Growth of Palate in Unilateral Cleft Lip and Palate Patients Undergoing Two-stage Palatoplasty and Orthodontic Treatment

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Abstract

The purpose of this study was to investigate the long-term effects of two-stage palatoplasty on the morphology of the maxillary alveolar arch and occlusion using plaster models of the maxilla and mandible obtained from patients with unilateral complete cleft lip and palate who also underwent orthodontic treatment. A total of 20 patients undergoing two-stage palatoplasty by Perko’s method (Group T) were enrolled. Plaster models of the maxilla and mandible were obtained from each patient at Time 1, on commencement of orthodontic treatment in the mixed dentition period; at Time 2, on that of orthodontic treatment in the permanent dentition period; and at Time 3, on completion of active orthodontic treatment. Analysis of occlusion and morphological analysis were performed using a 3-dimensional measuring system. The results were compared with 15 patients who underwent one-stage palatoplasty by the push-back method using a mucoperiosteal flap (Group P). Alveolar morphology and the relationship between the maxilla and mandible were satisfactory in Group T. The palates in Group T were deeper and larger than those in Group P. Alveolar collapse in Group T was milder, and impairment of the alveolar morphology less notable than in Group P, as surgical invasion to the anterior alveolar region was avoided during the palatal growth period. These results suggest that two-stage palatoplasty is advantageous for jaw development.

Key words: Two-stage palatoplasty — Plaster model — 3-dimensional analysis — Growth of palate — Unilateral cleft lip and palate

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**Introduction**

A key problem with palatoplasty as primary surgery for a cleft palate is that it has to satisfy the contradictory objectives of normalizing speech while allowing maxillary growth. Therefore, much controversy has long surrounded which is the best type of surgical procedure for achieving these goals and at what age it should be performed\(^{16,17}\). A consensus has yet to be reached, however\(^{19}\). Pushback palatoplasty by the mucoperiosteal flap method involves actively displacing the palate posteriorly by preparing a palatal flap after periosteal detachment, and is often performed as a one-stage procedure in patients with complete cleft lip and palate. Even though it allows adequate restoration of velopharyngeal closure function, however, severe impairment of jaw development and reverse occlusion of the incisor region have been reported with this approach\(^9\). With two-stage palatoplasty, on the other hand, a compromise must be made between facilitation of speech function and that of palatal growth\(^{1,14,18,23}\).

Satisfactory maxillary growth has been achieved with Perko’s two-stage palatoplasty\(^{6,7,10,15}\). One study investigated growth and development of the maxillary alveolar arch and palate between immediately before soft palate closure and after hard palate closure based on Moire Topography using maxillary models\(^{12}\). Another study performed measurements in maxillary models obtained using a 3-dimensional digitizer in 20 patients at the age of 5 years, before hard palate closure; at the second stage of surgery, at 6 years; after hard palate closure; and at 8 years and 6 months, at the start of orthodontic treatment in the mixed dentition period. They analyzed growth and development of the maxillary alveolar arch and palate, and compared the results with those in patients after one-stage palatoplasty by the push-back method using a mucoperiosteal flap. The results showed that, after two-stage palatoplasty, the larger and deeper the palate, the less noticeable disturbance in development of the alveolar arch, in comparison with after one-stage palatoplasty, before commencement of orthodontic treatment\(^{11}\). There have only been few reports, however, of long-term follow-up of maxillary growth in patients after two-stage palatoplasty.

The purpose of the present study was to clarify the long-term effects of two-stage palatoplasty by investigating palatal morphological change after two-stage palatoplasty until completion of orthodontic treatment.

**Materials and Methods**

1. **Participants**

The study participants comprised 20 patients (10 boys and 10 girls) with unilateral complete cleft lip and palate who underwent two-stage palatoplasty by the Perko’s method at the Department of Oral & Maxillofacial Surgery, Tokyo Dental College (Group T). Each patient underwent second-stage surgery comprising closure of the hard palate and 1 year of speech training under a speech therapist (before to their entering elementary school). This was followed by orthodontic treatment at Hellman’s dental age IIIA, with the aim of correction of occlusion and promotion of jaw development. At Hellman’s dental age IIIB (mixed dentition), a bone graft was placed on the alveolar cleft in all patients\(^5\). Plaster models of the maxilla and mandible were obtained from all patients at Time 1, at commencement of orthodontic treatment in the mixed dentition period (mean age, 8 years and 7 months); at Time 2, at commencement of orthodontic treatment in the permanent dentition period (mean age, 12 years and 3 months); and at Time 3, on completion of active orthodontic treatment (mean age, 16 years and 8 months). Any disorder other than cleft lip and palate meant exclusion from the study.

