Maxillary Movement in Cleft Patients Treated with Internal Tooth Borne Distractor

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Abstract Cleft lip and palate is associated with maxillary hypoplasia and retrognathism. Surgery and distraction have been the most common treatment approaches used. The aim of this study was to objectively assess the quantum and direction of movement of the anterior maxilla in cleft patients treated with an internal tooth borne distractor. A prospective clinical study design was followed in which 8 consecutive patients with cleft maxillary hypoplasia were included in the age range of 15–25 years. All patients had undergone secondary alveolar bone grafting earlier. Anterior maxillary distraction was performed using a tooth borne appliance in all 8 patients after necessary osteotomy. Lateral cephalograms were obtained preoperatively, pre-distraction and postdistraction. The angular and linear change at the maxillary anterior segment, rotation of the palatal plane, mandibular plane, increase in lower facial height and vertical changes of the anterior and posterior dentoalveolar segments were measured. The movement of the anterior maxillary segment was demonstrated anteriorly and superiorly in all the patients. The anterior and posterior dentoalveolar heights were increased post-distraction. There was also an increase in lower anterior facial height and the mandibular plane angle. Predictable superior and anterior movement of the anterior maxilla along with significant increase in palatal length could be achieved with the internal tooth borne distractor leading to remarkable improvement in esthetics and better function.

Keywords Cleft palate · Internal tooth borne distractors · Maxillary distraction

Introduction

Cleft lip and palate (CLP) is a congenital malformation resulting from non-fusion of lip and palate during development in utero. These malformations contribute to feeding difficulties right from birth, persistent and recurring ear infections, speech difficulties, dental problems and psychological challenges. Cleft lip and palate patients present with a tendency for maxillary hypoplasia and retrognathism with a class III skeletal relationship and malocclusion.

Craniofacial distraction osteogenesis (DO) is a rapidly growing field that has opened new vistas for the management of several congenital and acquired craniofacial deformities including CLP. Maxillary DO has significantly changed the management of severe maxillary retrusion in CLP patients because it provides bone regeneration by gradual skeletal advancement in combination with expansion of the soft-tissue functional matrix. Polley and Figueroa [1] in 1997 described a technique of maxillary distraction for severe maxillary hypoplasia using a rigid external distraction (RED) device. Rachmiel et al. [2] in 2005 reported stable results 2 years after maxillary distraction in 12 patients with clefts.

External and internal distraction devices have been used for maxillary DO. Internal maxillary distraction has definite advantages over the RED system in the form of good patient compliance and convenience. The main advantages are less physical and psychological stress on the patients and a shorter duration of hospitalization. Disadvantages of internal distraction when compared with external distractors include technique sensitive fixation methods, less

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flexibility in vector management and vector control and limited quantum of achievable advancement. Internal maxillary distraction has been widely used in the treatment of cleft palate patients. In a meta-analysis of cleft maxillary osteotomy and distraction osteogenesis, Cheung and Chua [3] in 2006 reviewed 26 papers on cleft maxillary distraction in 276 patients. Most maxillary advancements measured 5–9 mm. External distractors (190 cases, 68.8 %) were used more often than were internal distractors (6 cases, 2.17 %) and facial masks (71 cases, 25.72 %).

Segmental distraction has been attempted with anterior maxillary osteotomy followed by gradual distraction. These distractors were either bone borne or tooth borne. Segmental distraction with a tooth borne distractor [4] offers several advantages. Tooth borne distractors produce significant lengthening and increase in the alveolar volume at the distraction site which can be used for orthodontic decrowding or for dental implant placement. The morbidity for the patient is far lesser than for full jaw distraction.

The extent and direction of movement of the maxillary segment when distracted with an internal tooth borne distractor is not known. Huang et al. [5] in 2007 reported that the distracted segment moves anteriorly and downwards and that there was no further forward growth after distraction in cleft patients. The present study was thus carried out to assess the extent and direction of movement of the distracted segment in cleft palate patients treated with internal tooth borne distractors. The direction and extent of movement of the segment before and after distraction was measured using cephalometry.

