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Evaluation of the Maxillary Morphological Changes Following Distraction Osteogenesis in Patients with Repaired Cleft Palate Using Three-dimensional CT Images

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Abstract

The purpose of this study was to document the morphological changes of maxilla following distraction osteogenesis (DOG) using three-dimensional CT images. The maxillary distraction using a face mask and/or an expansion screw was applied in nine cleft palate patients aged from 9 to 11 years. Cephalograms, photographs, and three-dimensional CT images before and three months after distraction were evaluated. Cephalometric analysis revealed that the estimated advancement and lateral expansion were achieved, and photographs showed the improvement of facial profile and occlusion. Superimpositions of pretreatment and posttreatment tracings of three-dimensional CT images facilitated to visualize the maxillary changes with distraction. It is confirmed that the whole maxilla moved forwards with a counterclockwise rotation, the maxillary lateral segments were moved forwards and outwards, and posterior elongation of the maxillary tuberosity, followed by the backward migration of the maxillary second molar.

From these results, it is suggested that advantages of the maxillary distraction osteogenesis during growing period include not only improvement in facial appearance and occlusion but provision of an osseous environment to permit spontaneous eruption of the second maxillary molar into the elongated area.

Key words; Distraction osteogenesis, Cleft lip and palate, Three-dimension, CT images, Maxilla

Introduction

Severe maxillary hypoplasia accompanied by midface retrusion and anterior and/or lateral crossbite were observed in a significant number of patients with repaired cleft palate[1-3]. Orthodontic maxillary protraction, however, does little to restore the maxillofacial relations[4-8]. Moreover, advancement of the maxilla by LeFort I osteotomy in those patients is often difficult and has a greater tendency to relapse, because of the scarring from previous operations[9-11]. Since the feasibility of distraction osteogenesis (DOG) in the membranous bone of the maxilla and midface has been demonstrated[12, 13], DOG has rapidly developed for managing maxillofacial deformities as an alternative procedure to conventional orthodontic surgery.

Until now, several articles have been published presenting successful results of maxillary DOG using

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various types of distraction devices in patients with repaired cleft palate[14-18)]. Although those patients present with maxillary hypoplasia in vertical, horizontal, and transverse dimensions, there have been few articles on three-dimensional evaluation of maxillary changes following distraction. The purpose of this study was to evaluate the changes in the maxilla itself following distraction using three-dimensional CT images in addition to photographic and cephalometric evaluation. A key distinguishing feature of the present study is its approach towards evaluating them by superimpositions of pretreatment and posttreatment CT images with three-dimensional reconstruction.

Subjects and methods

Subjects

The subjects consisted of nine patients aged from 9 to 11 years, five with repaired unilateral and four with repaired bilateral cleft lip and palate, in whom the primary lip and palate repairs were performed during infancy or early childhood at several hospitals in Miyazaki Prefecture, Japan. Although attempts were made to treat their midfacial retrusions and anterior and/or lateral crossbites through the use of the maxillary protracting appliance and/or the lateral expansion appliance, their responses fell short of expectations. Therefore, after obtaining informed consent from all patients, the maxillary distraction osteogenesis was selected as an alternative method. They were classified into three groups according to the type of maxillary hypoplasia: Group A (n=2); anteroposterior hypoplasia, Group B (n=4); anteroposterior and lateral hypoplasia, and Group C (n=3); anteroposterior and lateral hypoplasia with the premaxilla in a normal position (Table 1). All patients and their parents or conservators granted the distribution or publication of their photographs as a voluntary contribution in the interest of public education.

Table 1. Number and Cleft Type of Subjects

Group	UCLP	BCLP	Total
A	1	1	2
B	4	0	4
C	0	3	3

UCLP: unilateral cleft lip and palate
BCLP: bilateral cleft lip and palate

Treatment

The treatment procedure in the present study was varied depending on requirements of each Group (Fig.1). The lingual arch appliance with vestibular hooks was placed in the maxillary dental arch in Group A, while the expansion screw with vestibular hooks was placed in Groups B and C prior to surgery (Fig.2). The high LeFort I osteotomy across the whole maxilla in Groups A and B and on both maxillary lateral segments except the premaxilla in Group C was performed, and the maxilla was down-fractured softly to ensure its mobility. After a 5-day latency period, the advancement was performed with elastics linked from a face mask to vestibular hooks with force of 900 g all day, which proceeded over the following 3 to 7 weeks in all Groups. The direction of advancement

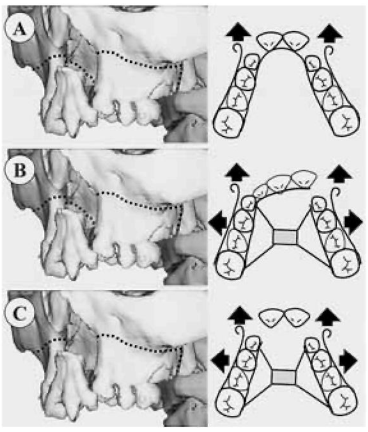

Fig. 1. Design of maxillary distraction in each Group. Broken lines indicate the site of osteotomy and arrows indicate the directions of advancement and lateral expansion.