Plaster models of the maxilla and mandible were also obtained from 15 other patients (8 boys and 7 girls) who underwent one-stage palatoplasty by the mucoperiosteal flap method at other institutions (Group P) at
time points corresponding to those in Group T. Informed oral consent was obtained from all patients prior to inclusion in the study.

1) Analysis of occlusion based on plaster models

(1) Examination of reversed occlusion at Time 1

The frequency of reversed occlusion at Time 1 was determined over the entire alveolar arch, with classification made according to the institutional norm at our department. The following 6 classes were therefore used: Type 1: reversed occlusion observed over the entire alveolar arch; Type 2: reversed occlusion observed only in small segments and incisor regions; Type 3: reversed occlusion observed in the bilateral molar regions; Type 4: reversed occlusion observed only in the small segments; Type 5: reversed occlusion observed only in the incisor regions; and Type 6: no reversed occlusion (Fig. 1).

(2) Measurement of overjet

Occlusion was determined at each time point by obtaining a paraffin wax impression after allowing the patient several practice runs involving biting in centric occlusion. These models were then used to measure overjet in the anterior tooth region of the maxillary and mandibular dental arches using calipers.

2) Morphological analysis of plaster models using a 3-dimensional measuring system

(1) Measurement process

A 3-dimensional measuring system was used to obtain data from the plaster models. This comprised scanning with a 3-dimensional digitizer (Matsuo Sangyo Co., Tokyo, Japan), preparation of surface models, and collection of data. The plaster model was fixed on the measuring arms of the digitizer for serial scanning and its surface data obtained. An He-Ne laser was applied to a point on the surface of the object to be measured. The position was calculated from the angle of the reflection beam and a cluster of 3-dimensional coordinate data prepared. The interval for serial scanning was 0.3 mm. The data obtained with the digitizer were exported to a workstation, Indigo2 soft (Silicon Graphics, Tokyo, Japan), and then edited using the software package DATASCULPT (Laser Design, Tokyo, Japan). The images of the data were then rotated or smoothed. A surface model was generated using the CAD software CAMAND (Camax System, Tokyo, Japan) and the values of the various items calculated. The areas were numerically expressed by using CAD software Surface (Image ware, Tokyo, Japan).

(2) Measurement points (Fig. 2a) and projected palatal curve (Fig. 2b)

P: maximally elevated point of the maxillary incisive papilla.
C: lowest point of the palatal side of the cervical line of the (deciduous) canine tooth on the non-cleft side;

C': lowest point of the palatal side of the cervical line of the (deciduous) canine tooth on the cleft side;

E: lowest point of the palatal side of the cervical line of the deciduous second molar or second premolar on the non-cleft side;

E': lowest point of the palatal side of the cervical line of the deciduous second molar or second premolar on the cleft side;

M: lowest point of the palatal side of the cervical line of the first molar on the non-cleft side;

M': lowest point of the palatal side of the cervical line of the first molar on the cleft side;

T: maxillary tuberosity on the non-cleft side; and

T': maxillary tuberosity on the cleft side.

C and C', E and E', M and M', and T and T' provided laterally symmetric points for measurement. The following curves prepared on the palatal surface by projecting the lines between each of these points determined perpendicularly toward the palate were regarded as the projected palatal curve:

Project C-C': curve on the palatal plane obtained by perpendicularly projecting C-C' toward the palate;

Project E-E': curve on the palatal plane obtained by perpendicularly projecting E-E' toward the palate; and

Project M-M': curve on the palatal plane obtained by perpendicularly projecting M-M' toward the palate.

(3) Measurement items
The following items were set for measurement of palatal width, length, cross-sectional area, and surface area (Fig. 3a–c):

C-C' width: distance between the lowest
points on the palatal sides of the cervical lines of the bilateral (deciduous) canine teeth;

E-E’ width: distance between the lowest points on the palatal sides of the cervical lines of the bilateral (deciduous) second molars;

M-M’ width: distance between the lowest points on the palatal sides of the cervical lines of the bilateral first molars;

T-T’ width: distance between the bilateral maxillary tuberosities;

C-C’ length: minimum distance between C-C’ line and P;

E-E’ length: minimum distance between E-E’ line and P;

M-M’ length: minimum distance between M-M’ line and P;

T-T’ length: minimum distance between T-T’ line and P;

Ccs: area of the plane surrounded by C-C’ and Project C-C’;

Ecs: area of the plane surrounded by E-E’ and Project E-E’; and

Mcs: area of the plane surrounded by M-M’ and Project M-M’.

