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Effects of retraction of anterior teeth and initial soft tissue variables on lip changes in Japanese adults

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SUMMARY The aim of this study was to examine the effects of retraction of anterior teeth and the initial soft tissue profile variables on upper and lower lip changes in Japanese adults. Pre- and post-treatment cephalometric radiographs of 33 Japanese female adults (aged 23.0 ± 5.0 years), with a Class II division 1 malocclusion, who had two or four first premolars extracted, were evaluated. Lateral cephalograms taken with the lips in a voluntary relaxed position were traced and compared. Nine linear and eight angular measurements were constructed for the hard tissue measurements and 16 linear and 2 angular for the soft tissue measurements.

Stepwise multiple regression analysis revealed that the horizontal upper lip position could be explained by the position of the maxillary incisor cervical point and the occlusal plane to SN with a 54 per cent contribution ratio, and horizontal lower lip position, maxillary incisor tip position, initial interlabial gap, and aesthetic line to the tip of lower lip with a 51 per cent contribution ratio. All parameters employed explained the horizontal position of the upper and lower lip with higher than 96 per cent confidence. While the horizontal positions could not be predicted by a limited number of parameters, the vertical positions of lips could be explained by three parameters with higher than 62 per cent confidence. The predictability found in this study could be beneficial for orthodontists in treatment planning.

Introduction

It is important to evaluate the social aspects of orthodontic treatment outcomes as well as to establish a functional occlusion (Sarver *et al.*, 2000). Profile improvement via orthodontic treatment is important in evaluating the treatment results. Orthodontic diagnosis and treatment planning should include an accurate prediction of facial aesthetics customized to a patient's morphological, racial, gender, and/or social background in order to obtain patient satisfaction and improve their social activity. Indeed, orthodontists are frequently questioned about possible facial profile changes created by a particular treatment plan. Since the perioral profile of the lip form is a critical factor in achieving facial aesthetics, it is necessary to evaluate and predict the post-treatment lip position before determining a treatment plan.

The prediction of lip change in response to tooth movement has commonly been expressed as the ratio of maxillary and mandibular incisor retraction to lip change. However, reports of this ratio vary considerably according to gender (Hershey, 1972; Wisth, 1974; Oliver, 1982; Yogosawa, 1990; Bishara *et al.*, 1995; Diels *et al.*, 1995), dentofacial morphology (Roos, 1977; Waldman, 1982; Talass *et al.*, 1987; Kusnoto and Kusnoto, 2001), and ethnicity (Garner, 1974; Rains and Nanda, 1982; Lew, 1989; Caplan and Shivapuja, 1997; Brock *et al.*, 2005). For Caucasians, the ratios of maxillary incisor retraction to upper lip retraction are from 2.24:1 to 2.93:1 and for mandibular incisor retraction to lower lip retraction from 1.11:1 to 1.23:1 (Rudee, 1964; Roos, 1977; Perkins and Staley, 1993). For African Americans, the ratios of maxillary and mandibular incisor retraction to upper and lower lip retraction are 1.75:1 and 1.2:1, respectively (Caplan and Shivapuja, 1997).

A previous study that evaluated the effects of retraction of anterior teeth on lip position in adult Japanese with bimaxillary protrusion (Yasutomi *et al.*, 2006) reported the ratios for maxillary incisor retraction to upper lip retraction and mandibular incisor retraction to lower lip retraction to be 1.85:1 and 1.32:1, respectively. In addition, lip response seemed to be influenced not only by the amount of incisor retraction but also by the lip structure itself. Oliver (1982) found that patients with thin lips or a high lip strain displayed a significant correlation between incisor retraction and lip retraction, whereas those with thick lips or low lip strain displayed no such correlation. Therefore, it is important to also include soft, as well as the hard tissue variables in predicting the soft tissue profile after orthodontic treatment. For Caucasians, several studies have evaluated the predictability of lip position in response

to changes in incisor position. This has been shown together with pre-treatment soft tissue factors (Rains and Nanda, 1982; Talass *et al.*, 1987; Brock *et al.*, 2005; Stalpers *et al.*, 2007). However, in previous studies dealing with this issue, the types of malocclusions were not clearly distinguished. This may affect the amount of soft tissue profile change. In addition, there are currently no studies related to adult Japanese with Class II division 1 malocclusions. The purpose of this study was therefore to examine the effects of the retraction of anterior teeth and the initial soft tissue profile variables on upper and lower lip changes in Japanese adults with Class II division 1 malocclusions**.**

