Original Article

Morphology of the Palatal Vault of Primary Dentition in Transverse View

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Abstract: The purpose of this study was to investigate the transverse view of the morphology of the palatal vault in the primary dentition at the primary second molar level. Observations were obtained from 150 dental stone casts of normal children (78 boys and 72 girls; aged four to five years). Palatal width, palatal depth, arch width, and primary second molar angulation were measured. There were no significant differences in palatal depth and primary second molar angulation between boys and girls or between the right and left sides. However, girls had a statistically significantly narrower upper dental arch width and palatal width than did boys. Palatal widths on the left side were statistically significantly larger than those on the right side for both sexes. Asymmetry in the palatal width greater than two mm was present in 21.8% of boys and 16.7% of girls. There was a correlation between buccal tipping in the upper primary second molar and greater palatal width. (*Angle Orthod* 2004;74:774–779.)

Key Words: Palatal vault, Palatal height, Dental arch width, Transverse view, Tooth angulation

INTRODUCTION

The human hard palate is formed by the palatine processes of the maxilla and the horizontal plates of the palatine bones. All components of the bony palate are joined together by the median and transverse sutural joints. In most instances, the palate is slightly concave toward the oral cavity, but the palate is sometimes subject to morphologic variations[1] that may be the result of pathologic conditions. Investigators have more often studied the transverse and anteroposterior components of the maxilla (dental arch widths and lengths) than its vertical components (palatal depths or heights).[2–7]

Although there are several studies regarding palatal height assessment, most have focused on craniofacial syndromes.[8–10] A high or narrow palate has been reported associated with a number of syndromes. Such investigations have not produced a consistent view of the normal range for the palatal height and width. Reference to a high or narrow palate in patients with these syndromes has been made on the basis of clinical observations without the benefit of background measurements. Knowledge of the normal range of palatal shape can act as a baseline for studies of certain oral developmental abnormalities.

The purpose of this study was to investigate the average values of palatal measurements of the normal primary dentition of children and to establish standards of palatal dimensions and shape for the primary second molar area at the transverse level using dental stone casts.

METHODS AND MATERIALS

Subjects were 150 Taiwanese children (78 boys and 72 girls) between the ages of four and five years. All subjects included in this study had a normal dental arch, a full complement of deciduous teeth, no midline deviation, no apparent caries, no growth disturbance, and a clinically acceptable symmetry of the arches. The following exclusion criteria were chosen to minimize variables influencing asymmetry: a history of orthodontic treatment; a history of dental trauma; and digital habits past the age of three years, evidence of a syndrome or craniofacial malformation or obvious facial asymmetry.

Informed consent was obtained from each subject and a parent or guardian before entry into the study. Alginate impressions of the upper and lower dental arches of each subject were taken by one of the authors (Dr Tsai), into which dental stone was immediately poured. All stone casts were trimmed using a wax bite in centric occlusion with the backs horizontal to the occlusal plane. The distal aspect of the upper stone casts was trimmed perpendicular to the

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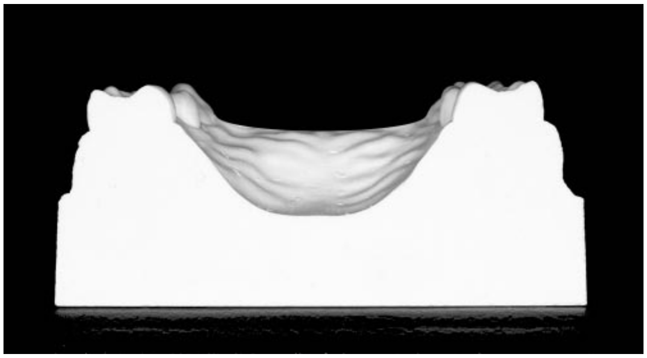

FIGURE 1. Distal surface of the stone casts.

