Immediate and Long-term Changes in the Pharyngeal Airway Passage following Maxillary Advancement with Distraction Osteogenesis in Adult Patients with Cleft Lip and Palate

Ashok Kumar Jena, Vidya Rattan, Satinder Pal Singh, Ashok Utreja

ABSTRACT

Objective: To evaluate the immediate and long-term effects of maxillary distraction osteogenesis on the pharyngeal airway passage and soft palate adaptation in adult patients with cleft lip and palate.

Design: A total of 12 North Indian adult patients in the age range of 17 to 34 years with cleft lip and palate underwent advancement of maxilla by distraction osteogenesis. Lateral cephalograms recorded prior to distraction, at the end of distraction, 6 months after distraction and at least 24 months (mean 25.5 ± 1.94 months) after distraction osteogenesis were used for the evaluation of immediate and long-term effects of maxillary distraction on the pharyngeal airway passage and adaptation of soft palate. Descriptive statistics, ANOVA and post-hoc test were used, and probability value (p-value) 0.05 was considered as statistically significant level.

Results: Maxillary distraction improved the depth of nasopharynx. The depth of oropharynx was increased significantly (p < 0.05) after immediate maxillary advancement; but at the end of 6 months and after 2 years of follow-up, the improvements were not significant. The length of soft palate was increased after immediate and long-term follow-up of maxillary distraction. The inclination of the soft palate was increased significantly (p < 0.01) after immediate advancement of maxilla and was remained stable till the end of 2 years postdistraction.

Conclusion: The advancement of the maxilla by distraction osteogenesis improved the pharyngeal airway passage in adult subjects of cleft lip and palate.

Keywords: Pharyngeal airway, Distraction osteogenesis, Cleft lip, Cleft palate.

INTRODUCTION

Maxillary hypoplasia is a common deformity in subjects with repaired cleft lip and palate. Distraction osteogenesis of the maxilla offers a solution for the correction of maxillary hypoplasia in cleft lip and palate subjects. The effects of maxillary distraction on the dimensions of pharyngeal airway passage in cleft lip and palate subjects are controversial. Advancement of the maxilla improves the quality of articulation in the labiodental area but might cause velopharyngeal incompetence.1 Several investigators have reported no evidence of significant change in the velopharyngeal function,1-4 while others have reported problems in the velopharyngeal closure following maxillary advancement.5-8 Although few studies are there in the literature mentioning the effects of maxillary distraction on the pharyngeal airway passage, nasorespiratory function and velopharyngeal functions in young and adult subjects of cleft lip and palate;9-11 but there is not a single study mentioning the long-term effects of maxillary distraction on the pharyngeal airway passage and adaptation of the soft palate in adult subjects of cleft lip and palate. Thus, the present study was designed to evaluate the immediate and long-term effects of maxillary distraction on pharyngeal airway passage and adaptation of soft palate in adult subjects of cleft lip and palate.

MATERIALS AND METHODS

The study was conducted on 12 (M = 7, F = 5) North Indian adult subjects in the age range of 17 to 34 years with complete cleft lip and palate who underwent advancement of maxilla by distraction osteogenesis. Among 12 subjects, eight were with unilateral cleft lip and palate and four with bilateral cleft lip and palate. None of the subjects had received alveolar bone grafting. All the subjects had severe anteroposterior maxillary hypoplasia with Class-III malocclusion and reverse overjet.
In all the subjects, maxillary arch was prepared by multibonded fixed orthodontic appliance prior to distraction. After the preparation of maxillary arch, the multibonded appliance was removed and an alginate impression was made for intraoral splint fabrication. High LeFort-I osteotomy with septal and pterygomaxillary disjunction was carried out. The splint was cemented to the maxillary arch with glass ionomer cement and the customized external distractor was fixed. After latency period of 4 to 6 days, distraction was started at the rate of approximately 1 mm per day by adjusting the screws attached to the traction wires of the intraoral splint. The distraction vector was parallel and along the occlusal plane. All the subjects were followed up weekly and active distraction was continued until 5 to 8 mm of positive overjet was achieved. After the consolidation period of approximately 6 to 8 weeks, the distractor and intraoral splints were removed. The fixed orthodontic appliance was again bonded and the correction was retained by Class-III elastic traction (¼", 6oz force). The same oral surgeon (VR) carried out the procedures in all the patients.