Subjects and methods

Sample size

A sample size calculation was undertaken using the nQuery Adviser software package (Version 6.01; Statistical Solutions, Cork, Ireland). The pilot study estimated that the effect size was 0.45. On the basis of a significance level of alpha 0.050, the sample size was calculated to achieve an 80 per cent power. The sample size calculation showed that in total, 32 subjects were necessary.

Subjects

The research protocol was approved by the Ethics Committee of Kyushu University. The subjects were selected from the files of the Orthodontic Clinics, Kyushu University Hospital, Fukuoka, Japan, which included more than 3000 completed cases. Their records contained pre- and post-treatment facial photographs, cephalograms, oral photographs, panoramic radiographs, dental casts, diagnostic records, treatment plans, and descriptive summaries of treatment progression.

Inclusion criteria were as follows:

1. Japanese adult females (minimum age at the beginning of treatment was 17 years);
2. Orthodontic treatment included extraction of the maxillary first premolars or all four premolars with subsequent retraction of the anterior teeth;
3. Pre- and post-treatment cephalometric radiographs of adequate diagnostic quality;
4. Pre-treatment Class II molar relationship according to the dental classification;
5. Pre-treatment maxillary incisor protrusion (U1–point A vertical line) of more than 6.0 mm;
6. Pre-treatment overjet of more than 5.0 mm.

Records of 33 females (aged 23.0 ± 5.0 years) were obtained. Twenty-four were treated with four first premolar extractions and the remaining nine with extraction of the maxillary first premolars. The pre-treatment cephalometric characteristics of these individuals are shown in Table 1. The average maxillary and mandibular arch length deficiencies were −1.52 ± 1.72 and −1.70 ± 1.91 mm, respectively. All patients were treated with edgewise appliances. Maximum anchorage mechanics were used with extraoral anchorage, palatal buttons, and transpalatal arches. The average treatment period was 37.5 ± 9.4 months.

Cephalometric analysis

Lateral cephalograms had been taken before and after active orthodontic treatment with the teeth in maximal intercuspation in a cephalostat orientated to the Frankfort horizontal plane. The lips were in their relaxed position as described by Burstone (1967). The radiographs were obtained with a DR-155-23HC (SSR-2B; Hitachi Medical Corporation, Tokyo, Japan) and exposed at 100 kV, 200

Table 1 Mean and standard deviations (SDs) of the pre-treatment cephalometric characteristics of the subjects ($N = 33$).

					Norm	
Mesurement	Mean	SD	Minimum	Maximum	Mean	SD
SNA (°)	81.04	3.64	71.90	86.90	82.3	3.4
SNB (°)	74.49	3.66	66.80	82.20	78.9	3.2
ANB (°)	6.55	2.18	2.30	10.70	3.4	1.8
Mandibular plane (°)	40.50	6.60	30.40	54.30	28.8	5.2
Go (°)	123.25	6.74	109.30	140.00	122.2	5.8
Ramus plane (°)	97.48	5.23	85.50	108.20	89.0	5.2
U1–SN-7 (°)	117.08	5.94	104.00	129.00	104.5	8.1
Occlusal plane (°)	19.10	4.77	10.30	27.90	11.4	4.0
L1–Md (°)	99.97	5.09	88.50	109.50	96.3	7.1
U1–A–vertical (mm)	9.52	2.34	6.00	14.00	5.3	2.2
L1–A–Pog (mm)	6.74	2.12	2.00	10.00	4.9	2.7
Overbite (mm)	2.44	1.58	−2.00	5.00	2.1	0.8
Overjet (mm)	8.17	1.77	5.00	11.50	2.9	0.7

