*Original Article*

# Blood Flow Distribution of Repaired Lip in Cleft Lip Patients

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**ABSTRACT**

**Objective:** To investigate the blood flow distribution in the repaired lip of cleft patients using a laser Doppler imager and to evaluate the difference in blood flow of the scar tissue between unilateral cleft lip patients with and without cleft palate.

**Materials and Methods:** Twenty patients with either unilateral cleft lip only (CL group, n = 8) or cleft lip and palate (CLP group, n = 12) were used as subjects. The blood flow of the upper lip was two-dimensionally visualized by a color scale alongside the corresponding photo image of the tissue surface with laser Doppler imaging. The upper lip photo image was divided into five regions: scar, white lip on the cleft side, white lip on the noncleft side, red lip on the cleft side, and red lip on the noncleft side. The average flux score (AFS), which is proportional to blood flow, was analyzed in each region.

**Results:** The AFS for the scar region was significantly ($P < .05$) lower than in the other four regions. The AFS for the red lip on the cleft side was not significantly different from that for the noncleft side. The white lip revealed a significantly ($P < .05$) higher score on the cleft side than on the noncleft side. The AFS ratio (AFS in the scar region/AFS in the white lip region) was significantly ($P < .01$) lower in the CLP group than in the CL group.

**Conclusions:** These results suggest that blood flow distribution in the repaired lip might be affected by the anatomic features of the cleft. (*Angle Orthod.* 2009;79:1182–1187.)

**KEY WORDS:** Cleft lip; Scar; Blood flow; Laser Doppler imaging

## INTRODUCTION

Cleft lip is a common congenital malformation. Cheiloplasty for cleft lip defects often results in severe scar formation, which, in turn markedly affects facial esthetics. Furthermore, it has considerable influence on the anterior occlusion, such as lingual inclination of the maxillary anterior teeth in unilateral cleft lip patients with or without cleft palate.[1–4] Finally, in orthodontic treatment, scar tissue makes it difficult to ideally align the anterior teeth. Therefore, assessment of scar tissue distribution in the repaired lip is of great importance for orthodontic diagnosis, treatment planning, and prognosis.

Many assessment tools are available for analysis of pathologic conditions of the skin. However, there is no general agreement on which is most appropriate for evaluation of scar tissue.[5] Clinical assessment of scar tissue in the repaired lip is based on subjective evaluations that distinguish from normal skin by aberrant color, rough surface texture, increased thickness (hypertrophy), contracture, and firmness.[6] However, subjective assessments can be affected by methodological approaches, professional experience, and stimulus type.[7] Laser Doppler imaging (LDI) provides an objective and specific assessment of blood flow over an exposed surface of tissue, and it has great potential in a variety of clinical applications.[8–10] It can produce two-dimensional color-coded maps of blood flow representing tissue vascularization. These can be analyzed

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**Table 1.** General Characteristics of Subjects

| Group | Number | Sex | Mean Age (Years) |
|---|---|---|---|
| CL | 8 | 6 males and 2 females | 10.6 ± 1.5 |
| CLP | 12 | 6 males and 6 females | 11.2 ± 2.2 |

to estimate average local blood flow. Therefore, LDI has been used for the detection of medical problems based on microvascular perfusion such as wound healing, skin burn, and systemic sclerosis.[8–10] As in scar tissue, where vascular density is lower than in vital tissue,[11] LDI may be a useful tool for examination of scar tissue extension.

The severity of the primary deformity is generally proportional to the difficulty of surgical reconstruction and subsequently with scar formation in the palate and lip. Furthermore, cleft palate is known to be a key factor in maxillary growth retardation. However, little is known about the influence of palatoplasty on the blood flow in a repaired lip. The aims of the present study were to use LDI to investigate blood flow distribution in repaired lips of patients and to evaluate the difference of blood flow in the scar tissue between patients with and without cleft palate.