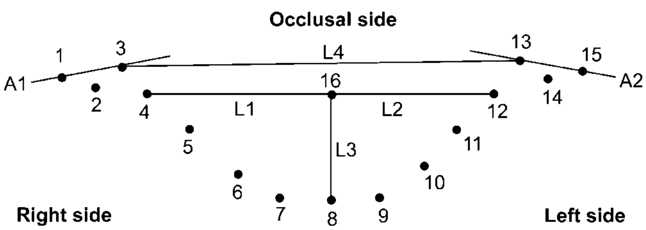

FIGURE 2. Reference points and measurements. Reference points—1: mesiobuccal cusp tip of the right upper primary second molar; 2: central fossa of the right upper primary second molar; 3: mesiopalatal cusp tip of the right upper primary second molar; 4: palatal cervical line of the right upper primary second molar; 5: point near upper third of the palate on the right side; 6: point near middle of the palate on the right side; 7: point near lower third of the palate on the right side; 8: midpalatal raphe; 9: point near lower third of the palate on the left side; 10: point near middle of the palate on the left side; 11: point near upper third of the palate on the left side; 12: palatal cervical line of the left upper primary second molar; 13: mesiopalatal cusp tip of the left upper primary second molar; 14: central fossa of the left upper primary second molar; 15: mesiobuccal cusp tip of the left upper primary second molar; 16: point that the perpendicular line from point 8 intersects the line point 4–12. Measurements—L1: distance between point 4 and point 16 (palatal width on the right side); L2: distance between point 12 and point 16 (palatal width on the left side); L3: distance between point 8 and point 16 (palatal depth); L4: distance between point 3 and point 13 (dental arch width); A1: angle formed by the intersection of the line point 1–3 to the line point 4–12 (right upper primary second molar angulation); A2: angle formed by the intersection of the line point 13–15 to the line point 4–12 (left upper primary second molar angulation).

midpalatal raphe up to the deepest parts of the central fossa of the upper second primary molars.

Standardized photographs of the distal surfaces of the stone casts were obtained at a 1:1 magnification using a digital camera (Figure 1). The camera was kept a constant distance from the distal surfaces of the casts to avoid problems of differential degrees of parallax.[3] Any distortion caused by the photographing process was automatically corrected for, using a known reference on a millimeter scale. Sixteen reference points (Figure 2) on the photographs were digitized as coordinates using customized software.

The straight line connecting the palatal cervical lines of the right and left upper second primary molars on the photograph were designated the X-axis. A straight line, vertical to the X-axis and passing through the midpalatal raphe on the photograph, was designated the Y-axis. The X-coordinate value of each reference point was considered the horizontal position (width) of the structure. A negative X-coordinate value indicates the right side, whereas a positive X-coordinate value indicates the left side. The Y-coordinate value of each reference point was considered a vertical position (depth) of the structure. Because all measurements were made by one of the authors, a measure of the reliability of her use of the instrument was obtained by comparing two sets of measurements made on 10 stone casts. The *t*-test indicated that none of the mean differences was significant, ie, there was no consistent trend toward a larger or smaller second measurement. To establish reliability of the measurements, a subset of 10 stone casts was digitized twice by a second examiner. The mean difference between examiners was also of very low magnitude.

Four linear and two angular measurements (Figure 2) were calculated from the coordinate values for each cast. Mean values and standard deviations of each coordinate value and measurement for boys and girls were calculated. Student's *t*-test was used to determine whether significant differences were present between boys and girls. Paired *t*-tests were used to determine whether differences between each set of bilateral measurements significantly differed. However, where the data were significantly skewed or where intragroup variances significantly differed, the Mann-Whitney *U*-test was used instead. The Spearman rank order correlation test between all measurements was then performed. Significance was predetermined at the 0.05 level of confidence. To describe the morphology of the palatal vault, the nine reference points (points 4 to 12) were used to apply a polynomial model[3] ($Y = a + bX + cX^2 + dX^3$) for boys and girls, respectively.

RESULTS

Mean values and standard deviations of the measurements and coordinate values as well as results of the Student's and paired *t*-tests used to assess mean values of measurements between boys and girls and mean coordinate values between the right and left sides are shown in Tables 1 and 2. The results indicate that the mean values of all linear measurements were uniformly larger in boys than in girls. There were statistically significant differences in the measurements L1, L2, and L4 between boys and girls. Girls had a statistically significantly smaller upper dental arch width and palatal width compared with those of boys. However, there were no significant differences in the palatal depth (L3) or upper primary second molar angulation (A1 and A2) between boys and girls.

