Lip Form Responses to Changes in Maxillary Incisor Position

Shin Chin Jin¹, Kazutaka Kasai¹, Tadamasa Iwasawa¹ and Eisaku Kanazawa²

(Received 4 July and accepted 19 October 1996)

Key words: lip form, three-dimensional measurement, changing ratio

Abstract

A study was conducted to assess the measurement accuracy of a laser three-dimensional measurement system for measuring facial profile and to investigate the changes in lower facial morphology caused by experimental protrusion of the upper incisors, and also to examine the relationship between the changes in lip form and lip thickness. The study subjects were 24 Japanese male dental students attending Nihon University School of Dentistry at Matsudo, who had normal overbite, overjet, and normal occlusion, and a good facial profile. The mean age was 23.2 years with a range of 21.5 to 25.8 years.

Three-dimensional measurements obtained by a computerized 3D laser scanning system were used to evaluate facial morphology. The measurement error of this system was less than 0.5 mm in any three-dimensional linear measurements. The stability and reproducibility of the recording procedure were evaluated. The changes in facial morphology caused by orthodontic treatment and orthognathic surgery were visualized in any direction by this three-dimensional graphic system. Lip thickness was not associated with changes in lip form. However, a relationship between the right and left corners of lip and lip thickness was noted. With regard to the ratio of changes in hard tissue and lips, the value of the original position for a 4 mm protrusion was not the same as that for a 4 - 8 mm protrusion. Also, the correlation of the changes in both groups was very low. The changes in lip thickness were associated with changes in stomion position, which in turn were related to the vertical change in the upper lip.

Introduction

In lower facial morphology, the relationships between hard tissue structures and soft tissue profiles vary among individuals. Some are related but some are independent, chiefly because the characteristics of the lips are influenced by their length, thickness, and also functional aspects such as tensing. However, some reports^[1-4] have described obvious changes in soft tissue profile associated with orthodontic treatment. The characteristics of the lips have some influence on lip responses to retraction of the upper and lower incisors. Oliver^[5] found that patients with thin lips due to high lip strain displayed a significant correlation between incisor retraction and lip retraction, whereas patients with thick lips or low lip strain displayed no such correlation. Wisth^[6] found that lip response, as a proportion of incisor retraction, decreased as the amount of incisor retraction increased. These findings indicate that lips have some inherent functional and morphological structures.

So far, the changes in soft tissue profile brought about by orthodontic treatment have been evaluated simply by using lateral cephalograms. However, these methods indicated a lack of information on soft-tissue changes. Three-dimensional measurement is needed by orthodontists and researchers studying facial morphology.

陳 信親¹、葛西一貴¹、岩澤忠正¹、金澤英作²

1 Department of Orthodontics, Nihon University School of Dentistry at Matsudo

2 Department of Anatomy, Nihon University School of Dentistry at Matsudo

To whom all correspondence should be addressed: Dr. Shin Chin Jin, Department of Orthodontics, Nihon University School of Dentistry at Matsudo, 2-870-1 Sakaecho-nishi, Matsudo, Chiba 271, JAPAN

The purposes of this study were to assess the measurement accuracy of a laser three-dimensional measurement system for measuring facial profile, to investigate the changes in lower facial morphology due to experimental protrusion of the upper incisors, and to examine the relationship between changes in lip form and lip thickness.

Materials and Methods

The study subjects were 21 Japanese male students attending Nihon University School of Dentistry at Matsudo, who had normal overbite, overjet and normal occlusion, and a good facial profile. The mean age was 23.2 years with a range of 21.5 to 25.8 years.

Cephalometric landmarks and variables

Cephalograms were taken with the subjects at rest, when soft tissue is judged subjectively to be in an unstrained habitual position. Liquid barium, which is able to indicate clearly the deepest point of the lip-gingival junction, was applied to the inside of the upper and lower lips. The following landmarks were identified on each cephalogram (Fig.1). 1) Labrale superius (Ls) : the point on the upper lip lying on the midsagittal plane at the upper margin of the vermilion border. 2) Labrale inferius (Li) : the point on the lower lip lying in the midsagittal plane at the lower margin of the vermilion border. 3) Soft tissue pogonion (S-Pog) : the most anterior point of the soft tissue chin. The distances between hard tissue and soft tissue were also measured. I) UL (upper lip thickness) : distance between Ls and below on the inside lip line (the barium line) perpendicular to the A-Pr line, II) LL (lower lip thickness) : distance between Li and below on the inside line (barium line) perpendicular to the Pog-Id line, III) Pog (pogonion thickness) : distance between hard tissue pogonion and soft tissue pogonion.