Subjects and Methods

Eight patients with cleft maxillary hypoplasia underwent maxillary DO with internal tooth borne distractor. There were 6 males and 2 female patients in the age range of 15–25 years (mean age was 19.5 years). The patients included 7 unilateral and 1 bilateral cleft lip and palate patients. All patients included in the study had class III skeletal malocclusion due to a retrognathic maxilla and an Angle's class III dental malocclusion with a mean reverse overjet of 4 mm preoperatively. All patients had undergone maxillary alveolar bone grafts so that the maxilla was united as a one-piece segment before distraction. None of the patients had mandibular osteotomies at the same time. Ethical approval for the study was obtained from the Institutional ethics committee. All the subjects were clearly explained about the study protocol and all of them gave informed consent. The details and aim of this study was

Fig. 1 Appliance used

clearly explained to all the patients before any measurements were taken.

Appliance Fabrication

The anterior maxillary distraction (AMD) device consisted of a hyrax screw which was placed longitudinally instead of transversely to produce antero-posterior expansion which was soldered to bands (Fig. 1). Bands were fabricated to provide anchorage for the device. Maxillary first molars served as the anchor teeth posteriorly and the premolars or canines were banded in the anterior segment. The appliance was tried for a passive fit before the surgery.

Surgical Technique and Distraction Osteogenesis

The osteotomy design was very similar to the Cupars method of anterior maxillary segmental osteotomy. The vertical osteotomy on the alveolar segment was placed interdental in the premolar region which was determined by the root inclination of the teeth in the vicinity of the osteotomy site and the number of teeth in the proximal and distal aspect of the osteotomy site which will be used for anchorage of the tooth borne appliance. Care was taken to ensure that the osteotomy was completed on the palatal alveolar bone and the palatal vault which may prevent complete mobilization and forward distraction of the segment. The anterior maxilla was down fractured with finger pressure and ensured that the segment was completely mobilized. The AMD appliance was fixed in the upper arch and adjusted to achieve an anatomically snug fit. The distractor was trial activated to confirm the completion of osteotomy and demonstrate the movement. The device was removed, cleaned and dried. The AMD appliance was then cemented with zinc phosphate cement.

Orthopantomograph and lateral cephalograms were taken on 1st post-operative day. The latency period before the initiation of distraction was four days. Distraction was

performed from the fifth post-operative day and was continued till the desired result was achieved. During the activation period, the AMD appliance was activated at a rate of 1 mm (0.5 mm twice daily). The appliance was sealed with light cure composite at the end of the activation period. A consolidation period of four months was maintained for all patients. The amount of required distraction was determined by the degree of maxillary retrusion and the extent of anterior crossbite as determined clinically and cephalometrically.

Cephalometric Analysis

Lateral cephalometric radiographs obtained preoperatively (T1) (Fig. 2), predistracted (T2) (Fig. 3), and four months after distraction (T3) (Fig. 4) were used for analysis. Cephalometric anatomic landmarks and reference lines used in this study are shown in Table 1. Radiographs obtained in each stage were traced on acetate paper. All tracings on each patient were precisely superimposed based on the sella-nasion plane (SN plane). Changes in the vertical and anteroposterior position of the PNS, the anterior nasal spine (ANS), point A, the tip of the upper incisor, mesiobuccal cusp of the maxillary first molar were measured at each stage. In addition, concave profile improvement, the amount of angular change of the palatal plane, the SNA angle, the ANB angle, and the mandibular plane to FH plane were measured at each stage. The change in lower facial height was also measured.

All the cephalograms were traced by a single investigator to eliminate bias. Four subjects were randomly selected from 8 patients. Each cephalometric radiograph was retraced, superimposed, and measured with square calipers. The error was less than 0.50 mm for linear measurements and less than 0.5° for angular measurements. This degree of error falls within the clinically acceptable limit.