The skeletal and dental norms of Japanese were derived from the analyses of Iizuka and Ishikawa (1957), Miyajima *et al.* (1996), and Ioi *et al.* (2007).

mA. All radiographs were traced by hand on matte acetate by one author (HH) in order to eliminate any inter-examiner variability. This procedure has been described previously (Yasutomi *et al.*, 2006). The X–Y coordinates used were identical to those used in a previous study (Yasutomi *et al.*, 2006). Briefly, the reference line X was assigned as the sella−nasion line, minus 7 degrees. The reference line Y was perpendicular to the reference line X, continuing through sella. For linear measurements, four lines were constructed for hard tissue horizontal (Figure 1a) and five lines for hard tissue vertical (Figure 1b). Nine linear and two angular measurements were constructed for soft tissue horizontal (Figure 1c) and five linear measurements for the soft tissue vertical (Figure 1d). Twenty-three linear and two angular measurements were recorded (Table 2). Eight angular cephalometric variables, including SNA, SNB, ANB, mandibular plane to SN angle, ramus plane to SN angle, maxillary incisor to SN-7 plane (U1–SN-7), occlusal plane to SN angle, and mandibular incisor to mandibular plane (L1–Md) were also measured.

Reliability

All cephalometric radiographs were retraced and redigitized after an interval of 2 weeks by the same author to calculate