## MATERIALS AND METHODS

Twenty patients with unilateral cleft lip, ranging in age from 8 to 12 years (mean ± SD = 10.8 ± 2.0 years) were the subjects. They were divided into two groups (Table 1). The cleft lip (CL) group consisted of 8 patients with only a cleft lip (six males and two females; mean age 10.6 years; SD 1.5 years), and the cleft lip and palate (CLP) group consisted of 12 patients with both cleft lip and palate (six males and six females; mean age 11.2 years; SD 2.2 years). All the patients underwent plastic surgery using the triangular flap method at approximately three months after birth in the Department of Reconstructive Plastic Surgery, Tokushima University Hospital. In addition, the CLP group underwent surgery for the cleft palate at about 12 months after birth. This study was approved by the Institutional Ethical Committee of Tokushima University Medical and Dental Hospital. Informed consent was obtained from each subject after appropriate explanation about the experiment.

### LDI Instrumentation and Methodology

The applied LDI contains an HeNe laser source with a 658-nm wavelength and 2.3 mW of nominal power. It is noninvasive, and it needs no physical contact with the body. Its sensor was positioned 50 cm from the upper lip of the subject lying on an examination table. The subject's head was fixed with the Frankfort horizontal plane perpendicular to the table (Figure 1). The device scanned the upper lip during a 2-minute period. The scanned area was 15 cm$^2$ in cross section and was represented by a picture comprising 256 × 256 pixels. The data were stored and displayed as a 256-level, grayscale photo image and a 16-level, color-coded perfusion image. The amount of blood flow was estimated as a "flux" score. The noise correction and flux signal normalization were performed after digitization.

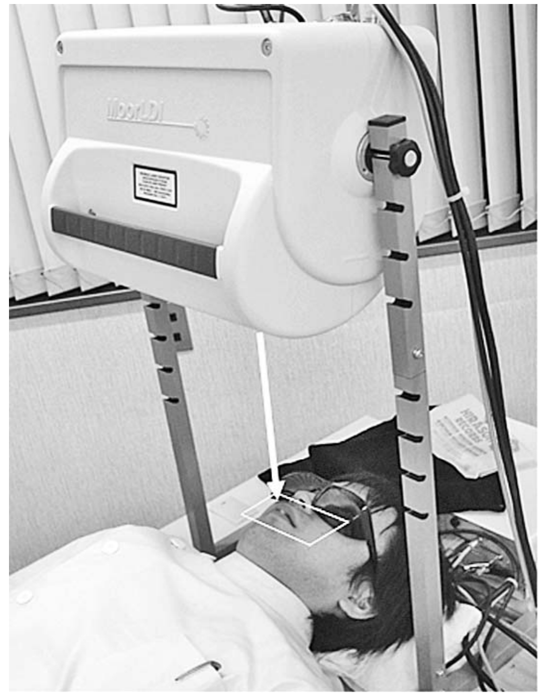


**Figure 1.** Scanning of the upper lip using the laser Doppler imager.

### Assessment

The upper-lip image was divided into five regions: scar area, white lip on the cleft side (WLCS), white lip on the noncleft side (WLNCS), red lip on the cleft side (RLCS), and red lip on the noncleft side (RLNCS) (Figure 2). The average flux score (AFS, a value proportional to blood flow) was analyzed for each region using Moor LDI V3.09 software (Moor Instruments Ltd, Axminster, UK). To compensate for individual differences, an AFS ratio was calculated. This ratio indicates the difference between the AFS values of the scar area and the white lip regions:

$$\text{AFS ratio} = [\text{AFS in the scar region (Scar)}] \div [\text{AFS in the white lip region (WLCS + WLNCS)}].$$

### Statistical Analysis

To check for differences of AFS among the five regions and the AFS ratio between the CL and CLP