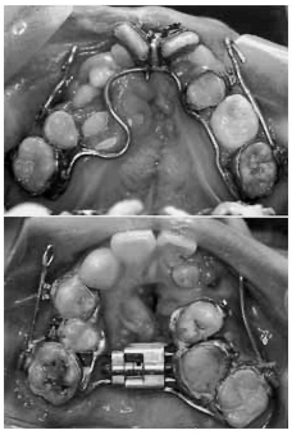

Fig. 2. Intraoral appliances in place prior to surgery. A lingual arch in Group A (*top*) and an expansion screw in Groups B and C (*bottom*).

Fig. 3. Advancement of the hypoplastic maxilla with a face mask and elastics.

was parallel to the occlusal plane, and the elastics were renewed once per day (Fig. 3). Simultaneous lateral expansion was started at a rate of 0.67 mm per day and proceeded over the following 11 to 18 days in Groups B and C. When the estimated advancements were achieved, the amount of force was reduced to 300 g for an additional 3 months to maintain the maxilla in the new position, and when the estimated lateral expansions were achieved, the intraoral appliance was left in place as a retainer for a further 3 months and replaced by the palatal bar. Approximately at 3 to 6 months after distraction, alveolar bone grafting was performed in all subjects. The palatal bar was removed 6 months after the alveolar bone grafting.

Evaluation

Facial and intraoral photographs, lateral and posteroanterior (P-A) cephalograms, and standardized CT images taken before the operation and 3 months after distraction were utilized for analysis. Landmarks and reference lines on lateral and P-A cephalograms are illustrated in Fig. 4, and measurement variables are shown in Table 2. In the present study, standardized CT images were reconstructed three-dimensionally and oriented using midsagittal and Frankfort-horizontal planes. Tracings of these three-dimensional CT images were superimposed on the zygomatic arch or the maxillary teeth to better describe the maxillary changes between pretreatment and posttreatment. Cephalograms and standardized CT images were traced on acetate paper and all tracings were carried out by a single experienced investigator (J.N.).

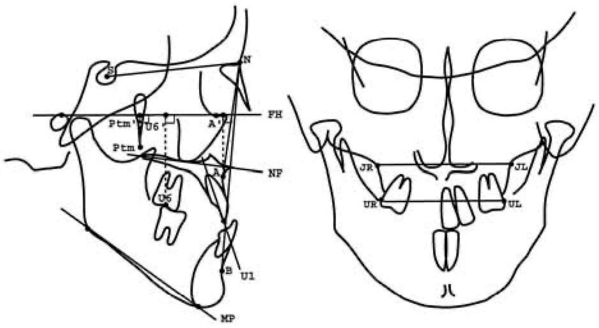

Fig. 4. Cephalometric landmarks and reference lines: N - nasion, S - sella turcica, Ptm - pterygomaxillary fissure, Ptm' - Ptm projected to FH, A - point A (subspinale), A' - A projected to FH, B - point B (supramentale), U6 - buccal groove of the maxillary first molar, U6' - U6 projected to FH, JR and JL - jugular points, UR and UL - the most lateral point on the buccal surface of the maxillary first molar, FH - Frankfort horizontal plane, NF - nasal floor, U1 - axis of upper incisor, MP - mandibular plane.

Table 2. Measurement Variables

Maxillary body		
NF to FH	:	angle between lines NF and FH
U1 to NF	:	angle between U1 axis and NF
U6'- Ptm'	:	projected distance of U6 and Ptm to FH
A' - Ptm'	:	projected distance of A and Ptm to FH
JR - JL	:	distance between points JR and JL
UR - UL	:	distance between points UR and UL
Facial skeletal pattern		
SNA	:	angle between lines SN and NA
SNB	:	angle between lines SN and NB
ANB	:	angle between lines NA and NB
MP to FH	:	angle between lines MP and FH

Results

Facial and intraoral findings

Pretreatment and posttreatment facial and intraoral photographs of one typical case in each Group are shown in Fig. 5 A-C.

Group A (Fig.5A): Midface retrusion and overclosure of the mandible were improved with the backward rotation of the mandible. The anterior crossbite was improved and the molar relation changed from Class I to II.