Fig.1 Landmarks and variables of cephalogram analysis.

1.Ls: Labrale superius.	I. UL: Upper lip thickness.
2.Li: Labrale inferius.	II. LL: Lower lip thickness.
3.S-Pog: Soft tissue pogonion.	III. Pog: Pogonion thickness.

Fig. 2 The principle of shape regeneration in a laser three-dimensional scanning machine.

Fig. 3

The protrusive appliance made of self-cured resin.

Fig. 4

The laser three-dimensional scanning machine.

Laser three-dimensional scanning system

In this study a laser three-dimensional scanning machine (NKK VOXELAN[®]) was used to obtain the facial profile. The procedure involves rotational scanning of a laser slit over the facial surface from diagonally below as well as picking up the image with a CCD camera placed directly in front. Fig. 2 shows the principle of shape regeneration^[7]. This system provides real-time operation of an image synthesizing unit and an image encoder. A projection angle coded image θ (x, y) is synthesized at the moment it passes each point on the facial surface in order to measure the value of the point. This is performed using the projecting angle of a laser slit. Then, the shape is regenerated (NEC PC9821 series).

The value for each pixel of θ (x, y) corresponds to the elevation angle from each point on the surface to the laser slit rotating axis. The facial height shape f (x, y) can be found as follows:

$$f(x, y) = z_0 - (x_0 - x) \tan \theta(x, y)$$

where x_0 and z_0 represent the x -coordinate and z -coordinate of the laser slit rotating axis, respectively.

Changes in soft tissue profile due to protrusion of the upper incisors

To assess the changes in the soft tissue profile due to protrusion of the upper incisors, we made a protrusive appliance from self-cured resin which made the inner surface of the lip protrude 4-mm or 8-mm (Fig.3).

The subject sat on a chair fitted with a headrest. The distance between the face and the scanning machine was 400 mm and the FH plane of the subject was parallel to the floor (Fig.4). Then the facial surface was scanned three times without the protrusive appliance, and with the 4 mm and 8 mm protrusive appliances.

Three-dimensional superimpositions of the original form and the 4 mm protrusion and that of the original form and the 8 mm protrusion were measured. The X, Y, Z value and three-dimensional distance of the four points on the facial surface (Fig.5) were calculated by three-dimensional measuring software (Medic Engineering, 3D SPHINX[®]). All statistical analyses were performed by the SPSS routine.

Measurement reliability

The reliability of measurements used in this study was examined by ten scans of a mannequin. The pooled standard deviation of measurement error within each set of three-

Fig. 5 Measurement points on the facial surface.

Ls: Labrale superius. R: Right lip corner.
Li: Labrale inferius. L: Left lip corner.

dimensional measurements for each scanning was calculated. The results showed that the error did not exceed ± 0.5 mm in any three-dimensional linear measurement. The mean difference between the actual distances and the three-dimensional linear distances was 0.11 mm, and the standard deviation was 0.24 mm.

Results

A three-dimensional wire frame model of the facial surface is shown in Fig.6, and Table 1 shows the means and standard deviations of X, Y, Z values and three-dimensional distances for the four measurement points. The X value shows the horizontal changes, the Y value the vertical changes and the Z value the antero-posterior changes. Table 2 shows the mean ratio of maxillary incisor change to the upper lip (Ls) and lower lip (Li) changes in terms of Z value and three-dimensional distance. The ratio for 4 mm protrusion was 2.78 and that for 8 mm protrusion was 3.09 in the antero-posterior direction. In the three-dimensional distance, the ratio for 4 mm protrusion was 1.65 and that for 8 mm protrusion was 2.33.

Correlation coefficients, describing the relationship between the thickness of the upper lip, lower lip and soft tissue pogonion and the changes in the four points, are shown in Table 3. Significant negative relationships were noted between lower lip thickness and changes in the right and left lip corners.