Results

The period of distraction ranged between 16 and 27 days. At the end of the distraction period, all patients had an improvement in profile which changed from concave to convex, extrusion of the maxillary posteriors, an increase in the mandibular plane and a positive overjet of 3 mm. There was upward movement of the anterior maxilla with opening of the bite and increased proclination of the upper anteriors. The results are tabulated in Table 2. The maxillary molars also exhibited distal movement and tipping. Orthodontic treatment was initiated in all patients with preadjusted edgewise appliance after a consolidation period of 4 months. The space gained during anterior maxillary distraction was

Fig. 2 Preoperative lateral cephalogram (T1)

Fig. 3 Predistracted lateral cephalogram (T2)

used for decrowding and aligning the upper arch along with lateral expansion to achieve ideal alignment. At the end of orthodontic treatment, an overjet and overbite of 2 mm was achieved.

Fig. 4 Postdistraction lateral cephalogram (T3)

Table 1 Cephalometric landmarks used in the study

S	Sella turcica
N	Nasion
Or	Orbitale
Po	Porion
ANS	Anterior nasal spine
PNS	Posterior nasal spine
A	A point
B	B point
FH	Frankfurts horizontal plane
Pg	Pogonion

Changes Seen in the Maxilla

Angular Changes

The improvement in profile as measured by the angle N-A-Pg showed a distinct reduction in concavity with a mean change of 7.6° . The value ranged from 2° – 14° . The changes in the SNA angle ranged from a maximum of 9° to a minimum of 2° with a mean of 5.25° . The mandibles of all the patients were rotated in a clockwise direction ranging between 3° and 8° with a mean of 5° . The palatal plane rotated in the anticlockwise direction and the range was between 2° and 6° with a mean of 4.2° . The skeletal class III pattern improved (ANB angle) for all patients and this

varied from a maximum of 10° in one patient to a minimum of 2° in one patient with a mean change of 5° . The upper central incisors showed proclination following distraction of the anterior segment. This varied from 6° to 17° . The mean changes in each variable are shown in Tables 3 and 4.

Linear Changes

The amounts of advancement and upward movement at point A after distraction ranged from 2–9 mm (mean 6 mm) and from 2–5 mm (mean 3.25 mm), respectively. The amounts of advancement and upward movement at the ANS point ranged from 2.0 to 8.0 mm (mean 4.5 mm) and from 2 to 5 mm (mean 3 mm), respectively. The superior movement of point A closely followed movement of the anterior nasal spine. The maxillary incisors showed superior movement ranging from 2 to 4 mm (mean of 2.8 mm). The maxillary molars also extruded ranging from 1 mm to a maximum of 4 mm (mean of 3.2 mm). The lower facial height increased in all patients ranging between 4 and 8 mm (mean of 5 mm).

Discussion

Maxillary hypoplasia is a common sequel in cleft lip and palate patients. This can be corrected by the following methods.

- Maxillary advancement at the Le Fort I or higher levels by traditional osteotomies.
- Maxillary distraction at the Le Fort I or higher levels using external or internal distractors.
- Anterior segmental distraction (segmental osteotomy followed by extra oral or intra oral distraction).

Most of the studies on distraction have reported on external bone borne distractors. The use of tooth borne distractor with a hyrax appliance has only been described recently but not much data has been reported [4]. Several authors have reported on internal distraction in CLP patients [5]. Most of these distractors required a high Lefort I osteotomy [2]. In the technique used in the present study, the distractor takes its anchorage entirely from the teeth and the surgical cuts are placed in the interdental areas.