The lateral cephalograms were recorded at the beginning of treatment (T₀), before distraction procedure (T₁), at the end of distraction (T₂), 6 months after the end of distraction (T₃) and at least 24 months after the distraction osteogenesis (T₄). The mean time interval between the T₂ and T₄ was 25.5 ± 1.94 months. For the evaluation of changes in the pharyngeal airway passage, lateral cephalograms recorded at T₁, T₂, T₃ and T₄ were traced manually and considered for analysis. While recording the lateral cephalograms, patients were in standing position with FH-plane parallel to the floor and teeth in centric occlusion. The head of the patients was erect. The cephalogram was exposed at the end-expiration phase of the respiration. Subjects were instructed not to move their heads and tongues, and not to swallow while exposure of the cephalograms. All the cephalograms were recorded with same exposure parameters and in a same machine. All the cephalograms were traced and analyzed by the same investigator (AKJ). All the linear and angular variables were measured twice and the mean was considered for statistical analysis. Various cephalometric landmarks, reference planes and linear and angular parameters for the evaluation of pharyngeal airway passage and adaptation of the soft palate are shown in Figure 1.

**Statistical Method**

All the statistical analyses were performed with SPSS software. The data were subjected to descriptive analysis for mean, range and standard deviation of all variables. ANOVA and post-hoc test were used and probability value (p-value) 0.05 was considered as statistically significant level.

**RESULTS**

The results of a few important skeletal cephalometric measurements and all the variables representing changes in the pharyngeal airway passage and soft palate before, immediately after, 6 months after and 25.5 months after maxillary distraction osteogenesis are described in Tables 1 and 2 respectively. The maxilla (M-point) moved 12.07 mm forward from the pterygomaxillary fissure (Ptm) with 5.75° counterclockwise rotation and moved 3.55 mm backward with 2.16° clockwise rotation at the end of 6 months after maxillary distraction. The SNB and FMA angles were comparable at various time intervals after maxillary distraction. During the first 6 months of postdistraction period, the skeletal changes showed relapse of approximately 30% and thereafter the improvements were almost stable.
The distance between Ptm and UPW was increased by 3.49 mm immediately after maxillary distraction. The Ptm-UPW distance was decreased 1.43 mm at the end of 6 months of follow-up and thereafter it was remained stable. However, the changes in the Ptm-UPW at various time intervals after maxillary distraction was not significant statistically (p = 0.420). The U-MPW was increased significantly (p < 0.05) after immediate maxillary distraction and decreased marginally during the postdistraction follow-up periods. The distraction osteogenesis of maxilla had no effect on the dimension of V-LPW. The PNS-U value was increased but the differences at various time intervals after distraction were not statistically significant (p = 0.252).

**DISCUSSION**

Small and retruded maxilla are characteristic in operated cleft lip and palate patients. The dimension pharyngeal airway passage in cleft lip and palate patients is also smaller than normal subjects.12,13 Advancement of maxilla by distraction osteogenesis offers the best solution for the improvement in cleft lip and palate subjects. However, advancement of the maxilla might cause velopharyngeal incompetence.1  

Advancement of maxilla increases the anteroposterior dimensions of the nasopharynx and resulting in an increased distance for soft palate to move during velopharyngeal closure.14 Several investigators have reported no evidence of any significant change in the velopharyngeal function,1,4 while others have reported problems in the velopharyngeal closure following maxillary advancement.3-8 The risk of speech distortion due to velopharyngeal insufficiency following maxillary distraction is similar to that observed in LeFort-I maxillary advancement.15 When the maxilla is brought forward, most noncleft patients usually have sufficient compensation to ensure normal velopharyngeal closure.16 However, in cleft patients the ability to compensate is usually impaired due to scar, small soft and hard palate, improper attachment of the muscles and muscular atrophy, and these patients remain already in the extended compensatory mechanism.16 It was observed that in patients with preoperative velopharyngeal competence, the velopharyngeal sphincture remains competent post-operatively and however the preoperative velopharyngeal insufficiency persisted after surgery.2 However, in patients with impaired velopharyngeal function, the midface advancement with distraction displaces the palate forward away from the posterior pharyngeal wall, but as advancement is gradual, the velopharyngeal mechanism became able to compensate and hypernasality does not occur. Harada et al17 reported that maxillary distraction of less than 15 mm had no remarkable effect on velopharyngeal function. When the entire maxilla is advanced surgically, the hard palate and the attached soft palate are advanced as well.9 In normal patients, the lateral pharyngeal and palatal musculature are able to compensate for this anatomic change to maintain velopharyngeal adequacy.14,17 Although the velopharyngeal function in cleft patients is fragile but it

