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Comparison of cephalometric norms between Japanese and Caucasian adults in antero-posterior and vertical dimension

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SUMMARY The aims of this study were to determine Japanese cephalometric norms in the antero-posterior and vertical dimension, and to test the hypothesis that there are racial differences in cephalometric measurements between Japanese and Caucasian norms. Radiographs were obtained from 25 healthy Japanese males (aged 25.1 ± 2.7 years) and 24 healthy Japanese females (aged 23.6 ± 1.3 years). Inclusion criteria were an ANB angle between 2 and 5 degrees, a normal occlusion with minor or no crowding, all teeth present except third molars, no previous orthodontic treatment, and no prosthetic replacement of teeth. Two angular and five linear measurements were constructed for the skeletal hard tissue analysis, one angular and six linear measurements for the dental hard tissue analysis, and two angular and seven linear measurements for the soft tissue analysis. The mean and standard deviations for the hard and soft tissue measurements were determined for each gender. Unpaired *t*-tests were used to determine the mean differences for each cephalometric measurement between the Japanese and the Caucasians.

In the antero-posterior dimension, the Japanese subjects had a significantly more retruded chin position ($P < 0.001$), typically protruding mandibular incisors, and protruded lip positions compared with the Caucasian norms. In the vertical dimension, the Japanese had a significantly steeper mandibular plane ($P < 0.01$). The Japanese females had a significantly larger lower face height and increased dental height ($P < 0.001$). The results of this study suggest that these cephalometric measurements might be helpful to formulate treatment plans for Japanese patients.

Introduction

Radiographic cephalometry was introduced simultaneously by Hofrath (1931) in Germany and Broadbent (1931) in the United States of America. Subsequently, the analyses of Downs (1948), Tweed (1953, 1954), and Steiner (1953) became popular for planning orthodontic treatment. At that time, attempts were made to include soft tissue measurements in the analyses (Ricketts, 1957, 1961; Burstone, 1967; Holdaway, 1983, 1984). Japanese cephalometric norms were developed in the 1950s and 1960s (Izuka and Ishikawa, 1957; Sakamoto, 1959; Yamauchi, 1959; Yamauchi and Sakuda, 1959; Ito and Suematsu, 1967; Yamauchi *et al.*, 1967; Shishikura, 1969; Yogosawa, 1969). Many of these reports were published in Japanese and therefore were not routinely utilized in the West.

The Japanese population has been found to be more retrognathic with a greater vertical direction of facial growth than Caucasians (Sakamoto, 1959; Engel and Spolter, 1981). Additionally, the Japanese have been found to have a more protrusive dentition than Caucasians (Yamauchi, 1959; Engel and Spolter, 1981). Nezu *et al.* (1982) stated that the appearance of more protrusive lip positions were evident in Japanese patients due to their more retruded chin positions. Historically, cephalometric norms for Japanese subjects (Izuka and Ishikawa, 1957; Iwasawa *et al.*, 1977; Uesato *et al.*, 1978) were limited to hard tissue analysis, particularly angular measurements derived from the analyses of Downs (1948), Tweed (1953, 1954), and Steiner (1953). Miyajima *et al.* (1996) developed linear measurements of the Japanese craniofacial structure using the analysis of McNamara (1984).

The aim of modern cephalometrics is to evaluate the relationship of the skeletal and dental functional units of the face and to implement treatment to establish the position of the units both horizontally and vertically (Proffit and Fields, 2000). However, most accepted analyses have been devoted to the antero-posterior (A-P) plane. Vertical linear measurements are particularly useful to evaluate anterior open bite and deep bite subjects. For example, in the case of an open bite, it is uncertain whether the problem is over-eruption of the posterior teeth or the lack of eruption of the anterior teeth. A vertical, linear measurement of the actual distances of the anterior and posterior teeth to the palatal and the mandibular plane may aid in determining if an open bite is related more to the anterior or posterior dimension of the facial skeleton. However, no study has reported the distances of the anterior and posterior teeth to the reference lines in Japanese. Moreover, as metropolitan areas in the world tend to have patients from more diverse racial or ethnic groups, it is becoming increasingly important that treatment plans are based on racial or ethnic group norms. The purpose of this study was to determine Japanese cephalometric norms in the A-P and vertical dimension, and to test the hypothesis that there are racial differences in cephalometric measurements between Japanese and Caucasian norms.