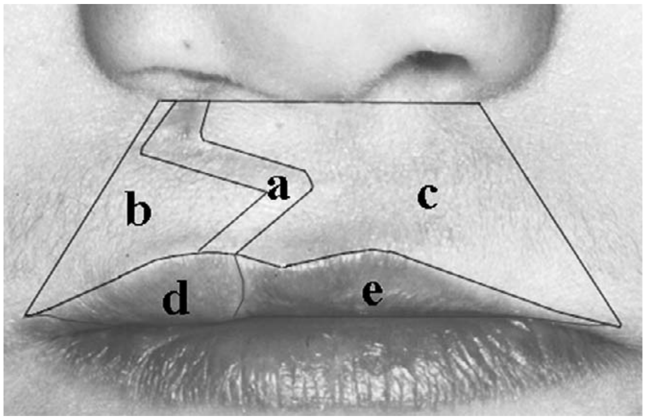


**Figure 2.** Design of measurement region: (a) Scar. (b) White lip on the cleft side (WLCS). (c) White lip on the noncleft side (WLNCS). (d) Red lip on the cleft side (RLCS). (e) Red lip on the noncleft side (RLNCS).

groups, statistical analyses were carried out by a Wilcoxon signed rank test and a Mann-Whitney *U*-test, respectively. $P < .05$ was regarded as significant.

## RESULTS

The blood flow images were displayed on the computer for analysis (Figure 3). As expected, a low flux area was found in the scar region. For all subjects, the lowest-flux area coincided with the tip of the triangular flap. The highlighted area, indicating high-flux perfusion, coincided with the red lip region.

Table 2 shows the AFSs in the five regions of the repaired upper lip for each subject. The AFS in the scar region is significantly lower than in the WLCS ($P < .01$) and the WLNCS ($P < .05$; Figure 4A, B). The AFS in the red lip was the highest among the five regions, although no significant difference between the cleft side and the noncleft side was found (Figure 4C). On the other hand, the AFS in the white lip was significantly ($P < .05$) higher on the cleft side than on the noncleft side (Figure 4D).

The AFS ratio was significantly ($P < .01$) lower in the CLP group than in the CL group (Figure 5). This indicates that in the CLP group, the AFS in the scar region was markedly lower than in the CL group.

## DISCUSSION

Laser Doppler flowmetry (LDF) can provide information on blood flow at a specific point in the tissue surface. Although this instrument provides a useful dynamic measurement of tissue perfusion, it is limited by only measuring a small fraction of the entire tissue, usually heterogeneous, microvasculature. Therefore, in this study, the LDI was applied to scan several points across the tissue surface.[8–10] Each measurement point was then used to compose a two-dimensional image directly related to the distribution of the tissue blood flow. This has several advantages over the single-point LDF measurement, the main advantage being the spatial information it gives about the microvascular blood flow. It has been demonstrated that an average measurement of several neighboring