Figure 3 shows the superimposition of the mean positions of each reference point of boys and girls. Figure 4

TABLE 1. Mean Values and Standard Deviations of the Measurements and the Results of *t*-Tests

	Boys (N = 78)			Girls (N = 72)			
Measurements	Mean	SD	Paired *t*-test	Mean	SD	Paired *t*-test	Student's *t*-test
L1	14.656	1.139	$P < .001$	14.181	1.190	$P = .006$	$P = .013$
L2	15.419	1.052		14.681	0.960		$P < .001$
L3	10.774	1.208		10.672	0.994		NS
L4	34.728	1.698		33.185	1.602		$P < .001$
A1	4.419	4.311	NS	3.568	5.254	$P = .002$	NS
A2	5.332	5.258		5.882	4.970		NS

[a] NS indicates not significant.

TABLE 2. Mean Values and Standard Deviations of the Coordinate Values and the Results of *t*-Tests

	Boys (N = 78)			Girls (N = 72)			
Reference points	Mean	SD	Paired *t*-test	Mean	SD	Paired *t*-test	Student's *t*-test
X-coordinate values							
Point 5	−11.487	1.081	$P < .001$	−11.090	1.157	$P = .005$	$P = .031$
Point 11	12.096	1.038		11.582	0.906		$P = .002$
Point 6	−7.824	1.003	$P < .001$	−7.733	0.917	NS	NS[a]
Point 10	8.313	0.944		7.892	1.338		$P = .027$
Point 7	−4.697	0.956	$P = .006$	−4.654	0.899	$P = .002$	NS
Point 9	4.949	0.933		5.251	1.337		NS
Y-coordinate values							
Point 5	−3.233	0.630	NS	−3.286	0.678	NS	NS
Point 11	−3.242	0.725		−3.349	0.540		NS
Point 6	−6.741	1.107	NS	−6.894	1.057	NS	NS
Point 10	−6.919	1.184		−7.174	1.427		NS
Point 7	−10.319	1.197	NS	−10.432	0.953	NS	NS
Point 9	−10.456	1.277		−10.201	1.413		NS

[a] NS indicates not significant.

shows the superimposition of the mean positions of the bilateral reference points on the palatal vault (points 5–11, 6–10, and 7–9). An ''X'' beside a reference point indicates that there was a statistically significant difference in the X-coordinate value of the reference point between boys and girls or between the right and left sides. Boys had statistically significantly wider palatal widths than did girls. The X-coordinate values of the reference points on the left side were statistically significantly larger than those on the right side for both sexes. However, there was little difference in palatal depths between boys and girls and between the right and left sides.

Distributions of the arithmetic differences between measurements L2 and L1 (right palatal width subtracted from the left palatal width) for boys and girls are shown in Figures 5 and 6, respectively. A negative arithmetic mean indicated that the right side measurement was larger than the left, whereas a positive arithmetic mean indicated that the left-side measurement was larger than the right. Asymmetry of greater than two mm was present in 21.8% of boys and 16.7% of girls.

Figure 7 shows the third-order polynomial equations and superimposition of the smallest, mean, and largest outlines of the morphology of the palatal vault for both sexes. The mean palatal vault curves of girls and boys were similar but the girls' mean curves were narrower than the boys'. The range between the smallest and mean curves in girls was larger than that in boys, whereas the range between the mean and largest curves in boys was larger than that in girls.

Results of the Spearman rank order correlation test are shown in Table 3. There was a positive correlation between measurements L1 and A1, whereas there were negative correlations between measurements L1 and A2 and between measurements L2 and A1. No measurements correlated with palatal depth (L3).

DISCUSSION

In previous dental investigations of maxillary arch dimensions in different ethnic groups, it was reported that knowledge of standards of maxillary arch dimensions

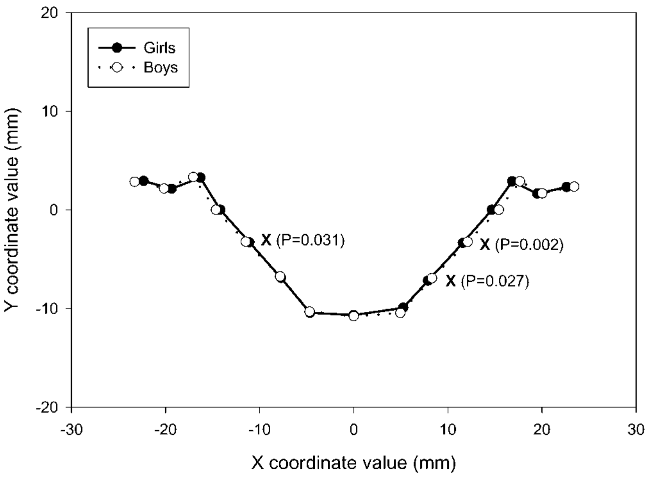

FIGURE 3. Superimposition of the mean positions of each reference point.