The palatal surface area was prepared as follows (Fig. 3d):

Csa: surface area of the palate surrounded by Project C-C’ and palatal cervical line anterior to the (deciduous) canine region;

Esa: surface area of the palate surrounded by Project E-E’ and palatal cervical line anterior to the deciduous second molars or second premolar; and

Msa: surface area of the palate surrounded by Project M-M’ and palatal cervical line anterior to the first molars.

3) Statistical analysis

The data were analyzed using the statistical program SPSS Base System for Windows Ver.7.5 (SPSS, Tokyo, Japan). A p value <0.05 was considered to indicate statistical significance. The frequency of the 6 types of reversed occlusion in Groups T and P at Time 1 was obtained at the first step. Comparisons of frequency of reversed occlusion at Time 1 between Groups T and P were made by using a 2 × 2 table and the Fisher’s exact test. Comparisons between Groups T and P at each time point of morphological measurement were made using a non-parametric Mann-Whitney U test.

Results

1. Frequency of reversed occlusion at Time 1

Table 1 shows the frequency of each of the 6 types of reversed occlusion in Groups T and P at Time 1. In Group T, Type 5 was observed most frequently at Time 1. In Group P, Type 2 was the most frequent at Time 1. A ×2 test table was obtained between the palatoplasty group and 2 groups (type 1–3 and type 4–6) of reversed occlusion (Table 2). A significant difference was observed in the frequency of reversed occlusion at Time 1 between Group T and P (p<0.05).

2. Measurement of overjet

At Time 1, overjet was negative in the anterior tooth region in both Groups T and P (Fig. 4). At Time 2, overjet was significantly greater in Group T than in Group P (p<0.05).
3. Palatal width

In Group T, the widths of C-C', E-E', M-M', and T-T' were all greater than in Group P at both Time 1 and 2 (Fig. 5). Differences were observed in the widths of M-M' and T-T' at Time 2 (p<0.05).

4. Palatal length

The lengths of C-C', E-E', and M-M' were greater and T-T' smaller in Group T than in Group P at Time 1 (Fig. 6). At Time 2, all palatal lengths were greater in Group T than in Group P. At Time 3, also, all palatal lengths were greater in Group T than in Group P. The length of T-T' was greater in Group T than in Group P at all times of measurement. Differences were observed in the lengths of M-M' and T-T' at Time 1 and Time 2 (p<0.05).

5. Palatal cross-sectional area

The palatal cross-sectional area was greater in Group T than in Group P at all time points, with significant differences observed in EcS at Times 2 and 3 (p<0.05) (Fig. 7).

6. Palatal surface area

The palatal surface area was greater in Group T than in Group P at all time points, with significant differences observed in Esa and Msa at Times 1 and 2 (p<0.05) (Fig. 8).

Discussion

1. Institutional time and method of measurement

With the Zürich approach, closure of the hard palate in two-stage palatoplasty is traditionally performed at the age of approximately 5 years. We believe, however, that it is better to perform this procedure at approximately 4 years and 6 months based on Graber's theory that the maxilla develops to 5/6 of the adult size by about this time\(^8\). Children are expected to enter elementary school at the age of 6 years in Japan. As such a patient would need to undergo more than 1 year of postoperative speech rehabilitation, closure of the palate must therefore be achieved at between 4 years and 6 months and 5 years of age\(^9\). All patients in Group T were treated according to this principle. In Group P, one-stage palatoplasty was performed using a mucoperiosteal flap. No systemic disorder was
observed in any patient. One earlier study analyzed growth and development in the maxillary alveolar arch and palate in children with unilateral complete cleft lip and palate who underwent two-stage palatoplasty. This was done using a 3-dimensional digitizer at immediately before palatoplasty of the hard palate, at the age of 6 years, after the procedure, and at the age of 8 years and 6 months, before commencement of dynamic orthodontic treatment. The courses of the patients thereafter are not described, however\textsuperscript{11}. At our institution also, orthodontic treatment is commenced at this point. Therefore, the times of investigation were set for at commencement of orthodontic treatment (mixed dentition period), at Time 1; at the beginning of orthodontic treatment (permanent dentition period), at Time 2; and on completion of orthodontic treatment, at Time 3. Speech training after two-stage palatoplasty is initiated at approximately 5 years at our department, before the patient would be expected to enter elementary school. It is considered difficult to initiate orthodontic treatment in the deciduous tooth period. Therefore, this is usually done at the age of 7–8 years, in the mixed dentition period, after eruption of the anterior teeth.