Subjects and methods

Subjects

According to a previous study (Miyajima *et al.*, 1996), the effective size of facial axis angle was estimated at 3.7 degrees (±4.0). On the basis of significance level of alpha of 0.05 (two sided) and a beta of 0.2, the sample size for each group was calculated to achieve 80 per cent power to detect the standardized effect size of 0.93 (3.7/4.0 degrees) between Japanese and Caucasians. The sample size calculation showed that 21 subjects for each group were necessary (Hulley *et al.*, 2001).

This study was a retrospective analysis of existing radiographs, and was performed in accordance with the guidelines of the Helsinki Declaration (1996).

Eight hundred and fifty dental students and staff members at Kyushu University who had given informed consent were screened for the investigation. Inclusion criteria were an ANB angle between 2 and 5 degrees, an Angle Class I occlusion with an arch length discrepancy of less than 2 mm, an overbite between 1.0 and 4.0 mm, an overjet between 1.0 and 4.0 mm, all teeth present except third molars, no previous orthodontic treatment, and no prosthetic replacement of teeth. Facial aesthetics were not considered. Twenty-five healthy Japanese males (aged 25.1 ± 2.7 years) and 24 healthy Japanese females (aged 23.6 ± 1.3 years) met the inclusion criteria.

Cephalometric analysis

All lateral cephalometric radiographs were taken, with the teeth in maximal intercuspation, in a cephalostat (DR-155-23HC, Hitachi Medical Corporation, Tokyo, Japan) orientated at the Frankfort horizontal plane, and exposed at 100 kV, 10 mA. The distance from the focus of the X-ray device to the midsagittal plane of the patient was 150 cm, and the distance from the film to the midsagittal plane 15 cm. Since no correction was made for the cephalometric measurements, all linear measurements had a 10 per cent enlargement factor included. All radiographs were traced by hand on matte acetate sheets and digitized on a personal computer by one author (HI), in order to eliminate inter-examiner variability. Cephalometric analyses were performed with the aid of a cephalometric software program (Winceph 5.5, Rise, Sendai, Japan). Two angular and five linear measurements were constructed for the skeletal hard tissue analysis (Figure 1), one angular and six linear measurements for the dental hard tissue analysis (Figure 2), and two angular and seven linear measurements for the soft tissue analysis (Figure 3).

The mean and standard deviations for the hard and soft tissue measurements were determined for each gender. The adult skeletal and dental Caucasian norms were derived from the analyses developed by Riolo *et al.* (1974), McNamara (1984), and Miyajima *et al.* (1996), and the soft tissue norms by Legan and Burstone (1980), Bishara *et al.* (1985), and Burstone and Marcotte (2000). The description of the Caucasian samples used for comparison is shown in Table 1.

