An evaluation of the sagittal upper airway dimension changes following treatment with maxillary protraction appliances

Rishabh Gupta,¹ G Shivaprakash,² Mala Ram Manohar,³

ABSTRACT

Aims and Objectives: This retrospective study was conducted to investigate the effect of treatment with a maxillary protraction appliance (MPA) on the development of craniofacial structures and the upper airway dimensions. Methods: Twenty patients (10 male and 10 female; mean age 10.3 +/- 1.12 years) with skeletal Class III malocclusion were included in this study and were evaluated by the use of lateral cephalograms obtained before and after treatment. Treatment changes were determined by means of linear and angular measurements. Results: A significant increase in maxillary forward growth, inhibition of mandibular forward growth, and clockwise rotation of the mandible were observed. The maxillary incisors were significantly proclined and the mandibular incisors significantly retroclined. A multiple-regression analysis revealed that maxillary growth had a significant positive effect on the upper-airway dimension. Conclusions: Facilitation of maxillary growth with a maxillary protraction appliance does contribute to a significant increase in the upper airway dimensions.

Keywords: Class III malocclusion, maxillary protraction, facemask, upper airway

Introduction

Treatment of skeletal Class III malocclusion is the most challenging, primarily because of the unpredictable and potentially unfavorable nature of growth in patients with this skeletal pattern. Typically, treatment approaches for young patients with Class III malocclusion have been directed at growth modification (1). Maxillary protraction appliances (MPA) have been used for the treatment of skeletal Class III malocclusions in growing patients with maxillary retrusion (2-3). Numerous studies have demonstrated that these appliances stimulate the forward displacement of the maxilla and reduce the forward displacement of the mandible. Clockwise rotation of the mandible, retroclination of the lower incisors, counter-clockwise rotation of the palatal plane, and proclination of the upper incisors has also been reported (4-9).

Pharyngeal size is very important for all subjects and especially for the patients with sleep apnea. The size of the naso-pharynx may be particularly important in determining, whether the mode of breathing is predominantly nasal or oral. The postural changes resulting from oral breathing could affect dento-facial growth and development (10).

Ozbek et al reported that the sagittal dimension of the upper airway significantly increased as a result of treatment with a functional appliance for growing patients with Class II malocclusion (11). Since, mandibular growth has a definite influence on the upper airway dimension, it may be speculated that maxillary growth could also have beneficial effects on the upper airway.

A strong positive association has been reported between the skeletal changes brought about by an MPA and airway width (12-18). Lee et. al. (18), Kilinc et al. (15) as well as Oktay and Ulukaya (14) have reported a significant change in both the oropharynx and the nasopharynx after treatment with an MPA while Sayinsu et al. (13) and Kaygisiz et al. (16) observed a significant change only in the nasopharynx. No such study has been reported in the Indian population till date.

The purpose of this study was to investigate the effect of maxillary protraction appliances on the upper airway dimensions. The hypothesis for the study was that maxillary protraction appliances (MPA) have no effect on the size of the upper airway passage in growing patients.

Materials and methods

This retrospective study utilized the pre-treatment and post-treatment lateral cephalometric radiographs of 20 patients, 10 male and 10 female, treated with Petit (GAC 17-100-20, Bohemia, NY) type face masks. The mean chronological age of the patients was 10.3 +/- 1.12 years at the beginning of the treatment.
**Inclusion criteria**

- Skeletal and dental Class III malocclusions with maxillary retrusion,
- Edge to edge incisor relationship or anterior crossbite,
- Flat or concave facial profile
- No congenital anomalies or endocrine problems

**Appliance design and activation**

In order to obtain a forward movement of the maxilla and maxillary dentition during the treatment period, elastic forces were applied between the face mask (Figure 1) and the hooks which were soldered to a bonded maxillary splint (Figure 2) in the canine-primary molar area above the occlusal plane. The maxillary splint incorporated a Hyrax type expansion screw in the middle of the palate which was activated once per day for 8-10 days to produce a disruption in the sutural system. The face mask was delivered 2-6 weeks after placement of the splint. The magnitude of the force applied was 350 grams per side and its direction was 30 degrees downward from the occlusal plane. The patients used their face masks 14 hours a day, and the treatment was continued until a normal overjet was achieved. The mean treatment time was 8 +/- 2.1 months.

All the lateral cephalograms were traced on a transparent cellulose acetate sheet of 0.003 inches thickness at the same time and by the same operator. Similar conditions of the light box and general illumination were maintained during viewing and tracing of all head films. All reference points were first identified, located, and marked. The reference planes were drawn, and, when the bilateral structures cast double shadows on the film, the technique of averaging the bilateral images was used.