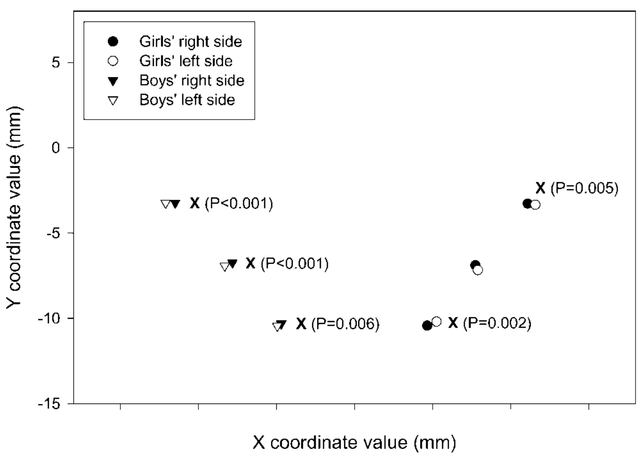

FIGURE 4. Superimposition of the right and left reference points on palatal vault.

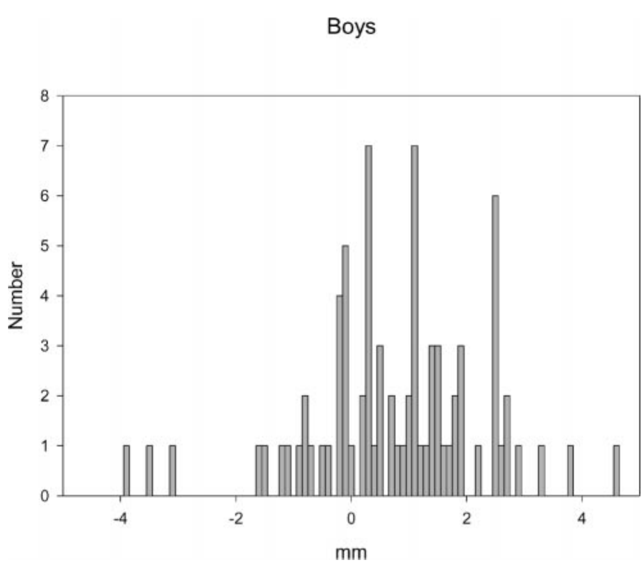

FIGURE 5. The distributions of the arithmetic differences between measurement L2 and L1 (boys).

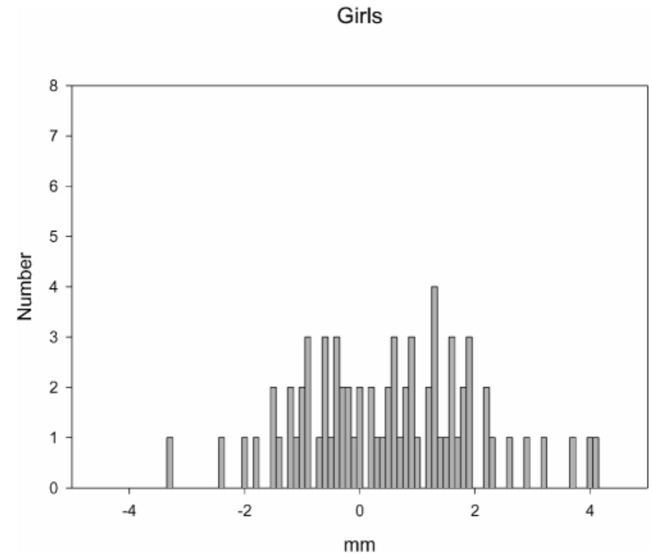

FIGURE 6. The distributions of the arithmetic differences between measurement L2 and L1 (girls).

would be useful in current clinical practice. For example, the growth and development of the maxilla and the availability of a useful range of stock impression trays for fixed and removable prosthodontic work were studied.[11] A reliable method of palatal measurement would also be beneficial for studying craniofacial deformation as well as normal growth patterns. Shapes of the palatal vault greatly differed between the sagittal and transverse views. On the transverse level, palatal vaults in different areas also present different forms. Because the midpalatal raphe in the area of the primary second molar is near the highest point of the palatal vault and can be easily identified, this study investigated standards of normal palatal dimensions in this area from the transverse view.