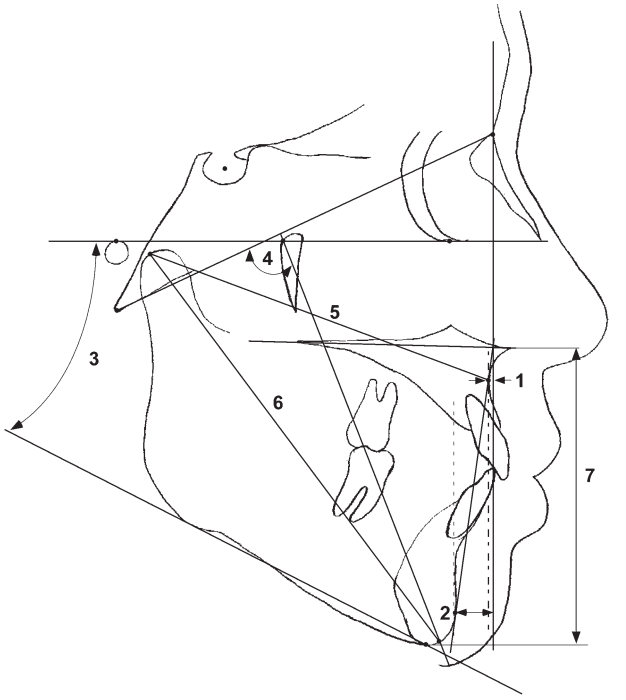

Figure 1 Skeletal hard tissue cephalometric reference points: 1 (nasion perpendicular to point A), the distance between nasion perpendicular line and point A measured perpendicular to the nasion perpendicular line; 2 (Pog to nasion perpendicular), the distance between pogonion and the nasion perpendicular line measured perpendicular to the nasion perpendicular line; 3 (Frankfort to mandibular plane angle), the angle between the Frankfort plane and the mandibular plane; 4 (facial axis angle), the angle formed by the basion–nasion plane and the plane from foramen rotundum to gnathion; 5 (effective midfacial length), the distance between condylion to point A; 6 (effective mandibular length), the distance between condylion to gnathion; 7 (lower face height), the distance between ANS and menton measured perpendicular to the Frankfort plane.

Reliability

A random selection of 10 cephalometric radiographs were traced and digitized twice by the same investigator. The error differences in landmark identification for the linear and angular measurements were within 0.63 mm and 0.71 degrees, respectively. The method errors for the soft tissue measurements are presented in Table 2. The method error was considered negligible.

Statistical analysis of the data

Unpaired *t*-tests were used to compare the mean differences of each cephalometric measurement between the Japanese and the Caucasians after *F*-tests for equal and unequal variances. The minimum level of statistical significance was set at $P < 0.01$.

Results

The mean and standard deviations of the cephalometric measurements for the Japanese and Caucasian males and females are shown in Tables 3 and 4, respectively.

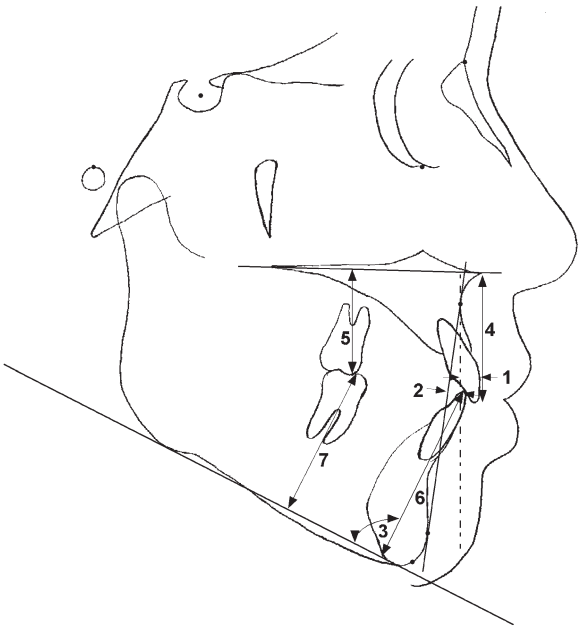

Figure 2 Dental hard tissue cephalometric reference points and analysis: 1 (upper incisor to point A vertical), the distance between the facial surface of the upper incisor and point A measured perpendicular to the nasion perpendicular line; 2 (lower incisor to A-Po line), the distance between the edge of the lower incisor and a line from point A to pogonion; 3 (lower incisor to mandibular plane angle), the angle formed by the long axis of the lower incisor and the mandibular plane; 4 (upper incisor to palatal plane), the distance from the edge of the upper incisor to the palatal plane; 5 (upper molar to palatal plane), the distance from the mesial cusp of the upper first molar to the palatal plane; 6 (lower incisor to mandibular plane), the distance from the edge of the lower incisor to the mandibular plane; 7 (lower molar to mandibular plane), the distance from the mesial cusp of the lower first molar to the mandibular plane.