**Table 1:** Treatment changes for skeletal measurements at various time intervals after distraction osteogenesis of maxilla

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-distr (T1) Mean ± SD</th>
<th>Immediate postdistr (T2) Mean ± SD</th>
<th>6 months postdistr (T3) Mean ± SD</th>
<th>Long-term postdistr (T4) Mean ± SD</th>
<th>p-value</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNM (°)</td>
<td>65.16 ± 4.26</td>
<td>78.5 ± 6.85</td>
<td>74.41 ± 4.64</td>
<td>73.33 ± 4.88</td>
<td>0.000</td>
<td>***</td>
</tr>
<tr>
<td>Ptm-M (mm)</td>
<td>37.32 ± 3.47</td>
<td>49.39 ± 2.94</td>
<td>45.84 ± 2.78</td>
<td>43.77 ± 3.07</td>
<td>0.000</td>
<td>***</td>
</tr>
<tr>
<td>S-N × M-PNS (°)</td>
<td>11.75 ± 5.75</td>
<td>6.00 ± 5.99</td>
<td>8.16 ± 4.74</td>
<td>9.41 ± 5.08</td>
<td>0.084</td>
<td>***</td>
</tr>
<tr>
<td>SNB (°)</td>
<td>80.58 ± 5.61</td>
<td>79.66 ± 4.71</td>
<td>79.91 ± 5.07</td>
<td>80.16 ± 5.23</td>
<td>0.976</td>
<td>NS</td>
</tr>
<tr>
<td>FMA (°)</td>
<td>27.83 ± 5.52</td>
<td>30.66 ± 5.38</td>
<td>29.00 ± 4.93</td>
<td>28.44 ± 5.65</td>
<td>0.609</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Table 2:** Treatment changes for all pharyngeal airway passage measurements and soft palate at various time intervals after distraction osteogenesis of maxilla

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-distr (T1) Mean ± SD</th>
<th>Immediate postdistr (T2) Mean ± SD</th>
<th>6 months postdistr (T3) Mean ± SD</th>
<th>Long-term postdistr (T4) Mean ± SD</th>
<th>p-value</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ptm-UPW (mm)</td>
<td>16.37 ± 5.05</td>
<td>19.86 ± 5.51</td>
<td>18.43 ± 5.30</td>
<td>18.56 ± 4.45</td>
<td>0.420</td>
<td>NS</td>
</tr>
<tr>
<td>U-MPW (mm)</td>
<td>11.57 ± 3.37</td>
<td>15.66 ± 3.34</td>
<td>14.75 ± 3.23</td>
<td>14.46 ± 3.07</td>
<td>0.023</td>
<td>NS</td>
</tr>
<tr>
<td>V-LPW (mm)</td>
<td>17.80 ± 3.89</td>
<td>16.87 ± 4.07</td>
<td>18.18 ± 3.83</td>
<td>17.60 ± 3.87</td>
<td>0.870</td>
<td>NS</td>
</tr>
<tr>
<td>PNS-U (mm)</td>
<td>33.32 ± 6.03</td>
<td>38.16 ± 6.07</td>
<td>36.19 ± 5.52</td>
<td>35.47 ± 5.63</td>
<td>0.252</td>
<td>NS</td>
</tr>
<tr>
<td>Sper × PNS-U (°)</td>
<td>39.83 ± 8.78</td>
<td>54.16 ± 11.16</td>
<td>50.91 ± 9.71</td>
<td>49.00 ± 8.16</td>
<td>0.005</td>
<td>NS</td>
</tr>
</tbody>
</table>
occasionally deteriorates following maxillary advancement.\textsuperscript{1,6} Schwart and Guner\textsuperscript{1} reported deterioration of velopharyngeal function occurring four months following maxillary advancement in 84\% of CLP patients, whereas Kanno et al\textsuperscript{18} did not experience any deterioration of velopharyngeal function following maxillary advancement in CLP patients. This was because during maxillary distraction, both the nasopharyngeal depth and velar length were increased.\textsuperscript{9} Chancharoensook, Whitehill and Samman also observed that advancement of maxilla either by osteotomy or distraction had no significant effect on speech outcome and velopharyngeal status.\textsuperscript{19}