Correlation coefficients describing the relationship between the changes due to 4 mm protrusion and those for 4 mm to 8 mm protrusion are shown in Table 4. Significant negative relationships were noted for the lower lip (Li), right and left lip corners. There was no such relationship for the upper lip point (Ls). In summary, the changes in lips for between 4 mm and 8 mm protrusion were different from those for 0 mm to 4 mm protrusion. These results seem to indicate that the soft tissue profile does not, in any respect, directly reflect changes in the underlying upper incisors. It is suggested that the changes in upper incisors can predict soft tissue changes with a reasonable degree of accuracy for 4 mm protrusion.

The changes in Ls and Li are shown in Figs.7 and 8. The patterns of changes were divided into three types. The first type (Type 1) showed that the changes for 8 mm protrusion were twice as numerous as these for 4 mm protrusion or more. The second type (Type 2) showed that the changes for 8 mm protrusion were less than twice those for 4 mm protrusion. The third type (Type 3) showed that the changes for 8 mm were less than changes for 4 mm protrusion. Most of the subjects showed Type 1 changes in this study.

Fig. 6 Three-dimensional wire frame model of the facial surface.

Fig. 7
Changes in the Labrale superius.

Fig. 8
Changes in the Labrale inferius.

Table 1 : Means and standard deviations of X, Y, Z values and
three-dimensional distances of four measurement points

		(mm)			
		4mm		8mm	
		mean	s.d.	mean	s.d.
X-value	Ls	-0.08	0.96	0.03	0.63
	Li	0.14	0.92	0.07	0.74
	R	0.81	1.62	1.28	2.15
	L	-0.39	1.37	-1.45	1.47
Y-value	Ls	0.53	1.69	0.86	1.88
	Li	-1.93	1.45	-2.91	2.60
	R	-0.81	1.34	-0.53	1.91
	L	-0.82	1.19	-0.72	1.48
Z-value	Ls	1.44	1.15	2.59	1.25
	Li	2.41	1.74	3.98	1.61
	R	3.14	1.99	6.18	2.59
	L	2.04	1.79	5.59	2.10
3-D distance	Ls	2.42	1.14	3.44	1.14
	Li	3.64	1.42	5.61	1.53
	R	4.02	1.78	6.78	2.98
	L	3.42	1.62	6.15	2.14

Table 2 : The mean ratios of changes in upper incisor protrusion to changes in Ls and Li
(incisor : lip)

		4mm	8mm
changes in Z-value	Ls	2.78 : 1	3.09 : 1
	Li	1.66 : 1	2.01 : 1
changes in 3-D distance	Ls	1.65 : 1	2.33 : 1
	Li	1.10 : 1	1.43 : 1

Table 3 : Correlations between the thickness of soft tissue and the changes in four measurement points

	UL	LL	Pog		UL	LL	Pog
Ls-x-4	-.09	-.35	.15	Ls-x-8	.12	.01	.03
Ls-y-4	-.14	-.12	.21	Ls-y-8	-.10	-.24	.10
Ls-z-4	-.08	.09	-.09	Ls-z-8	-.08	.20	-.21
Ls-d-4	-.17	-.10	.07	Ls-d-8	-.21	.00	.10
Li-x-4	-.30	-.41	-.17	Li-x-8	.11	-.03	-.07
Li-y-4	-.05	-.37	-.07	Li-y-8	-.13	-.01	.12
Li-z-4	-.14	-.28	-.31	Li-z-8	-.26	-.24	-.04
Li-d-4	-.22	-.09	-.20	Li-d-8	-.21	-.09	-.02
R-x-4	.01	-.23	.09	R-x-8	-.02	-.06	-.27
R-y-4	-.20	-.54**	.12	R-y-8	-.22	-.44*	-.11
R-z-4	-.17	-.34	-.29	R-z-8	-.26	-.09	-.51*
R-d-4	-.14	-.18	-.28	R-d-8	-.21	-.08	-.48*
L-x-4	-.05	-.26	-.13	L-x-8	-.03	-.35	.04
L-y-4	-.14	-.48*	.02	L-y-8	-.25	-.52*	-.10
L-z-4	-.10	-.25	-.23	L-z-8	-.27	-.08	-.34
L-d-4	-.11	-.16	-.09	L-d-8	-.18	.06	-.29

significant at * p < 0.05 , ** p < 0.01

Table 4 : Correlations between the changes for 4-mm protrusion and the differences for 4-mm protrusion and 8-mm protrusion