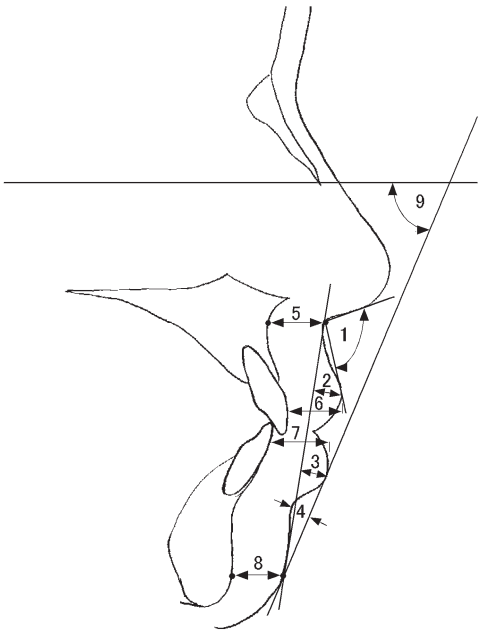

Figure 3 Soft tissue cephalometric reference points and analysis: 1 (nasolabial angle), the angle formed by a line tangent to the base of the nose and a line tangent to the upper lip; 2 (upper lip protrusion), the distance between labrale superius and a line from subnasale to soft tissue pogonion; 3 (lower lip protrusion), the distance between labrale inferius and a line from subnasale to soft tissue pogonion; 4 (labiomental sulcus), the maximum depth from a line connecting soft tissue pogonion and the lower lip; 5 (point A to subnasale), the distance from point A to subnasale measured parallel to the Frankfort plane; 6 (incision superioris to upper lip), the distance from incision superioris to the upper lip measured parallel to the Frankfort plane; 7 (incision inferioris to lower lip), the distance from incision inferioris to the lower lip measured parallel to the Frankfort plane; 8 (pogonion to pogonion′), the distance from hard tissue pogonion to soft tissue pogonion measured parallel to the Frankfort plane; 9 (*Z* angle), the angle formed by the intersection of Frankfort plane and a line connecting soft tissue pogonion and the most protrusive lip point.

Skeletal relationship

Skeletally, mandibular A-P position in the Japanese males and females was significantly more retruded compared with that of Caucasians (Tables 3 and 4). Vertically, the Japanese showed a significantly larger Frankfort to mandibular plane angle and a significantly smaller facial axis angle (Tables 3 and 4). In particular, Japanese females had a significantly larger lower face height than Caucasian females (Table 4).

Dental relationship

The Japanese subjects had significantly more protruded mandibular incisors compared with the Caucasians (Tables 3 and 4). Vertically, the distance of the lower incisor or lower molar to the mandibular plane was significantly larger in the Japanese females (Table 4).

Soft tissue analysis

The Japanese male subjects had a significantly smaller nasolabial angle than Caucasians (Table 3), and both males and females had significantly more protruded lip positions compared with Caucasians (Tables 3 and 4). The labiomental sulcus in Japanese males was significantly larger than that in Caucasians (Table 3). The thickness of the base of the upper lip in the Japanese subjects was significantly thinner than that of Caucasians (Tables 3 and 4). Moreover, the thickness of the soft tissue chin in the Japanese females was significantly thicker than that of Caucasians (Table 4). While the Japanese males had a significantly smaller *Z* angle than Caucasians, there was no significant difference in this angle between the Japanese and the Caucasian females (Table 4).

Discussion

Sample size

Consideration must be given to sample size determination for Japanese and Caucasian samples. It is acknowledged that there were slightly fewer subjects in the Caucasian groups than the sample size calculation suggested. Moreover, since the sample sizes for the Japanese males and females

were also relatively small, the results should be interpreted with caution. Although it was still useful to analyse the groups to evaluate whether there were any interesting trends, the groups were convenience samples and some bias may have been introduced.

