar distraction.

On average, the experimental group had a 5537.4-mm³ increase in OA volume from T1 to T2 in contrast to the 2220.5-mm³ increase exhibited by controls attributable to growth. Functional appliance usage explains

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Table 1. Descriptive Statistical Values, Experimental Sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>T1, Pretreatment</th>
<th>T2, Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (y)</td>
<td>11.7</td>
<td>1.75</td>
</tr>
<tr>
<td>Airway volume (mm³)</td>
<td>9081.90</td>
<td>3406.15</td>
</tr>
<tr>
<td>A-P hyoid bone position (mm)</td>
<td>25.4</td>
<td>2.93</td>
</tr>
<tr>
<td>Airway A-P dimension (mm)</td>
<td>7.24</td>
<td>2.21</td>
</tr>
<tr>
<td>Airway transverse dimension (mm)</td>
<td>21.19</td>
<td>4.15</td>
</tr>
<tr>
<td>SNA (°)</td>
<td>80.38</td>
<td>2.73</td>
</tr>
<tr>
<td>SNB (°)</td>
<td>74.79</td>
<td>2.95</td>
</tr>
<tr>
<td>ANB (°)</td>
<td>5.59</td>
<td>1.53</td>
</tr>
<tr>
<td>SN-GoGn (°)</td>
<td>31.68</td>
<td>5.03</td>
</tr>
</tbody>
</table>

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Figure 3. Hyoid-posterior pharyngeal wall measurement.
approximately 39.1% of airway A-P dimensional changes in our sample, 30.3% of A-P hyoid bone positional changes, 28.5% of SNA changes, 27.7% of airway transverse dimensional changes, 18.7% of airway volume changes, and 12.3% of the change in ANB.

**DISCUSSION**

Functional appliances such as the MARA are used in the orthopedic treatment of skeletal Class II patients to place the mandible in a more favorable A-P position. It is expected that this anterior posturing increases the OA volume and A-P airway dimensions during functional jaw orthopedic treatment and thereafter. Similar to the findings of the present study, Iwasaki et al. found a 5000.2-mm³ increase in OA volume after treatment with the Herbst appliance compared with a 2451.6-mm³ increase in skeletal Class I controls.¹⁵

Statistically significant decreases in SNA (P = .000) and ANB (P = .026) were found in the experimental group, possibly due to restriction of maxillary growth found by other investigators.¹⁶ This “headgear effect” could have been a limiting factor in the amount of forward mandibular growth. Thus, the significant increase in airway volume, dimensions, and hyoid bone position cannot be attributed solely to mandibular anterior positioning relative to the cranial base.

Rather, the statistical analyses in this study indicated that forward positioning of the mandible with functional appliances influences oropharyngeal changes through alterations in the airway morphology and A-P hyoid bone position. These findings confirm the results of other studies using the Twin-block,¹⁷,¹⁸ acrylic-splint Herbst,¹⁹ and activator.²⁰ Mean A-P airway dimension decreased from T1 to T2 in controls and was accompanied by a small increase in transverse dimension. Although the experimental group had a significantly narrower A-P dimension than did controls at T1, functional appliance treatment resulted in significant widening of the airway in the transverse and A-P dimensions. Hence, the oropharynx became wider in the transverse dimension from T1 to T2 and more elliptical in shape, as described by Abramsom et al.²¹

The present study demonstrated an anterior change in A-P hyoid bone position in the experimental group that was three times that of controls. This may indicate an alteration in tongue posture with functional appliance treatment. The hyoid bone, which is suspended by muscles and ligaments without bony articulations, plays an important role in maintaining airway dimensions and has been found to vary in position according to the position of the mandible. It is more posteriorly positioned in skeletal Class II patients than in Class I or