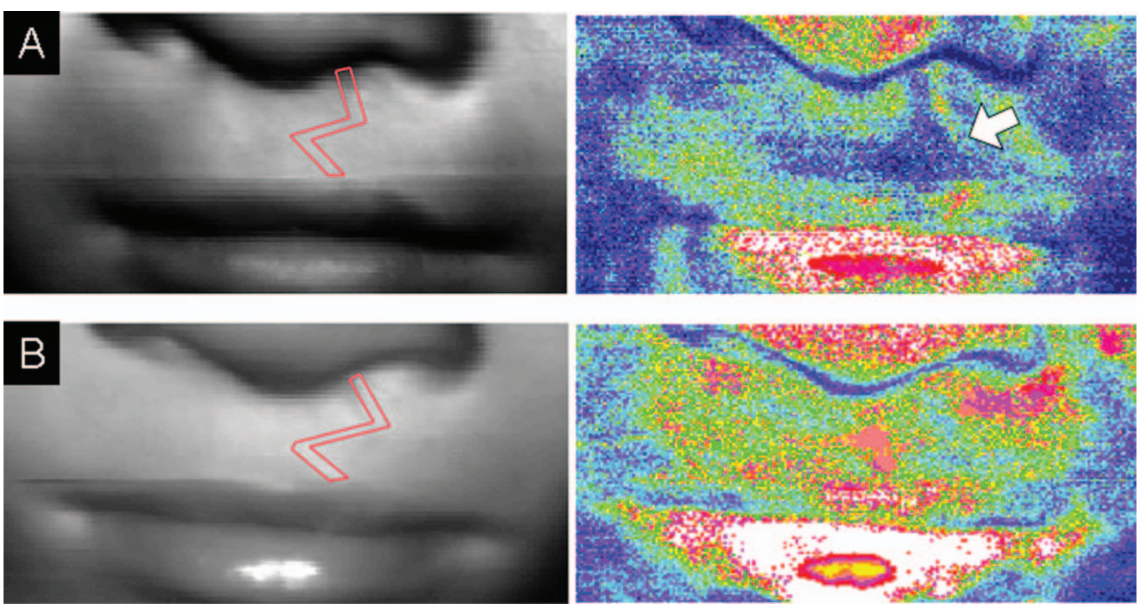


**Figure 3.** Blood-flow images of the upper lip of a subject with unilateral cleft lip and palate (CLP) (panel A: case 16) and a subject with unilateral cleft lip (CL) (panel B: case 2). The left panels depict the light intensity (photographic) image of the repaired upper lip and the right panels represent the flow. Sixteen colors were used to encode the perfusion. Blue areas indicate low perfusion, green-to-yellow areas highlight midrange perfusion, and red-to-white areas display high-flux perfusion. Arrow indicates the low blood flow region in panel A.

**Table 2.** Average Flux Scores (AFSs) at 5 Regions of the Upper Lip*

| Case No. | Sex | Cleft Type | Cleft Side | Average Flux Score (AFS) | | | | | | AFS ratio (a/[b & c]) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Scar (a) | WLCS (b) | WLNCS (c) | WL (b & c) | RLCS (d) | RLNCS (e) | |
| 1 | M | CL | R | 868.0 | 730.5 | 646.8 | 672.9 | 993.6 | 752.7 | 1.290 |
| 2 | F | CL | L | 601.9 | 761.1 | 689.1 | 707.2 | 763.2 | 768.9 | 0.851 |
| 3 | M | CL | R | 770.9 | 692.9 | 579.1 | 610.8 | 654.3 | 609.8 | 1.262 |
| 4 | M | CL | R | 317.4 | 355.7 | 346.1 | 349 | 297.0 | 309.5 | 0.910 |
| 5 | M | CL | L | 570.3 | 585.4 | 517.1 | 537.4 | 842.3 | 805.0 | 1.061 |
| 6 | F | CL | R | 1018.2 | 1084.2 | 1050.4 | 1061 | 703.5 | 753.5 | 0.960 |
| 7 | M | CL | L | 395.3 | 652.9 | 434.0 | 500.7 | 1022.3 | 974.9 | 0.790 |
| 8 | M | CL | R | 649.1 | 935.4 | 701.1 | 780.1 | 1073.1 | 1073.1 | 0.832 |
| 9 | M | CLP | R | 295.5 | 577.1 | 641.3 | 616 | 597.1 | 577.6 | 0.480 |
| 10 | F | CLP | L | 437.9 | 676.2 | 672.8 | 674 | 773.0 | 880.8 | 0.650 |
| 11 | F | CLP | R | 408.5 | 554.5 | 613.5 | 589.2 | 917.4 | 705.8 | 0.693 |
| 12 | M | CLP | R | 505.4 | 633.6 | 450.4 | 513.5 | 681.5 | 545.0 | 0.984 |
| 13 | F | CLP | R | 340.4 | 504.2 | 490.1 | 495.5 | 537.3 | 455.3 | 0.687 |
| 14 | F | CLP | L | 296.4 | 426.8 | 393.9 | 404.4 | 429.0 | 426.7 | 0.733 |
| 15 | F | CLP | L | 421.6 | 586.1 | 595.8 | 593.3 | 556.8 | 941.6 | 0.711 |
| 16 | M | CLP | L | 319.6 | 498.6 | 502.2 | 500.9 | 594.2 | 619.8 | 0.638 |
| 17 | M | CLP | L | 341.9 | 531.6 | 544.9 | 541.6 | 664.3 | 675.5 | 0.631 |
| 18 | M | CLP | R | 408.2 | 492.6 | 501.5 | 499.3 | 513.7 | 603.5 | 0.818 |
| 19 | M | CLP | R | 542.9 | 928.0 | 734.3 | 799.6 | 1235.0 | 1163.7 | 0.679 |
| 20 | F | CLP | R | 446.9 | 600.0 | 705.1 | 671.7 | 891.4 | 1022.9 | 0.665 |