The advantages of the 3-dimensional measurement system using a laser digitizer employed in the present study are that measurements can be performed over almost the entire surface of the maxillary model without direct contact with the site to be measured, and that this can be done in one go. Furthermore, measurements of distances and areas can be performed easily by the use of CAD software. The points to be measured can be faithfully reproduced on the surface of the model, and the precision of measurement is good, at $\pm 0.025$ mm. Therefore, this system is very useful for morphometry in very complicated palatal structures with clefts. It is particularly effective for calculating mean height and distance, allowing measurement of distances at 200 points and instantaneous calculation of mean values. The cervical line of each tooth can be readily determined as a border line by using a mark made at the lowest point of the lingual surface of the cervical line on the model when calculating surface area. The palatal cross-sectional area can also be determined in any desired plane.

The strongest characteristic of the present study was the evaluation of 3-dimensional factors by determining palatal cross-sectional and surface areas using this system. It should be noted, however, that this does necessitate great accuracy in the plaster models to be used.

2. Differences in growth and development between Groups T and P

Evidence of reversed occlusion in the alveolar arch was more marked in Group T than in Group P. Reversed occlusion was often observed in the incisor region alone in Group T, while it was seen in both the incisor region and small segments in Group P. Furthermore, overjet after two-stage palatoplasty (Group T)
showed edge-to-edge or normal occlusion at Time 2. These results suggest that occlusion was better in Group T than in Group P before commencement of orthodontic treatment, at Time 2. In one earlier study analyzing maxillary growth in adult white males with unilateral cleft lip and palate using standardized lateral radiograms of the head, no clear change was observed in the position of the maxillary incisors. Other studies have noted that neither surgical method nor timing of the procedure affected facial growth or speech development, however. In these studies, the relationship between the maxillary and mandibular incisors was satisfactory in patients treated by the Zürich approach.

At all time points in the present study, palatal width was greater in Group T than in Group P, except in the posterior area of the alveolar arch. Palatal width was smaller in Group P than in Group T in the anterior area, but greater in Group P than in Group T in areas posterior to the alveolar arch. This was probably due to the less surgically invasive nature of the procedure in the alveolar region anterior to the second deciduous molars. Alveolar collapse, that is, fan-shaped change with narrowing of the anterior area and widening of the posterior area, was marked in Group P, but not in Group T. This was possibly due to delayed hard palate plasty owing to periosteal detachment, as a basic principle of two-stage palatoplasty.

After surgical treatment for cleft lip and palate, the palate is generally shallow and flattened in comparison with that in healthy individuals. In the present study, the palate was deeper in Group T than in Group P at Time 1. This may have been because suturing in the median region in palatoplasty in the latter group resulted in a more shallow palate due to larger bilateral palatal flaps.

The palatal surface and cross-sectional areas were greater in Group T than in Group P, suggesting that the palatal capacity was also larger. With two-stage palatoplasty, the cleft narrows spontaneously after the first-stage (soft palate plasty). This may explain how shallowing of the palate was avoided and sufficient height and depth obtained in Group T. Alveolar collapse was milder and impairment of the alveolar morphology less notable in Group T than in Group P, as surgical invasion of the alveolar region anterior to the first deciduous molars during the palatal growth period in early childhood was avoided. This allows the tongue to rest in the center of the oral cavity to the advantage of oral function, particularly mastication and articulation, compared with push-back palate plasty using a mucoperiosteal flap, which was used in Group P.

Palatal width, length, and cross-sectional and surface areas all showed increasingly satisfactory results from Time 1 to Time 3 in Group T. We believe that this significant growth between Time 1 and Time 2 was due to anterior and lateral development of the maxilla because of orthodontic treatment during the mixed dentition period. This suggests that two-stage palatoplasty is advantageous for palatal growth. Further study including an analysis of standardized lateral head radiograms is necessary, however, to investigate the path of catch-up growth after two-stage palatoplasty and whether satisfactory maxillary growth rendering secondary orthognathic surgery unnecessary occurs.

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