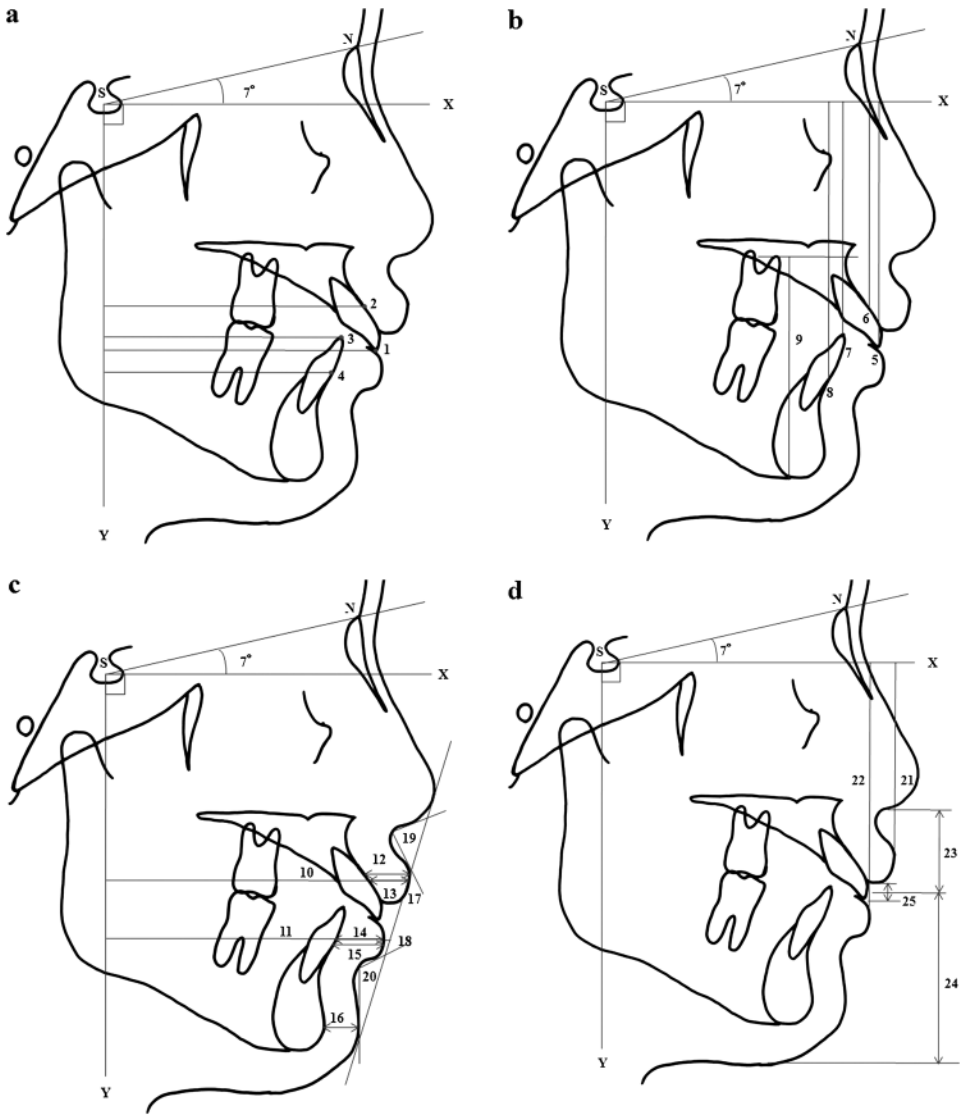

Figure 1 (a) Horizontal linear measurements of the hard tissues: 1, H–tU1; 2, H–cU1; 3, H–tL1; and 4, H-cL1. (b) Vertical linear measurements of the hard tissues: 5, V–tU1; 6, V–cU1; 7, V–tL1; 8, V–cL1; and 9, LFH. (c) Horizontal linear measurements of the soft tissues: 10, H–U-lip; 11, H–L-lip; 12, cU thickness; 13, Ls thickness; 14, Li thickness; 15, cL thickness; 16, chin thickness; 17, E–Ls; 18, E–Li; 19, nasolabial angle; and 20, labiomental angle. (d) Vertical linear and angular measurements of the soft tissues: 21, V–U-lip; 22, V–L-lip; 23, Sub-St; 24, St–Me; and 25. interlabial gap.

Table 2 Horizontal and vertical measurements of the hard and soft tissues.

Measurement	Explanation
Horizontal linear measurements of the hard tissues	
H-tU1	Maxillary incisor tip (tU1) to Y-line
H-cU1	Maxillary incisor cervical point (cU1) to Y-line
H-tL1	Mandibular incisor tip (tL1) to Y-line
H-cL1	Mandibular incisor cervical point (cL1) to Y-line
Vertical linear measurements of the hard tissues	
V-tU1	tU1 to x-line
V-cU1	cU1 to x-line
V-tL1	tL1 to x-line
V-cL1	cL1 to x-line
LFH	Lower face height
Horizontal linear measurements of the soft tissues	
H-U-lip	Most anterior point of the upper lip (U-lip) to Y-line
H-L-lip	Most anterior point of the lower lip (L-lip) to Y-line
cU thickness	Lip thickness at cU1 point
Ls thickness	Lip thickness at U-lip point
Li thickness	Lip thickness at L-lip point
cL thickness	Lip thickness at cL1 point
Chin thickness	Pogonion to soft tissue Pogonion distance
E–Ls	E-line to U-lip
E–Li	E-line to L-lip
Nasolabial angle	The lower border of the nose and upper lip tangent
Labiomental angle	Soft tissue chin and lower lip tangent
Vertical linear measurements of the soft tissues	
V-U-lip	U-lip to x-line
V-L-lip	L-lip to x-line
Sub–St	Subnasale to stomion distance
St–Me	Stomion to soft tissue menton distance
Interlabial gap	Stomion superious to stomion inferious distance

the error of the method. Intraclass correlation coefficients (ICC) were used for detecting the intra rater agreement. No major differences were found since all ICC were greater than or equal to 0.86. This method error was therefore considered to be negligible.

Statistical analysis of the data

Pearson's correlation coefficients were calculated to assess the association between the hard and soft tissue measurements. The significance level of $P < 0.05$ was selected.