**Cephalometric analysis**

Reference points and cephalometric variables used in the study are shown in Figure 3. In addition to the conventional cephalometric variables, some specific variables to evaluate the sagittal upper-airway dimension and head posture were defined according to Hiyama and co-workers (12) as -

- **SPPS**: The antero-posterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the soft palate on a line parallel to the FH plane (the line through Po and Or) that runs through the middle of the line from PNS to P.
- **MPS**: The antero-posterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through P.
- **IPS**: The antero-posterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through C2i.

**SN-CVT**: The angle formed by the SN plane and CVT (the line through C2 and C4).

Values at the beginning of the treatment (T1) and that following completion of maxillary protraction (T2) as well as the differences between the 2 values were evaluated for each variable.

**Statistical analysis**

All the statistical analyses were done using SPSS (Version 15) software. Results are expressed as mean ± SD. The effects of the maxillary protraction appliance on craniofacial structures and airway sizes were investigated by means of a paired t-test. To determine the relationship between the changes in the upper airway dimension and craniofacial morphology, a multiple regression analysis was performed. A p-value of 0.05 or less was considered significant.

**Results**

**Changes in the craniofacial morphology and upper-airway dimension**

The mean and standard deviation of each variable measured at the beginning (T1) and end (T2) of treatment and of the differences between them (T2-T1) are presented in Table 1 along with the results of the paired t-test.

The mean value of SNA significantly increased from 80.8° to 83.9° (P<0.05), and that of SNB significantly decreased from 83.4° to 82.1° (P<0.05). As a consequence of these changes, the mean value of ANB significantly increased from -2.6° to 1.7° (P<0.01). The mean value of SN-MP also increased from 31.4° to 32.3°. The mean value of U1-SN significantly increased from 107.3° to 110.9° (P<0.05), which indicated labial tipping of the maxillary incisors. The mean value of L1 to MP significantly decreased from 89.8° to 88.1° (P<.01), which indicated lingual tipping of the mandibular incisors.

The SPPS width increased in 16 patients and decreased in 4 patients. The MPS width also increased in 16 patients and decreased in 4 patients. The IPS width increased in 14 patients and decreased in 6 patients. As a result, no significant changes were demonstrated in the upper-airway dimension. The SN-CVT angle increased in 16 patients and decreased in 4, and again there was no significant change.

**Relationship between changes in the craniofacial morphology and upper-airway dimensions**

The results of correlation analysis between the craniofacial and pharyngeal variables are presented in Table 2. In the multiple-regression analysis, the change in the upper-airway dimension was considered a dependent variable, whereas changes in SNA, SNB, SN-MP, and SN-CVT were selected as independent variables. The standardized regression coefficient indicates the magnitude and direction of the influence...
Table 1: The mean and standard deviation of each variable measured at the beginning (T1) and end (T2) of treatment and of the differences between them (T2-T1) along with the results of the paired t-test.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean at T1</th>
<th>SD</th>
<th>Mean at T2</th>
<th>SD</th>
<th>Mean Difference (T2-T1)</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA</td>
<td>80.8°</td>
<td>3.0°</td>
<td>83.9°</td>
<td>2.5°</td>
<td>3.1°</td>
<td>2.6°</td>
<td>*</td>
</tr>
<tr>
<td>SNB</td>
<td>83.4°</td>
<td>4.2°</td>
<td>82.1°</td>
<td>4.2°</td>
<td>-1.4°</td>
<td>1.1°</td>
<td>*</td>
</tr>
<tr>
<td>ANB</td>
<td>-2.6°</td>
<td>2.8°</td>
<td>1.7°</td>
<td>2.8°</td>
<td>4.4°</td>
<td>1.9°</td>
<td>**</td>
</tr>
<tr>
<td>SN-MP</td>
<td>31.4°</td>
<td>5.3°</td>
<td>32.3°</td>
<td>4.5°</td>
<td>0.9°</td>
<td>1.6°</td>
<td>NS</td>
</tr>
<tr>
<td>UI-SN</td>
<td>107.3°</td>
<td>11.3°</td>
<td>110.9°</td>
<td>11.3°</td>
<td>3.6°</td>
<td>2.1°</td>
<td>*</td>
</tr>
<tr>
<td>LI-SN</td>
<td>89.8°</td>
<td>6.7°</td>
<td>88.1°</td>
<td>8.3°</td>
<td>-1.6°</td>
<td>1.1°</td>
<td>*</td>
</tr>
<tr>
<td>SPPS</td>
<td>13.6 mm</td>
<td>2.9 mm</td>
<td>14.4 mm</td>
<td>2.8 mm</td>
<td>0.8 mm</td>
<td>2.0 mm</td>
<td>NS</td>
</tr>
<tr>
<td>MPS</td>
<td>12.1 mm</td>
<td>2.8 mm</td>
<td>12.6 mm</td>
<td>3.0 mm</td>
<td>0.6 mm</td>
<td>4.2 mm</td>
<td>NS</td>
</tr>
<tr>
<td>IPS</td>
<td>13.3 mm</td>
<td>3.4 mm</td>
<td>12.9 mm</td>
<td>2.3 mm</td>
<td>-0.4 mm</td>
<td>4.2 mm</td>
<td>NS</td>
</tr>
<tr>
<td>SN-CVT</td>
<td>100.6°</td>
<td>6.0</td>
<td>99.9°</td>
<td>7.8 mm</td>
<td>-0.8°</td>
<td>3.9 mm</td>
<td>NS</td>
</tr>
</tbody>
</table>