* WLCS indicates white lip on the cleft side; WLNCS, white lip on the noncleft side; RLCS, red lip on the cleft side; RLNCS, red lip on the noncleft side; CL, cleft lip only; CLP, cleft lip and palate.

pixels can overcome the location sensitivity of LDF. Thus the AFS ratio can be used for comparison studies between individuals.[8]

Prior to this experiment, we examined the reproducibility of LDI measurements. Using three subjects with cleft lip, image scanning was conducted three times at intervals of about a month. This procedure revealed no significant differences in the obtained AFS among the three registrations (data not shown). By application of Pearson's correlation coefficient, no evidence of a large random error between the readings of LDI could be demonstrated (reliability coefficient, 0.94–0.97). Consequently, the results were considered reliable.

It was found that in the repaired upper lip, the AFS of the scar region was significantly lower than in the white lip. Because mature scar tissue is fibrous with a

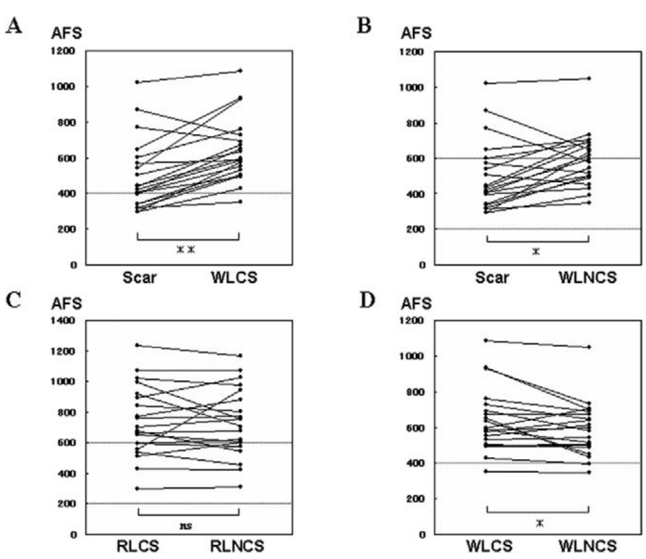


**Figure 4.** Comparison of the average flux score (AFS) at five regions in the repaired upper lip. The AFS for the scar region was significantly lower than those for the white lip on the cleft side (WLCS) (A) and the white lip on the noncleft side (WLNCS) (B). Statistical analysis was performed by a Wilcoxon signed rank test (* $P < .05$; ** $P < .01$). The AFS for the red lip was not significantly different when comparing the cleft side with the noncleft side (C). The AFS for the white lip was significantly ($P < .05$) higher on the cleft side than on the noncleft side (D).