A previous study[12] estimated that the height of the palatum osseum in persons younger than 12 years of age was much lower than that in adults. According to the same authors who were assessing vertical development, the height of the palatal vault showed an average value of 11.8 mm for the age group of 14 to 15 years; 13.0 mm for the age group of 16 to 18 years and 13.8 mm for adults. Other research[13] showed that the average value of the height of the palatum osseum was 12.4 mm, with a standard deviation of 2.81. In 290 male skulls, the average value of the height of the palatum osseum was 12.6 mm and in 210 female skulls, it was 12.1 mm.[13] In this study, the mean palatal depth was 10.77 mm in boys and 10.67 mm in girls with no significant differences between the sexes. From these results, it is reasonable to surmise that the height of the palatal vault may increase with age and that the vaults in males may be a little higher than those in females of comparable ages. Further study to confirm this hypothesis is required.

Tooth eruption has a marked effect on the form of the

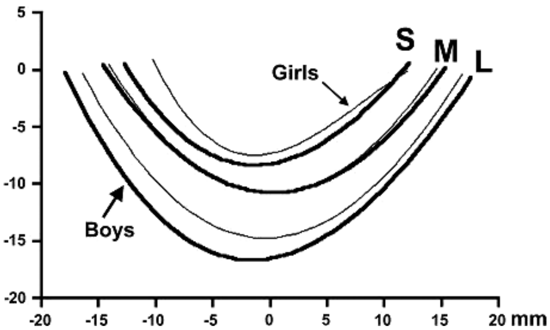

FIGURE 7. Superimposition of the smallest, the mean, and the largest outlines of the palatal vault. Thick solid line: boys' curves. Fine solid line: girls' curves. S, the smallest curve; M, the mean curve; L, the largest curve.

TABLE 3. Spearman Rank Order Correlation Test

Measurements	L1	L2	L3	L4	A1	A2
L1				0.685***	0.373***	−0.233**
L2				0.628***	−0.195*	
L3						
L4					0.229**	
A1						
A2						

* $P < .05$; ** $P < .01$; *** $P < .001$.

dental arches with the shape determined by the direction of alveolar bone growth and the size of the arch determined by the size and alignment of the teeth.[14] The results in this study showed that palatal widths were larger in boys than in girls and that the primary second molar angulation was correlated with palatal widths, whereas palatal depths were correlated with no other measurements. This suggests that palatal widths might be more easily influenced by environmental factors than are palatal depths.

Dentoalveolar compensation may modify the underlying skeletal or dental asymmetry.[15] Hewitt[15] suggested that the dentoalveolar region is more adaptive and shows a greater degree of symmetry than the remainder of the face, probably because of the compensatory growth of the alveolus. However, the lack of perfect symmetry of the dentofacial complex is well documented.[16,17] The anthropologic investigation of Gundara and Zivanovic[18] showed craniofacial asymmetry as common in most persons. In this study, it was found that 21.8% of boys and 16.7% of girls had asymmetries in palatal widths of greater than two mm and that the widths of the palatal vault on the left side were statistically significant larger than those on right side for both sexes. These results are in concurrence with the results of a previous study,[19] which reported that palatal widths were consistently wider on the left-hand side in both intubated and nonintubated children, with the differences being statistically significant at the level of the second primary molars.

Children with allergies or enlarged tonsils were found to have high palatal vaults,[20] and these children would possibly be expected to develop malocclusion in the future. Therefore, it is important to know the standards of the palatal dimensions and carefully observe the shape of the palatal vault in growing children periodically. The polynomial function used in this study is an equation of the third degree and of minimal complexity, which enables one to trace curves through the reference points. It provided good curve fitting for the outline of the palatal vaults, with the polynomial producing the best correlation coefficients. This study found that the mean curves of palatal depths of both sexes were similar, but the mean curves for palatal widths were narrower for the girls than those of boys. The range between the smallest and mean curves in girls was larger than that in boys, whereas the range between the mean and largest curves in boys was larger than that in girls. The methods used in this study are helpful for understanding standards of palatal dimensions and shapes and differences between boys and girls.