* P < 0.05 ; ** P < 0.01 ; NS indicates not significant.

Table 2: Results of correlation analysis between the craniofacial and pharyngeal variables

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Change in SPPS</th>
<th>Change in MPS</th>
<th>Change in IPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA (b₁)</td>
<td>0.889 (0.259)*</td>
<td>0.090 (0.054)</td>
<td>0.885 (0.551)</td>
</tr>
<tr>
<td>SNB (b₂)</td>
<td>0.785 (1.04)</td>
<td>1.60 (0.995)</td>
<td>1.30 (0.821)</td>
</tr>
<tr>
<td>SN-MP (b₃)</td>
<td>0.370 (0.454)</td>
<td>0.675 (0.442)</td>
<td>1.17 (0.774)</td>
</tr>
<tr>
<td>SN-CVT (b₄)</td>
<td>0.216 (0.715)*</td>
<td>0.597 (0.738)*</td>
<td>0.758 (0.707)*</td>
</tr>
<tr>
<td>R</td>
<td>0.92</td>
<td>0.76</td>
<td>0.72</td>
</tr>
<tr>
<td>R²</td>
<td>0.84</td>
<td>0.58</td>
<td>0.52</td>
</tr>
</tbody>
</table>

b₁-b₄ indicate regression coefficients; numbers in parentheses represent standardized regression coefficients; R, multiple correlation co-efficients; R², coefficients of determination; * P<0.05
Fig. 1: Petit type face mask.

Fig. 2: Bonded maxillary splint with hooks attachment of elastics in the canine premolar area above the occlusal plane.

Fig. 3: Reference points and cephalometric variables used in the study:

1) SNA; 2) SNB; 3) U1 to SN; 4) L1 to MP; 5) SPPS; 6) MPS; 7) IPS; SN-CVT
The change in SN-CVT had a significantly positive effect on changes in all variables regarding the upper-airway dimension (P<0.05). The change in SNA also had a significantly positive influence on the change in SPPS (P <0.05). On the other hand, changes in SNB and SN-MP did not significantly change the upper-airway dimension.

Discussion

Many issues related to maxillary protraction remain controversial. Application of maxillary protraction appliances can produce good results in patients having skeletal Class III malocclusion with a maxillary deficiency.

Changes in the craniofacial morphology

The treatment effects of the protraction face mask therapy in the present study were observed as a combination of skeletal and dental changes of the maxilla and mandible (Table 1). Significant increases were observed in the SNA and ANB angles whereas significant decrease occurred in SNB angle. SN-MP angle also showed a mean increase though it was not statistically significant. In addition to this, U1-SN angle showed a mean increase while L1-MP angle showed a mean decrease, both of which were statistically significant.

The face mask thus affected both the maxilla and mandible. Elastic forces applied to the upper dentition stimulated the forward growth of the maxilla and moved the maxillary teeth forward, while the reciprocal forces acting on the mandible caused a clockwise rotational effect. These results are compatible with the results regarding maxillary protraction in the literature.

Regarding the effect of maxillary expansion, previous studies that evaluated the effects of maxillary expansion and protraction have claimed that statistically more forward movement of point A was achieved in their expansion groups, but the angular change was very similar in the expansion group and the non-expansion group (4). In a meta-analysis by Kim et al. it has been suggested that the use of an expansion appliance enhances the protraction effect in terms of time with less dental effect which is actually more desirable (1).

Relationship between changes in the craniofacial morphology and upper-airway dimensions

No significant changes were observed in the upper-airway dimension during treatment. It is commonly accepted that there is a relationship between head posture and upper airway size (12,19). The multiple-regression analysis demonstrated that the change in SN-CVT had a significantly positive influence on changes in SPPS, MPS, and IPS indicating that a greater change in SN-CVT was associated with a greater change in the upper airway dimension (Table 2). Thus, there was a strong correlation between the changes in head posture and those in the upper airway dimension. Accordingly, it is necessary to control the influence of confounding factor of head posture while evaluating the relationship between changes in the craniofacial factors and upper-airway dimension.