Skeletal relationship

The analysis of Steiner (1953) is considered to be the first modern cephalometric analysis. ANB angle, which indicates the skeletal discrepancy of the jaws, became a specific guide in treatment planning. The mean ANB angle in a sample of Japanese with normal occlusions was reported to be 4.5 degrees by Miura *et al.* (1963) and 2.56 ± 1.08 degrees by Iwasawa *et al.* (1977). These reports suggest that subjects whose ANB angle is between 2 and 5 degrees in this study would be regarded as a representative Japanese population with a normal occlusion.

ANB angle is influenced by the vertical height of the face and the A-P position of nasion (McNamara, 1984), and therefore, the use of this angle is sometimes misleading. To overcome this issue, McNamara (1984) introduced his analysis in which the A-P position of the maxilla and mandible was evaluated with reference to the nasion perpendicular line to the Frankfort plane. This analysis depends primarily upon linear, rather than angular measurements to aid in treatment planning for both orthodontic and orthognathic surgery cases. In this study, in order to delineate racial and ethnic differences, the results were compared with previously reported Caucasian data (Riolo *et al.*, 1974; Legan and Burstone, 1980; McNamara, 1984; Bishara *et al.*, 1985; Miyajima *et al.* 1996; Burstone and Marcotte, 2000). For Caucasians, the maxilla (point A) should be on or slightly ahead of the nasion perpendicular line (Proffit and Fields, 2000). In this study, the Japanese maxillary position relative to the nasion perpendicular line was nearly the same as that of Caucasians. The mandibular position relative to the cranial base, as measured by the facial axis angle for the Japanese, demonstrated a more retruded position in both males and females compared with Caucasians. These results suggest that the Japanese population with normal occlusions is more dolichofacial than brachyfacial, while Caucasians with normal occlusions tend to be more brachyfacial than dolichofacial (Christie, 1977). Considering the vertical dimension, the Japanese sample had a significantly larger Frankfort to mandibular plane angle and a significantly smaller facial axis angle than the Caucasians. However, the small mean differences between the two groups should be taken into account when evaluating the clinical significance. The lower face height of the Japanese females was significantly larger than that of Caucasian females, although there was little difference in lower face height between the Japanese and the Caucasian males. Engel and Spolter (1981) reported that the Japanese tended to have a more vertical mandibular growth pattern than Caucasians. This characteristic appears to be more significant in females than males.

Table 1 Description of the Caucasian samples used for comparison.

Author and year	Mean age (years)		Sample size (*n*)	
	Male	Female	Male	Female
Skeletal and dental norms				
Riolo *et al.* (1974)	16.0	16.0	23	9
McNamara (1984)	30.8	26.7	38	73
Miyajima *et al.* (1996)	36.0	39.0	44	81
Soft tissue norms				
Legan and Burstone (1980)	20–30	20–30	20	20
Bishara *et al.* (1985)	Adulthood	Adulthood	20	15
Burstone and Marcotte (2000)	27.4	21.2	20	20

Table 2 Reliability of the soft tissue measurements.

Variables	Error difference
Nasolabial angle (°)	0.71
Upper lip protrusion (Ls to Sn-Pg′) (mm)	0.15
Lower lip protrusion (Li to Sn-Pg′) (mm)	0.02
Labiomental sulcus (mm)	0.26
Point A to subnasale (mm)	0.15
Incision superioris to upper lip (mm)	0.45
Incision inferioris to lower lip (mm)	0.29
Pogonion to pogonion′ (mm)	0.47
Z angle (°)	0.31

Methods errors were assessed by a random selection of 10 cephalometric radiographs.