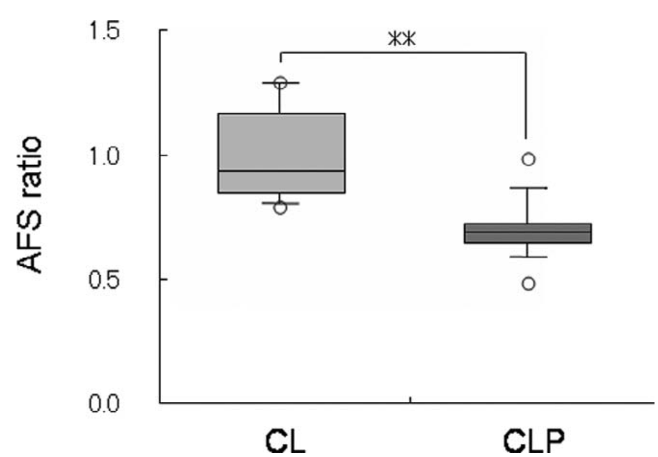


**Figure 5.** Comparison of the average flux score (AFS) ratio between the cleft lip (CL) and cleft lip and palate (CLP) groups. The AFS ratio of the CLP group was significantly lower than that of the CL group. Statistical analysis was performed by a Mann-Whitney *U*-test (** $P < .01$).

low density of cells and blood vessels and a more parallel-aligned collagen, a lower flux value in the scar region of the repaired upper lip is not surprising. Interestingly, the AFS of the cleft side of the white lip was significantly higher than that of the noncleft side. The main artery of the upper lip is the superior labial artery, a branch of the facial (external maxillary) artery. It runs in the marginal part of the lip parallel with the bundles of the orbicularis oris muscle and produces branches upward toward the nasal base. The bilateral superior labial arteries meet at the median line and link up.[12] In a nonrepaired subject with unilateral CL, the superior labial artery on the cleft side generally follows the course of the orbicularis oris muscle and deviates parallel with the edge of the cleft upward to the nasal ala. On the noncleft side, the artery behaves in the same way, but its diameter is considerably smaller with fewer branches than on the cleft side.[12] This may explain our result. Therefore, the blood flow in the white lip of a CL patient may be affected by intrinsic anatomical features such as the course of the orbicularis oris muscle and the state of its blood supply.

The AFS ratio of the CLP group was found to be significantly lower than that of the CL group. In general, the severity of the cleft is evaluated from its appearance at birth.[13,14] For instance, the primary facial deformities of subjects with unilateral CLP include larger ocular hypertelorism, wider cleft, greater deviation of the columella base, and more severe retrusion of the affected alar base as compared with unilateral CL patients. Furthermore, the upper lip area is significantly smaller in the unilateral CLP group than in the unilateral CL group, even if there is no distinct difference in defect of the upper lip in both groups.[15] Therefore, the present result indicates that a history of cleft palate can affect the blood flow in the scar region of the repaired lip. Also, the surgical technique and extent of surgical intervention may affect the nature of the resultant scar tissue. Although the primary deformities in the CL group were not evaluated in the present study, their severity may affect the difficulty of surgical reconstruction and the extent of resultant scar formation.

In addition to facial esthetic problems, scar formation in the repaired lip has considerable influence on anterior occlusion such as lingual inclination of the maxillary anterior teeth.[1–4] However, with regard to maxillary growth in CLP patients, only bony clefts retard maxillary growth, and the repaired lip is regarded to have no adverse effect on the basal maxilla no matter its size or position.[2,16] On the other hand, from animal experiments[17] and clinical experience,[18–20] it has been concluded that the repaired lip must also be an important factor in maxillary growth retardation. The isolated effects of lip repair on maxillary growth in unilateral CLP patients are difficult to evaluate clinically and the effects remain controversial. The assessment of blood flow using LDI appears to be useful for objective evaluation of scar tissue in the repaired lip. Therefore, further studies are necessary to evaluate relationships between scar formation in the repaired lip and dentofacial morphology.

## CONCLUSIONS

The present results suggest that blood flow distribution in the repaired cleft lip might reflect anatomic features of the cleft and surgical interventions for closure. Moreover, the extent of the scar might be related to the cleft type, because blood flow in the scar region of unilateral CLP patients appears to have lower perfusion than in unilateral CL patients.