The use of palatal distractor in the anteroposterior direction to advance a retruded maxilla after an alveolar osteotomy was reported by Gunaseelan et al. [4] in 2007. The authors modified the hyrax screw and presented an alternative technique involving distraction of the entire segment of the cleft anterior maxilla by a tooth borne palatal distractor. The technique of usage and the results

Table 2 Comparison of pre and post distraction changes

	Patient 1 Pre–post changes	Patient 2 Pre–post changes	Patient 3 Pre–post changes	Patient 4 Pre–post changes	Patient 5 Pre–post changes	Patient 6 Pre–post changes	Patient 7 Pre–post changes	Patient 8 Pre–post changes
Concave profile improvement (N-A-Pg) (deg)	7	8	10	12	13	2	6	3
Class III skeletal pattern improvement (ANB) (deg)	2	4	7	8	10	2	4	2
Maxillary retrognathism (SNA) (deg)	2	5	8	9	8	3	4	3
Palatal plane tipping (angle of inclination)	4	6	3	6	5	1	5	2
Anterior movement of apical base (N-A) (deg)	6	6	5	8	7	2	3	3
Increase in palatal length (ANS-PNS) (mm)	6	6	6	7	9	4	5	4
Anterior movement of ANS (HP-ANS) (mm)	5	4	5	6	7	2	2	3
Superior movement of ANS (N-ANS) (mm)	3	3	3	2	2	3	5	2
Superior movement of point A (N-A) (mm)	3	3	3	4	2	4	5	2
Superoinferior changes in PNS (N-PNS) (mm)	2	4	2	3	4	2	3	3
Lower facial height(ANS-Me) (mm)	6	7	4	6	8	4	6	4
Opening of mandibular plane (SN-MP) (deg)	6	6	3	5	7	4	5	4
Proclination of upper incisor (U1-SN) (deg)	6	7	10	17	14	7	11	7
Vertical movement of max incisor (U1-NF) (mm)	3	3	4	4	3	2	2	2
Posterior movement of max molar (U6-PTV) (mm)	1	2	2	3	2	1	1	1
Vertical movement of max molar (U6-NF) (mm)	4	5	2	3	3	3	4	3

Table 3 Mean angular changes

	Mean (deg)	SD
Concave profile improvement (N-A-Pg)	7.6	3.7
Class III skeletal pattern improvement (ANB)	4.9	2.8
Maxillary retrognathism (SNA)	5.25	2.5
Palatal plane tipping (angle of inclination)	4	1.7
Opening of mandibular plane (SN-MP)	5	1.2
Proclination of upper incisor (U1-SN)	9.8	3.6

obtained were illustrated with 2 cases of cleft lip and palate.

The results of this study indicate that the maxilla moves anteriorly and superiorly when distracted with internal tooth borne distractors. Huang et al. [5] in 2007 reported on the long term follow up in growing patients treated with distraction osteogenesis with rigid

external distractor. They concluded that the distracted segment moves anteriorly and downwards and that there was no further forward growth after distraction in cleft patients.

The movement of the anterior nasal spine was in a forward and upward direction thereby helpful in opening the bite. This movement varied between 5 and 2 mm. The reason for this could be the rigidity of the hyrax appliance and placement vector of the screw in the palatal region.

All patients in this study had anterior maxillary osteotomies followed by a latency period of 4 days and distraction using the hyrax tooth borne distraction device. The patients were then maintained in a consolidation phase for a period of 4 months. The anterior maxillary segment including anterior floor of the nose and the teeth in the anterior segment were all moved anteriorly by distraction. The anterior maxillary skeletal base moved forward along

Table 4 Mean linear changes

	Mean (mm)	SD
Increase in palatal length (ANS-PNS)	5.9	1.5
Anterior movement of ANS (HP-ANS)	4.25	1.7
Superior movement of ANS (N-ANS)	2.9	0.9
Superior movement of point A (N-A)	3.4	0.9
Superoinferior changes in PNS (N-PNS)	2.9	0.7
Lower facial height (ANS-Me)	5.6	1.4
Vertical movement of max incisor (U1-NF)	2.8	0.7
Posterior movement of max molar (U6-PTV)	1.6	0.6
Vertical movement of max molar (U6-NF)	3.4	0.8

with anterior nasal spine and point A by as much as 6 mm. There was anchorage loss with certain amount of posterior movement of the first molars. The effective increase in the palatal length was as high as 9 mm in one patient with an average increase of 6.5 mm. Good volume of bone regenerate was noticed in the entire alveolar region.