Dental relationship

The lower incisors in Japanese adults were significantly more protruded and tipped forward than those in Caucasians. Miyajima *et al.* (1996) reported that the lower incisor position relative to point A-pogonion (A-Po) line was 4.0 mm for Japanese males and 4.9 mm for Japanese females. This study showed similar results regarding lower incisor position (male: 4.2 mm, female: 4.9 mm). Considering the vertical dimension, the lower incisor or lower molar to the mandibular plane in Japanese females was significantly larger than that of Caucasian females. These differences might be attributed to the longer lower face height in Japanese females. The mean value in the dental vertical position may be useful to determine which teeth contribute more to the overall facial pattern. It would be helpful in treatment planning for clinicians to ascertain which teeth contribute more to the vertical disharmonies of open or deep bites. However, because of the small mean and standard deviation differences and the mean age differences between

Table 3 Comparison of sample means between Japanese and Caucasian males.

Variables	Japanese males		Caucasian males		Significance
	Mean	SD	Mean	SD	
Skeletal relationship					
Nasion perpendicular to point A (mm)	–0.3	3.2	1.1	2.7	NS
Pogonion to nasion perpendicular (mm)	–6.8	5.4	–0.3	3.8	***
Frankfort to mandibular plane angle (°)	25.1	4.1	21.3	3.9	***
Facial axis angle (°)	86.3	2.9	90.5	3.5	***
Effective midfacial length (mm; condylion to point A)	96.9	4.1	99.8	6.0	*
Effective mandibular length (mm; condylion to gnathion)	130.4	4.8	134.3	6.8	*
Lower face height (ANS–menton; mm)	74.8	4.6	74.6	5.0	NS
Dental relationship					
Upper incisor to point A vertical (mm)	5.5	1.7	5.3	2.0	NS
Lower incisor to A-Po line (mm)	4.2	1.6	2.3	2.1	***
Lower incisor to mandibular plane angle (°)	97.8	6.9	92.3	7.4	**
Upper incisor to palatal plane (mm)	31.7	2.7	33.0	3.2	NS
Upper molar to palatal plane (mm)	26.6	2.0	27.9	3.1	NS
Lower incisor to mandibular plane (mm)	48.8	2.8	48.9	3.0	NS
Lower molar to mandibular plane (mm)	40.2	2.9	38.0	2.8	NS
Soft tissue relationship					
Nasolabial angle (°)	93.4	11.7	102.0	8.0	**
Upper lip protrusion (Ls to Sn-Pg′; mm)	6.3	1.4	3.0	1.0	***
Lower lip protrusion (Li to Sn-Pg′; mm)	5.6	1.7	2.0	1.0	***
Labiomental sulcus (mm)	5.7	1.3	4.0	2.0	***
Point A to subnasale (mm)	16.5	1.6	19.7	1.4	***
Incision superioris to upper lip (mm)	14.3	1.7	13.7	2.2	NS
Incision inferioris to lower lip (mm)	14.8	1.4	15.5	1.9	NS
Pogonion to pogonion′ (mm)	14.3	2.2	13.3	1.7	NS
Z angle (°)	69.5	5.3	75.5	8.3	**

The skeletal and dental norms of Caucasians were derived from analyses developed by Riolo *et al.* (1974), McNamara (1984), and Miyajima *et al.* (1996). The soft tissue norms of Caucasians were derived from analyses developed by Legan and Burstone (1980), Bishara *et al.* (1985), and Burstone and Marcotte (2000).
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
NS, not significant.

the two groups, these results should be interpreted carefully.

Soft tissue analysis

The data showed that the Japanese males had a significantly smaller nasolabial angle than Caucasians. Moreover, the Japanese males and females had significantly more protruded lip positions than Caucasians. These characteristics of the soft tissues were confirmed by previous research (Iwasawa *et al*., 1977; Nezu *et al*., 1982; Alcalde *et al*., 2000). Nezu *et al*. (1982) reported that the normal lower lip protrusion to the aesthetic line was 2.0 mm in Japanese and –2.0 mm in Caucasians. As there were no significant differences in upper and lower lip thickness between the two groups, these characteristics might be due to the protruding lower incisors inherent in the Japanese population. Although skeletally, the Japanese subjects had a significantly more retruded chin position compared with Caucasians, there was no significant difference in the Z angle between the Japanese and the Caucasian females. These results suggest that the thicker soft tissue chin in the Japanese females might compensate for the retruded chin position.