The dental cast analysis in this study was based on two-dimensional measurements. Because various three-dimensional analyzing systems[21,22] have been developed in the field of dentistry, a further study will be devoted to obtain contact or noncontact three-dimensional information, such as the size of the palatal surface area and the volume of the oral cavity.

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REFERENCES

1. Vidic B. Morphologic variations of the transverse palatine sutusre in Yugoslav skulls. *J Dent Res.* 1967;46(6):1473.
2. Odajima T. A longitudinal study on growth and development of dental arches of primary, mixed and permanent dentitions. *Shikwa Gakuho* 1990;90(3):369–409.
3. Tsai HH. Tooth-position, arch-siz**e**, and arch-shape in the primary dentition. *J Dent. Child.* 2001;68(1):17–22.
4. Nystrom M, Ranta R. Sizes of dental arches and interdental space in 3-year-old children with and without cleft lip/palate. *Eur J Orthod.* 1989;11(1):82–88.
5. Bishara SE, Jakobsen JR, Treder JE, Stasi MJ. Changes in the maxillary and mandibular tooth size-arch length relationship from early adolescence to early adulthood. A longitudinal study. *Am J Orthod Dentofacial Orthop.* 1989;95(1):46–59.
6. Brown T, Abbott AH, Burgess VB. Age changes in dental arch dimensions of Australian Aboriginals. *Am J Phys Anthropol.* 1983;62(3):291–303.
7. Foster TD, Grundy MC, Lavelle CL. A longitudinal study of dental arch growth. *Am J Orthod.* 1977;72(3):309–314.
8. Panchon-Ruiz A, Jornet-Carrillo V, Sanchez del Campo F. Palate vault morphology in Down syndrome. *J Craniofac Genet Dev Biol.* 2000;20(4):198–200.
9. Westling L, Mohlin B, Bresin A. Craniofacial manifestations in the Marfan syndrome: palatal dimensions and a comparative

cephalometric analysis. *J Craniofac Genet Dev Biol.* 1998;18(4): 211–218.
10. Kiliaridis S, Katsaros C. The effects of myotonic dystrophy and Duchenne muscular dystrophy on the orofacial muscles and dentofacial morphology. *Acta Odontol Scand.* 1998;56(6):369–374.
11. Klemetti E, Lassila L, Lassila V. Biometric design of complete dentures related to residual ridge resorption. *J Prosthet Dent.* 1996;75(3):281–284.
12. Redman RS, Shapiro BL, Gorlin RJ. Measurement of normal and reportedly malformed palatal vaults. II. Normal juvenile measurements. *J Dent Res.* 1966;45(2):266–269.
13. Vidic B. Variations in height of the palatum osseum as a function of other vertical dimensions and angles of the skull. *J Dent Res.* 1971;50(1):14–16.
14. Lavelle CL, Flinn RM, Foster TD, Hamilton MC. An analysis into age changes of the human dental arch by a multivariate technique. *Am J Phys Anthropol.* 1970;33(3):403–411.
15. Hewitt AB. A radiographic study of facial asymmetry. *Br J Orthod.* 1975;2(1):37–40.
16. Bishara SE, Burkey PS, Kharouf JG. Dental and facial asymmetries: a review. *Angle Orthod.* 1994;64(2):89–98.
17. Pirttiniemi PM. Associations of mandibular and facial asymmetries-a review. *Am J Orthod Dentofacial Orthop.* 1994;106(2): 191–200.
18. Gundara N, Zivanovic S. Asymmetry in East African skulls. *Am J Phys Anthropol.* 1968;28(3):331–337.
19. Macey-Dare LV, Moles DR, Evans RD, Nixon F. Long-term effect of neonatal endotracheal intubation on palatal form and symmetry in 8-11-year-old children. *Eur J Orthod.* 1999;21(6):703–710.
20. Galvez J, Methenitou S. Airway obstruction, palatal vault formation and malocclusion: a cross-sectional study. *J Pedod.* 1989; 13(2):133–140.
21. Chaya H, Ishikawa H, Imai T, Nakamura S. A three-dimensional analyzing system of face using stereophotogrammetry and computer graphics. *J Jpn Orthod Soc.* 1988;47(3):560–578.
22. Soma K, Hisano M, Kuroki T, Ishida T, Kuroda T. High accuracy measuring device for dental cast using device with flat laser beam. *J Stomatol Soc Jpn.* 1992;59(1):259–264.