Group B (Fig. 5B): Midface retrusion was improved with the advancement of the midface and the backward rotation of the mandible. The anterior and lateral crossbite was improved and the molar relation changed from Class I to II.

Group C (Fig. 5C): The flattened cheek line

Fig. 5A. Lateral facial photographs (*top*) and intraoral photographs (*bottom*) of one typical case in Group A (*left*-pretreatment, *right*-posttreatment). Midface retrusion and overclosure of the mandible in the pretreatment photographs were improved with the backward rotation of mandible as shown in the posttreatment photographs. The anterior crossbite before treatment was improved.

Fig. 5B. Lateral facial photographs (*top*) and intraoral photographs (*bottom*) of one typical case in Group B (*left*-pretreatment, *right*-posttreatment). Midface retrusion before treatment was improved with the advancement of midface and the backward rotation of the mandible after treatment. The anterior and lateral crossbite before treatment was improved

Fig. 5C. Lateral facial photographs (*top*) and intraoral photographs (*bottom*) of one typical case in Group C (*left*-pretreatment, *right*-posttreatment). The flattened cheek line before treatment changed to round and the mandible rotated backwards. The upper central incisors were in a normal position before and after treatment. Before treatment, the upper lateral incisors were congenitally missing and both lateral segments were occluded lingually to the mandibular dental arch.

changed to round and the mandible rotated backwards. The upper central incisors were in a normal position before and after treatment. Before treatment, the upper lateral incisors were congenitally missing and both lateral segments were occluded lingually to the mandibular dental arch. After treatment, the spaces of missing incisors were closed and the molar relation changed from Class I to II.

3D CT images

Pretreatment and posttreatment three-dimensional standardized CT images and their superimpositions of the lateral and basal tracings of one typical case in each group are shown in Fig. 6A-C. Their characteristic findings in each Group were as follows.

Group A (Fig. 6A): From the superimpositions of the lateral and basal tracings on the zygomatic arch (e, f), the maxillary body was moved forwards with an upward rotation of the anterior part of the maxilla. However, the shape and the position of the pterygomaxillary fissure were unchanged. From the superimpositions of the lateral and basal tracings on the maxillary teeth from canine to first molar (g, h), the maxillary tuberosity was elongated posteriorly and the second molar migrated backwards.

Group B (Fig. 6B): The findings in the superimpositions on the zygomatic arch were similar to those in Group A except that the maxillary body and maxillary

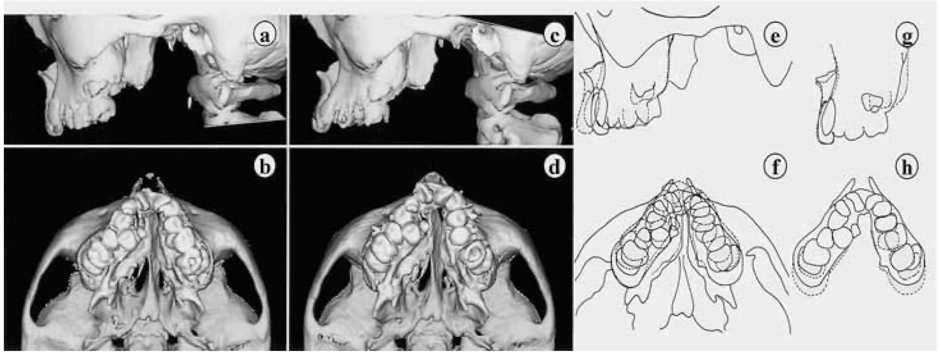

Fig. 6A. Three-dimensional CT images and superimpositions of tracings of one typical case in Group A. Pretreatment (a-lateral, b-basal) and posttreatment (c-lateral, d-basal) CT images, superimpositions on the zygomatic arch (e-lateral, f-basal) and on the maxillary teeth (g-lateral, h-basal). Gray areas and dotted lines in superimpositions indicate posttreatment.