Conclusions

The mean and standard deviations of skeletal, dental, and soft tissue cephalometric norms for male and female Japanese adults were developed and compared with Caucasian norms. For the A-P dimension, the Japanese subjects had a significantly more retruded chin position, typically protruding mandibular incisors, and protruded lip positions compared with Caucasian norms. For the vertical dimension, the Japanese had a significantly steeper mandibular plane angle. Japanese females had a significantly larger lower face height together with increased distances of the anterior and posterior teeth to the mandibular plane.

These results suggest that Japanese with normal occlusions tend to be more dolichofacial than brachyfacial. Since the subjects in the study represent the Japanese population with normal occlusions, the A-P and vertical linear cephalometric measurements might be helpful in formulating treatment

Table 4 Comparison of sample means between Japanese and Caucasian females.

Variables	Japanese females		Caucasian females		Significance
	Mean	SD	Mean	SD	
Skeletal relationship					
Nasion perpendicular to point A (mm)	–0.7	3.2	0.4	2.3	NS
Pogonion to nasion perpendicular (mm)	–7.3	6.7	–1.8	4.5	***
Frankfort to mandibular plane angle (°)	26.5	6.2	22.7	4.3	**
Facial axis angle (°)	86.6	3.7	90.2	3.2	***
Effective midfacial length (mm; condylion to point A)	91.5	4.7	91.0	4.3	NS
Effective mandibular length (mm; condylion to gnathion)	121.5	5.5	120.2	5.3	NS
Lower face height (ANS–menton; mm)	71.0	4.6	66.7	4.1	***
Dental relationship					
Upper incisor to point A vertical (mm)	5.3	2.2	5.4	1.7	NS
Lower incisor to A-Po line (mm)	4.9	2.7	2.7	1.7	***
Lower incisor to mandibular plane angle (°)	99.5	5.8	94.9	6.3	**
Upper incisor to palatal plane (mm)	31.9	2.5	30.0	2.9	*
Upper molar to palatal plane (mm)	25.3	1.8	24.8	2.2	NS
Lower incisor to mandibular plane (mm)	46.1	3.1	41.5	3.1	***
Lower molar to mandibular plane (mm)	38.2	2.2	32.6	2.9	***
Soft tissue relationship					
Nasolabial angle (°)	99.0	9.0	102.0	8.0	NS
Upper lip protrusion (Ls to Sn-Pg′; mm)	6.5	1.7	3.0	1.0	***
Lower lip protrusion (Li to Sn-Pg′; mm)	6.1	1.8	2.0	1.0	***
Labiomental sulcus (mm)	4.6	1.1	4.0	2.0	NS
Point A to subnasale (mm)	13.9	1.5	15.3	1.6	**
Incision superioris to upper lip (mm)	11.3	2.1	10.9	1.6	NS
Incision inferioris to lower lip (mm)	12.4	2.1	12.9	1.8	NS
Pogonion to pogonion′ (mm)	13.4	1.9	11.1	1.8	***
Z angle (°)	67.5	7.0	71.3	7.7	NS

The skeletal and dental norms of Caucasians were derived from analyses developed by Riolo *et al.* (1974), McNamara (1984), and Miyajima *et al.* (1996). The soft tissue norms of Caucasians were derived from analyses developed by Legan and Burstone (1980), Bishara *et al.* (1985), and Burstone and Marcotte (2000).
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
NS, not significant.

plans for Japanese patients. Additional research on the issues of hard and soft tissue analysis of well-balanced profiles in Japanese adults appears to be warranted.

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