In order to determine whether the head posture was the same during both of the projections, the SN-CVT measurement was used, and no statistically significant differences were found in head posture measured on the first and second radiographs (Table 1). This result shows that the airway passage measurements were not affected by the positioning of the patients.

In addition to the variable regarding head posture (SN-CVT), skeletal variables such as SNA, SNB, and SN-MP were used as independent variables in this study. The change in SNA also had a significantly positive effect on the change in SPPS (Table 2). Thus, a greater forward maxillary growth was associated with a greater increase in the superior upper-airway dimension.

This is similar to findings of Hiyama et al who found that maxillary growth induced by protraction treatment had a significant positive effect on the superior upper airway dimension (12). Similarly, in the study by Oktay and Ulukaya, maxillary protraction appliances were applied, and significant distances and increments in area were observed in the upper part of the airway space, especially at the naso-pharynx (13). Based on these findings, it is suggested that facilitating maxillary growth in growing patients during maxillary protraction treatment could contribute to an increase in the upper airway dimensions and improve the respiratory function of patients with maxillary hypoplasia.

It has been suggested that a change in the mandibular position could influence the upper-airway morphology. The results of the multiple-regression analysis did not indicate that this change had any significant effect on the upper airway (Table 2). As suggested by Hiyama et al, since this inhibition of mandibular forward growth during MPA treatment does not have a negative effect on the upper-airway dimension, it should be favorable for the orthodontist (12).

As regards the influence of maxillary expansion, it appears to affect an expansion at the anterior nares, which contributes to nasal resistance reduction as a result of an increase in the intranasal capacity. The effect can vary from no appreciable change to a marked decrease in nasal airflow resistance. The influence of expansion is thus exerted intra-nasaly rather than at the level of the upper airway (20,21).

This study did not include untreated controls to compare with the patients who were treated using maxillary protraction for two reasons. First, it was
difficult to get such patients. Second reason relates to whether the increase in the upper-airway dimension is actually related to maxillary growth induced by maxillary protraction. Ozbek et al demonstrated that 15 untreated subjects of mean age: 11.3 years showed only negligible changes in the upper-airway dimension during a 1.8-year observation period (11). Taylor et al also concluded that a greater rate 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 very small between 9 and 12 years (22). Because the mean age of the subjects in the present study was 10.3 +/- 1.1 years and the mean treatment time was 8 +/- 2.1 months, it was thought that the changes in pharyngeal measurements related to growth were negligible and the increase in the upper airway dimension could be related to the increased maxillary growth induced by MPA treatment. Thus, a control group was not included in this study.

Possible explanations have been put forward for the underlying mechanism of increase in the superior airway dimensions by maxillary protraction. According to Ozbek et al an increase in the volume of the oral cavity possibly induced by increased maxillary forward growth could bring the tongue to a more anterior position. This change in tongue posture could induce the soft palate to a more anterior position, which might result in an increase in the superior upper airway dimension (11). Clockwise rotation of the mandible might also influence the tongue posture. The orthopedic force applied by the MPA might induce an anterior displacement of PNS, which could result in a forward movement of the soft palate and an increase in the superior upper airway dimension.

It must be kept in mind that this study was essentially a 2-dimensional cephalometric measurement of the upper-airway dimensions. We still do not know whether changes in respiratory function could be induced following the increased maxillary growth using an MPA. In future, the clinical effects of maxillary protraction on respiratory function should be carefully examined 3-dimensionally including monitoring of respiratory function during wakefulness and sleep.

Conclusion

The hypothesis is thus rejected. Facilitation of maxillary growth with a maxillary protraction appliance does contribute to a significant increase in the upper airway dimensions.

References

14. Hu¨ samettin Oktaya; Esengu¨ l Ulukayab. Maxillary Protraction Appliance Effect on the Size of the


About the Authors

1) Dr. Rishabh Gupta, MDS
Registrar
Department of Orthodontics and Dentofacial Orthopedics
Indira Gandhi Government Dental College
Jammu, India.
E-mail – rishabh_dr@yahoo.com

2) Dr. G Shivaprakash, MDS
Professor and Head
Department of Orthodontics and Dentofacial Orthopedics.
College of Dental Sciences, Davangere, India

3) Dr. Mala Ram Manohar, MDS
Professor
Department of Orthodontics and Dentofacial Orthopedics.
College of Dental Sciences, Davangere

Correspondence Address

Dr. Rishabh Gupta
197, Sector – 1
Channi Himmat Colony
Jammu Tawi - 180011
Jammu & Kashmir
E-mail – rishabh_dr@yahoo.com
Phone No. +91 9419987170