In the present study, when the maxilla was brought forward by the distraction osteogenesis, the depth of nasopharynx (Ptm-UPW) was improved but the improvement was not significant. However, many previous studies reported significant increase in the anteroposterior dimension of the superior part of the upper airway passage after LeFort-I advancement of the maxilla in cleft lip and palate patients,\textsuperscript{10,20,21} in non-cleft patients\textsuperscript{22} and in obstructive sleep apnea patients.\textsuperscript{23} Ko et al\textsuperscript{24} observed an increase in the nasopharynx depth by 1:1 ratio with bony movement after maxillary distraction in cleft patients. Helliovaara et al\textsuperscript{25} also observed a positive correlation between the amount of horizontal maxillary advancement and amount of change in the nasopharyngeal airway. It was also observed that when the maxilla was advanced moderately, the changes in the nasopharyngeal airway were more significant.\textsuperscript{21} In the present study, the mean forward movement of the maxilla was 12.07 mm at point-M from the pterygomaxillary fissure (Ptm) and the increase in the depth of nasopharynx was only 3.49 mm which was much less as comparison to the results of previous studies.\textsuperscript{21,24} However, we found a significant improvement in the depth of oropharynx (U-MPW) following immediate advancement of the maxilla. When the maxilla was brought forward by the distraction osteogenesis, the posterior nasal spine and soft palate were also moved forward along with maxilla and improved the depth of oropharynx. However, at the end of six months of maxillary distraction, the improvement was not significant. This finding was similar to the findings of many previous studies where no significant improvement in the oropharyngeal airway depth was found after six months of maxillary advancement by LeFort-I osteotomy in cleft patients.\textsuperscript{20,21}

In this study, the length of the soft palate was increased by 4.84 mm following 12.07 mm of maxillary advancement. However, during follow-up period when the maxilla moved back, the length of the soft palate was also reduced. When the maxilla was moved forward, the distance from the nasopharyngeal wall to soft palate was increased and the length of the soft palate was increased as a compensatory measure to achieve velopharyngeal closure.\textsuperscript{14} The improvement in the length of the soft palate could be because of its stretch rather than its growth. Kummer et al\textsuperscript{25} also found evidence for compensatory changes in the velopharyngeal function in the form of velar stretching and lengthening after maxillary advancement. In the present study, there was 0.4 mm lengthening of the soft palate per millimeter of maxillary advancement. Schendel et al\textsuperscript{26} also reported 0.4 mm increase of soft palate length per millimeter of maxillary advancement by maxillary osteotomies in patients with cleft lip and palate. However, many previous authors reported no change in the soft palate length following maxillary advancement by LeFort-I osteotomy in the subjects with cleft lip and palate.\textsuperscript{20,21,24} In distraction patients since the palate was advanced in small increments (approximately 1mm per day), the palate had time to adapt to the change before the maxilla was advanced another 1 mm.\textsuperscript{15}

One of the most prominent finding was the change in the inclination of soft palate. The soft palate became more horizontal following maxillary distraction. Ko et al\textsuperscript{24} also reported similar observation. We found 14.33° increase in the inclination of the soft palate following 12.07 mm advancement of the maxilla. At the end of 6 months of follow-up, the inclination was 11.08° more than that of before distraction, and after that the inclination was almost stable. Schendel et al\textsuperscript{26} noticed that the angle between the soft palate and hard palate increased 2° per millimeter of maxillary advancement. In contrast to the finding of Schendel et al\textsuperscript{26} in this study, only 1.18° increase in the soft palate angulation per millimeter of maxillary advancement.

Thus, the present study showed that distraction osteogenesis was an efficient method for the advancement of maxilla in adult patients with cleft lip and palate. Advancement of the maxilla had no significant effect on the nasopharyngeal airway passage, but significantly improved the oropharyngeal airway passage. As the oropharyngeal airway passage increased, the length and inclination of the soft palate were also increased as an adaptive mechanism to maintain velopharyngeal closure. As the effect of maxillary distraction on the dimensions of pharyngeal airway passage is minimum and the adaptation of soft palate is very good, it appears that there should not be any speech distortion following maxillary distraction in adult cleft lip and palate subjects. However, further study should be carried out to evaluate the effect of maxillary distraction on velopharyngeal function and speech in adult subjects with cleft lip and palate.

**CONCLUSION**

The following conclusions were drawn from the present study:

1. The depth of the nasopharynx was improved marginally by the distraction osteogenesis of maxilla.
2. The depth of the oropharynx was increased significantly after immediate maxillary distraction but, after long-term follow-up, the change was very minimum.
3. Maxillary distraction increased the length of soft palate.
4. The inclination of soft palate was increased significantly by maxillary distraction and remained increased during the postdistraction period.

**REFERENCES**

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