### Table 2. Descriptive Statistical Values, Control Sample Grouped by Cervical Vertebrae Maturation Stage (CVMS)

<table>
<thead>
<tr>
<th>CVMS</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>1(n=8)</td>
<td>7844.2</td>
<td>2.32</td>
<td>26.09</td>
<td>4.65</td>
<td>3.98</td>
<td>2.56</td>
<td>8.26</td>
<td>1.69</td>
<td>27.56</td>
<td>1.09</td>
</tr>
<tr>
<td>2(n=19)</td>
<td>9873.98</td>
<td>2.44</td>
<td>26.09</td>
<td>4.65</td>
<td>3.98</td>
<td>2.56</td>
<td>8.26</td>
<td>1.69</td>
<td>27.56</td>
<td>1.09</td>
</tr>
<tr>
<td>3(n=20)</td>
<td>3303.98</td>
<td>2.44</td>
<td>26.09</td>
<td>4.65</td>
<td>3.98</td>
<td>2.56</td>
<td>8.26</td>
<td>1.69</td>
<td>27.56</td>
<td>1.09</td>
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<tr>
<td>4(n=12)</td>
<td>1271.73</td>
<td>2.44</td>
<td>26.09</td>
<td>4.65</td>
<td>3.98</td>
<td>2.56</td>
<td>8.26</td>
<td>1.69</td>
<td>27.56</td>
<td>1.09</td>
</tr>
<tr>
<td>5(n=10)</td>
<td>9638.87</td>
<td>2.44</td>
<td>26.09</td>
<td>4.65</td>
<td>3.98</td>
<td>2.56</td>
<td>8.26</td>
<td>1.69</td>
<td>27.56</td>
<td>1.09</td>
</tr>
<tr>
<td>6(n=8)</td>
<td>1080.03</td>
<td>2.44</td>
<td>26.09</td>
<td>4.65</td>
<td>3.98</td>
<td>2.56</td>
<td>8.26</td>
<td>1.69</td>
<td>27.56</td>
<td>1.09</td>
</tr>
</tbody>
</table>
III.22–24 A posteriorly displaced hyoid bone has been correlated with severity of the obstructive sleep apnea syndrome and has been found to improve with mandibular advancement surgery.25 Similarly, functional appliances advance the position of the mandible and tongue, resulting in an anterior pull on the hyoid bone by the connecting musculature and ligaments and improving airway morphology, as supported by the findings of our study. Although the change in mandibular position did not reach statistical significance, it could have been of clinical significance, whereby the concomitant advancement of the tongue could have influenced the change in airway volume and dimensions.26,27

Although the sample was relatively small, a power analysis was used for study design to determine the minimum sample size.28 The minimum sample size was determined to be 11 subjects to be able to correctly reject the null hypothesis. Due to limitations in the number of controls satisfying the inclusion criteria, the present study did not control for gender. Past research on the influence of gender has produced conflicting results. Abramson et al. reported no effect of gender on measured airway parameters,21 whereas Tan et al. found larger oropharyngeal airway volumes in males.29 Hence, there is a need for future studies with more untreated subjects to account for gender as a potential confounding factor.

Another factor requiring investigation is the effect of palatal expansion on the oropharyngeal airway, which is unclear. The treated group included patients who had palatal expanders as a component of the MARA. While the effect of expansion was not accounted for in the present study, it may not have a significant influence. Several studies have used CBCT scans to evaluate airway changes following palatal expansion, finding no statistically significant effect on OA volume,30–34 although significant effects have been demonstrated in the nasopharyngeal airway.35

Lastly, CBCT scans were obtained in the current study with subjects in a seated position. It has been established that gravitational pull of soft tissues while in the supine position may cause airway collapse. A 36.5% decrease in oropharyngeal area has been previously reported in obstructive sleep apnea patients with a positional change from upright (standing) to supine.36 Although supine CBCT scans would have ideally been utilized, it would be unethical to expose growing patients to the radiation of multiple scans. Since a 30% variation in airway volume has been demonstrated with positional change,37 our findings can be extrapolated.

CONCLUSIONS

- Functional appliance therapy with the MARA increases oropharyngeal airway volume, airway dimensions, and A-P hyoid bone position in growing patients. Therefore, the null hypothesis was rejected.
- Future studies are necessary to clarify the relationship between the symptoms of sleep-disordered breathing and the effects of functional jaw orthopedics.

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AIRWAY CHANGES AFTER TREATMENT WITH THE MARA


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