The mandibular plane angle was increased in all patients indicating that the mandible rotated in a clockwise direction. An increase in lower anterior facial height was also noted which could be attributed to the extrusion of the upper posterior dentition leading to a clockwise rotation of the mandible. Increase in lower facial height can also be attributed to the upward rotation of the maxillary anterior segment.

Wen-Ching Ko et al. [6] in 2000 conducted a study to evaluate the soft tissue profile changes after maxillary advancement with DO. They found that maxillary DO improved the soft tissue profile by increasing nasal projection, normalizing the nasolabial angle, and making the upper lip more prominent. More upper anterior tooth show in the rest position was obtained, but the upper lip length did not change. The concave facial profile became convex, with improved facial balance and aesthetics. In our study, skeletal movement was accompanied by forward positioning of the upper lip and also increased fullness of the para nasal area. The improvement of the naso-labial angle further enhanced facial aesthetics. This movement has been stable for more than 6 months follow-up in all the patients.

Wiltfang et al. [7] in 2002 studied the long term results of distraction osteogenesis of the maxilla and midface. They found that long-term cephalometric and clinical evaluation after a mean follow-up period of 24 months in the intraoral distraction group and 12 months in the extraoral distraction group showed stable results concerning the skeletal and dental relations. Our study revealed similar finding with the movement being stable for more than 6 months follow-up in all the patients.

The maxillary posterior segment demonstrated anchor loss and was seen to move posteriorly. This could also lead

to an increase in lower facial height and opening of the mandibular plane angle. Extrusion was also noticed in the maxillary posterior segment. There was an increase in the maxillary anterior dentoalveolar height between pre and post distraction.

The finding of our study correlate well with the findings of Kumar et al. [8] who demonstrated that Le Fort I internal distraction for severe cleft maxillary deficiency leads to better dental occlusion, less relapse and better speech results. The patients treated with internal tooth borne distractor in this study also showed improved dental occlusion, better facial aesthetics and less relapse.

Tooth borne distraction has several advantages compared to bone anchored distractors. These include:

- (a) Ease of application
- (b) Less morbidity such as cheek and lip ulcers seen with bone anchored appliances
- (c) Removal of appliance at the end of consolidation period is very simple and can be done without anaesthesia
- (d) Economical
- (e) Less chances of infection since there are no fixation screws

The procedure however does have a few disadvantages such as:

- (a) Vector control unidirectional only
- (b) Need for more diligent oral hygiene maintenance
- (c) Activation at home being difficult

The ease of anchoring the appliance and the ease of adaptation to the appliance by the patient especially during the consolidation phase is significant. Distraction osteogenesis with internal devices reduces the physical and psychological stress on the patient caused by the external devices [9].

The bone regenerate in the alveolar region can be used to either decrowd the maxillary teeth with fixed orthodontics or to anchor titanium implants to support a fixed dental prosthesis. A consolidation period of at least 4 months is required to reduce the percentage of relapse.

The procedure is not without complications. These include:

- (i) Root damage of permanent teeth adjacent to the osteotomy site
- (ii) Anterior open bite due to the segment moving upwards
- (iii) Bur breakage during surgery
- (iv) Appliance fracture
- (v) Appliance dislodgement

Maxillary distraction osteogenesis with either external or internal devices can give good results. These techniques

have provided dramatic outcomes in cleft lip and palate patients. Each technique has its own advantages and disadvantages, as well as different treatment effects. Long-term follow-up and assessment of these patients is needed to understand the relapse potential and the stability of DO with internal tooth borne distractors.

Conclusion

Eight patients with cleft palate were treated with segmental anterior maxillary distraction for the management of maxillary retrognathism. It was found that the maxillary anterior segment moved anteriorly and superiorly with a change in patients' profile from concave to convex, improved facial aesthetics and better dental relations. There was an opening of the mandibular plane, anteinclination of the palatal plane and increase in lower anterior facial height. Extrusion of the maxillary anterior and posterior segments was also observed. Tooth borne segmental distraction of the anterior maxilla can thus be considered as a viable treatment option for the management of patients with cleft lip and palate.

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