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## REFERENCES

1. Hagerty RF, Hill MJ. Facial growth and dentition in the unoperated cleft palate. *J Dent Res.* 1963;42:412–421.
2. Liao YF, Mars M. Long-term effects of lip repair on dentofacial morphology in patients with unilateral cleft lip and palate. *Cleft Palate Craniofac J.* 2005;42:526–532.
3. Mars M, Houston WJB. A preliminary study of facial growth and morphology in unoperated male unilateral cleft lip and palate subjects over 13 years of age. *Cleft Palate J.* 1990; 27:7–10.
4. Ross RB, Johnston MC. *Cleft Lip and Palate.* Baltimore, Md: Williams & Wilkins; 1972.
5. van Zuijlen PP, Angeles AP, Kreis RW, Bos KE, Middelkoop E. Scar assessment tools: implications for current research. *Plast Reconstr Surg.* 2002;109:1108–1122.
6. Christofides E, Potgieter A, Chait L. A long term subjective and objective assessment of the scar in unilateral cleft lip repairs using the Millard technique without revisional surgery. *J Plast Reconstr Aesthet Surg.* 2006;59:380–386.
7. Ritter K, Trotman CA, Phillips C. Validity of subjective evaluations for the assessment of lip scarring and impairment. *Cleft Palate Craniofac J.* 2002;39:587–596.
8. Bray R, Forrester K, Leonard C, McArthur R, Tulip J, Lindsay R. Laser Doppler imaging of burn scars: a comparison of wavelength and scanning methods. *Burns.* 2003;29:199–206.
9. Murray A, Herrick A, King T. Laser Doppler imaging: a developing technique for application in the rheumatic diseases. *Rheumatology.* 2004;43:1210–1218.
10. Ng EY, Fok SC, Goh CT. Case studies of laser Doppler imaging system for clinical diagnosis applications and management. *J Med Eng Technol.* 2003;27:200–206.
11. Chu S, Ishikawa H, Kim T, Yoshida S. Analysis of scar tissue distribution on rat palates: a laser Doppler flowmetric study. *Cleft Palate Craniofac J.* 2000;37:488–496.
12. Fara M. The anatomy of cleft lip. *Plast Reconstr Surg.* 1975; 2:205–214.
13. Cosman B, Crikelair GF. The shape of the unilateral cleft lip defect. *Plast Reconstr Surg.* 1965;35:484–493.

14. Landsay WK, Farkas GF. The use of anthropometry in assessing the cleft-lip nose. *Plast Reconstr Surg.* 1972;49: 286–293.
15. Nakamura N, Suzuki A, Takahashi H, Honda Y, Sasaguri M, Ohishi M. A longitudinal study on influence of primary facial deformities on maxillofacial growth in patients with cleft lip and palate. *Cleft Palate Craniofac J.* 2005;42:633–640.
16. Liao YF, Mars M. Long-term effects of palatal repair on dentofacial morphology in patients with unilateral cleft lip and palate. *Cleft Palate Craniofac J.* 2005;42:594–600.
17. Bardach J. The influence of cleft lip repair on facial growth. *Cleft Palate J.* 1990;27:76–78.
18. Capelozza Filho L, Normando AD, da Silva Filho OG. Isolated influences of lip and palate surgery on facial growth: comparison of operated and unoperated male adults with UCLP. *Cleft Palate Craniofac J.* 1996;33:51–56.
19. Kapucu MR, Gursu KG, Enacar A, Aras S. The effect of cleft lip repair on maxillary morphology in patients with unilateral complete cleft lip and palate. *Plast Reconstr Surg.* 1996;97:1371–1375.
20. Li Y, Shi B, Song QG, Zuo H, Zheng Q. Effects of lip repair on maxillary growth and facial soft tissue development in patients with a complete unilateral cleft of lip, alveolus and palate. *J Craniomaxillofac Surg.* 2006;34:355–361.