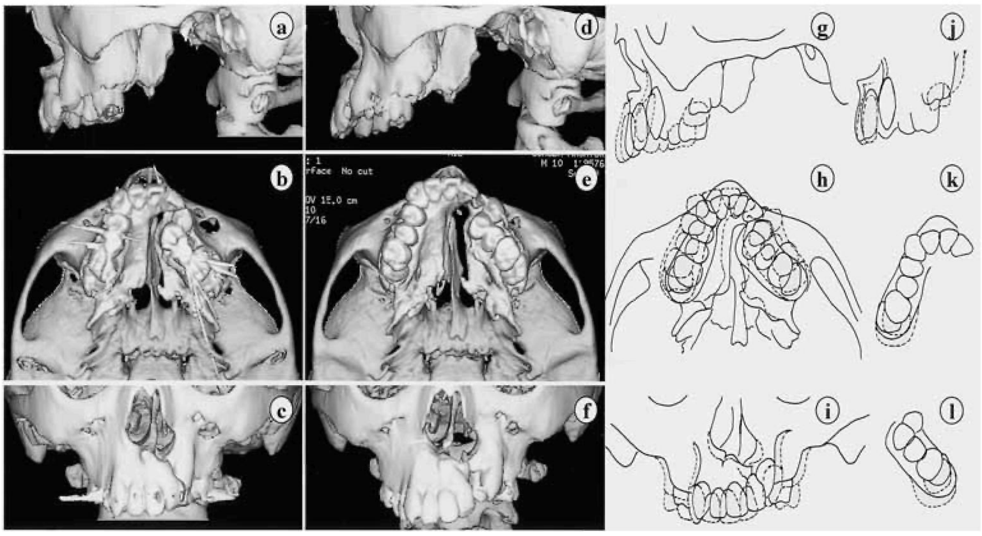

Fig. 6B. Three-dimensional CT images and superimpositions of tracings of one typical case in Group B. Pretreatment (a-lateral, b-basal, c-frontal) and posttreatment (d-lateral, e-basal, f-frontal) CT images, superimpositions on the zygomatic arch (g-lateral, h-basal, i-frontal) and on the maxillary teeth (j-lateral, k-basal of the right segment, l- basal of the left segment). Gray areas and dotted lines in superimpositions indicate posttreatment.

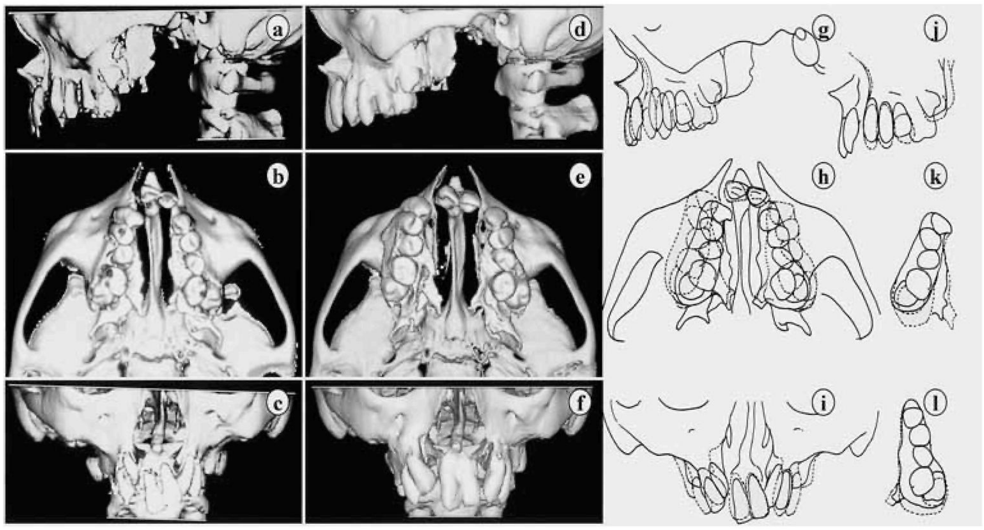

Fig. 6C. Three-dimensional CT images and superimpositions of tracings of one typical case in Group C. Pretreatment (a-lateral, b-basal, c-frontal) and posttreatment (d-lateral, e-basal, f-frontal) CT images, superimpositions on the zygomatic arch (g-lateral, h-basal, i-frontal) and on the maxillary teeth (j-lateral, k-basal of the right segment, l-basal of the left segment). Gray areas and dotted lines in superimpositions indicate posttreatment.

teeth were moved forwards and downwards in the lateral tracing (g). In the basal tracing (h), both the major and minor segments were moved forwards and outwards with widening of palatal and alveolar clefts. In the frontal tracing (i), both the major and minor segments were moved with slight outward inclination and an increase of the maxillary width. The bone step indicating the osteotomy site was recognized on the pyriform margin and the pyriform was widened below the bone step. From the superimpositions of the lateral and basal tracings on the maxillary teeth of each segment (j, k, l), the maxillary tuberosity was elongated posteropalatally and the second molar migrated backwards.

Group C (Fig. 6C): From the superimpositions on the zygomatic arch, the lateral segment was moved forwards and downwards with an upward rotation of the anterior part of the lateral segment, however, both the position and shape of the pterygomaxillary fissure were