	Ls-z-d*	Li-z-d	R-z-d	L-z-d	Pog-d
Ls-z-4	-.18	.03	.22	-.15	-.15
Li-z-4	-.23	-.63**	-.05	-.03	-.30
R-z-4	-.25	-.35	-.42*	-.38	-.18
L-z-4	-.04	-.46*	-.08	-.43*	.02
Pog-4	.16	-.01	-.05	.06	-.27

* d: The differences between 4-mm protrusion and 8-mm protrusion
significant at * p < 0.05 , ** p < 0.01

Discussion

The results of this study indicated that the soft tissue profile does not, in any respect, directly reflect changes in the underlying upper incisors. Lip thickness was not associated with changes in the lips, although changes in the right and left corners of the lip were associated with lip thickness.

In the ratio of the changes in hard tissue and lips, the value of the original position relative to 4 mm protrusion, was not the same as that for 4 mm to 8 mm protrusion. Furthermore the correlation of changes in both groups was very low. These findings indicated that the changes in the lower lip were more complex than those for the upper lip. We categorized lip changes into three types. The key for categorizing the groups was the changes in the stomion caused by the differences in flexibility of the upper and lower lips.

The soft tissue change following orthodontic treatment is usually considered secondary to tooth and skeletal alterations. Yogosawa^[8] found that anterior dental protrusion and lower facial height are the two factors leading to lip strain. The change in the soft tissue profile caused by tooth movement has distinct characteristics which cannot be calculated or easily described in a formula. Facial soft tissue configuration may be as variable as malocclusion itself. To properly predict post-treatment change, individual cases must be studied carefully for soft tissue movement patterns. It is especially important to study the relaxed lip posture due to its accuracy in determining post-treatment posture, as Burstone^[9] has described. Therefore, for clinical application, understanding the basic response of facial soft tissue treatment and preoperative relaxed lip posture provides some kind of framework for the prediction of post-orthodontic facial profile changes.

The upper lip is suspended from the nose and anterior nasal spine, which may explain why changes in upper lip vermilion height are not closely associated with maxillary incisor retraction. A decrease in upper lip vermilion height was correlated with retraction of the upper and lower lips. Decreases in the upper and lower lip vermilion heights were also correlated. A decrease in upper lip vermilion height was associated with a decrease in the interlabial gap, an association perhaps related to upper lip retraction^[10].

In this study, the flexibility of the upper lip was poor, compared with the lower lip. The changing ratio of the upper incisor / Ls was 1.6 times the ratio of Li, and there was no significant relationship between Ls and any other variable. From the viewpoint of the lip profile changes, the changes in the stomion were strongly related to the protrusive changes in Ls. In the case of upward changes in the stomion, Ls showed a protrusive position. In the contrast in the case of downward changes in the stomion, Ls did not show a protrusive position. Therefore, upper lip protrusion was influenced by the direction of the stomion.

The mean ratio of maxillary incisor retraction to upper lip retraction has been a common computation in past studies. For an orthodontic treatment group, Rudee^[11] found a ratio of 2.93 : 1, Roos^[12] found a ratio of 2.5 : 1, and Perkins and Staley^[10] found a ratio of 2.24 : 1.

In the present study, the ratio for the horizontal maxillary incisor protrusion to the horizontal upper lip retraction was 2.78 (4-mm) and 3.08 (8-mm), which was close to Rudee's results.

The results of this study indicated that changes in the lips were associated with changes in stomion position, which in turn were related to the flexibility of the lower lip. The more flexible the lower lip, the more upward a position the stomion showed. More information about changes in soft tissue profile should be provided in further studies of lip characteristics such as their length, flexibility, and tension.

Conclusions

1. Three-dimensional measurements obtained by a computerized 3D laser scanning system were used to evaluate facial morphology. The measurement error of this system was less than 0.5-mm after superimposing. The stability and reproducibility of the recording procedure were evaluated. The changes in facial morphology due to orthodontic treatment and orthognathic surgery were visualized in any direction with this three-dimensional graphic system.
2. Lip thickness was not associated with changes in the lips. In contrast, the relationship between the right and left corners of the lip and lip thickness was investigated.
3. With regard to the ratio of changes in hard tissue and lips, the value of the original position relative to 4-mm protrusion was not the same as that of 4-mm to 8-mm protrusion, and the correlation of changes in both groups was very low.
4. The changes in lips were associated with changes in stomion position, which in turn were related to the vertical change in the upper lip.

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