Stepwise multiple regression analysis was used to determine the best combination of variables that predict lip changes during orthodontic treatment at a significance level of $P < 0.05$ (JMP; SAS Institute Inc., Cary, North Carolina, USA).

Results

The means and standard deviations of the pre- and post-treatment measurements and the changes between them are shown in Table 3. Table 4 shows the correlations between the changes in lip position and the hard and pre-treatment soft tissue variables in the horizontal and vertical planes.

Horizontal lip changes

Pearson's correlation showed significant positive correlations between the horizontal changes in upper lip position and the horizontal changes of maxillary incisor tip position ($R = 0.40$), maxillary incisor cervical point ($R = 0.52$), mandibular incisor cervical point ($R = 0.40$), and vertical changes of the mandibular incisor cervical point ($R = 0.40$). There were significant positive correlations between the horizontal changes of lower lip position and those of maxillary incisor tip position ($R = 0.47$), mandibular incisor tip position ($R = 0.38$), and mandibular incisor cervical point ($R = 0.41$).

Stepwise multiple regression analysis revealed that every 1 mm of retraction of the maxillary incisor cervical point produced a 0.45 mm retraction of the upper lip. Horizontal upper lip position could be explained by the position of the maxillary incisor cervical point and the occlusal plane to SN with a 54 per cent contribution ratio (Table 5). None of the other single hard or soft tissue variables produced good correlations or predicable regression models. The contribution ratios of ANB and SNA changes were only 4 and 3 per cent, respectively. All other variables showed lower ratios. However, the horizontal upper lip position could be explained by all variables with almost a 100 per cent contribution ratio.

Every 1 mm of maxillary incisor tip retraction would produce a 0.38 mm retraction of the lower lip. Horizontal lower lip position could be explained by the position of the maxillary incisor tip, the pre-treatment E-line to Li, and interlabial gap with a 51 per cent contribution ratio (Table 5). None of the other single hard or soft tissue variables produced good correlations or predicable regression models. The contribution ratios of the horizontal change of the mandibular incisor cervical point and the vertical change of the mandibular incisor tip were only 8 and 3 per cent, respectively. All other variables showed lower ratios. However, horizontal lower lip position could be explained by all variables with a 96 per cent contribution ratio.

Vertical lip changes

Pearson's correlation indicated a significant positive correlation between the vertical change of upper lip position and those of maxillary incisor tip position ($R = 0.44$), mandibular incisor tip position ($R = 0.43$), and mandibular incisor cervical point ($R = 0.46$). There was also a significant positive correlation between the vertical change of lower lip position and the horizontal changes of the maxillary incisor cervical point ($R = 0.42$), the vertical changes of the maxillary incisor tip position ($R = 0.60$), and the maxillary incisor cervical point ($R = 0.49$).

Table 3 Mean and standard deviations (SDs) of the horizontal (H) and vertical (V) pre- and post-treatment measurements and the treatment changes.

	Pre-treatment		Post-treatment		Changes				
Variables	Mean	SD	Mean	SD	Mean	SD	Min	Max	
Hard tissues									
H-tU1 (mm)	76.43	6.00	68.65	6.10	7.79	2.29	3.00	11.50	***
H-cU1 (mm)	73.74	5.13	70.11	5.04	3.63	1.18	0.70	6.00	***
H-tL1 (mm)	68.87	6.12	65.58	6.61	3.29	2.70	0.50	9.10	***
H-cL1 (mm)	64.18	6.31	61.55	6.33	2.62	1.96	−1.20	6.60	***
V-tU1 (mm)	81.67	4.06	81.97	3.61	−0.30	2.47	−5.50	5.60	
V-cU1 (mm)	68.38	3.98	68.63	3.62	−0.25	2.26	−4.50	4.80	
V-tL1 (mm)	77.61	3.84	79.19	3.94	−1.58	2.64	−7.30	3.40	*
V-cL1 (mm)	87.01	3.98	88.55	4.17	−1.54	2.39	−7.40	2.70	*
LFH (mm)	70.83	5.26	71.20	5.37	−0.37	1.95	−5.00	4.70	
U1–SN-7 (°)	117.08	5.94	99.44	8.67	17.64	8.51	2.00	34.00	***
L1–Md (°)	99.97	5.09	98.23	5.15	1.74	5.85	−12.40	14.50	*
SNA (°)	81.04	3.64	80.32	3.59	−0.73	1.05	−3.30	1.10	*
SNB (°)	74.49	3.66	73.82	3.82	−0.68	0.94	−3.00	0.80	*
ANB (°)	6.55	2.18	6.51	2.19	−0.03	1.19	−3.00	2.20	
Mandibular plane (°)	40.50	6.60	40.96	6.42	0.50	2.03	−3.50	7.00	
Ramus plane (°)	97.48	5.23	97.61	4.61	0.13	3.65	−7.30	6.60	
Occlusal plane (°)	19.10	4.77	24.16	5.45	5.06	2.72	−1.00	11.50	***
Soft tissues									
H-U-lip (mm)	87.68	5.75	84.45	5.61	3.24	1.35	1.30	6.50	***
H-L-lip (mm)	82.49	6.33	79.02	6.16	3.48	1.71	−0.60	6.40	***
V-U-lip (mm)	71.90	4.10	72.16	3.76	−0.25	2.94	−6.50	5.50	
V-L-lip (mm)	87.31	4.98	87.38	3.90	−0.07	2.85	−5.00	10.50	
Nasolabial angle (°)	93.97	10.64	100.11	10.39	9.42	7.19	−5.50	25.00	***
Labiomental angle (°)	127.42	18.74	131.17	13.91	3.74	12.05	−19.00	39.00	
E–Ls (mm)	3.81	1.93	0.98	2.01	2.84	1.31	0.70	6.70	***
E–Li (mm)	4.89	2.92	2.08	2.59	2.80	1.90	−1.00	6.90	***
cU thickness (mm)	13.18	1.31	13.70	1.61	−0.52	1.15	−2.70	1.70	
Ls thickness (mm)	11.68	1.97	13.14	1.77	−1.45	2.05	−6.20	2.60	**
cL thickness (mm)	17.82	2.47	16.62	1.91	1.20	1.88	−3.20	5.50	*
Li thickness (mm)	18.12	2.56	16.09	2.12	2.02	2.47	−3.20	6.80	**
Chin thickness (mm)	12.52	2.75	13.11	2.44	−0.59	1.90	−5.50	5.00	*
Sub–St (mm)	25.98	2.49	25.61	2.27	0.38	1.60	−2.50	4.00	
St–Me (mm)	46.85	5.90	47.49	5.91	−0.64	−2.37	−6.00	6.00	
Interlabial gap (mm)	1.25	2.29	0.21	0.81	1.04	2.36	−3.30	10.00	*

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Stepwise multiple regression analysis revealed that every 1 mm of maxillary incisor tip intrusion would produce 0.54 mm upward movement of the upper lip. Vertical upper lip position could be explained by the position of the maxillary incisor tip, the pre-treatment interlabial gap, and nasolabial angle with a 62 per cent contribution ratio (Table 5).

Every 1 mm of maxillary incisor tip intrusion would produce 0.66 mm upward movement of the lower lip. Vertical lower lip position could be explained by the position of the maxillary incisor tip, the pre-treatment interlabial gap, and stomion to soft tissue menton distance with a 76 per cent contribution ratio (Table 5).

Discussion

The decision concerning extraction or non-extraction of the mandibular first premolars in Class II division 1 cases is mainly based on the aesthetic treatment goal determined by the maxillary incisor position, achievement of functional occlusion, and the stability of the dentition. In this study, patients were included who had extraction of two maxillary or all four premolars. The amount of maxillary incisor retraction and the post-treatment maxillary incisor position to the cranium were not significantly different between the two groups. Moreover, the values found were within the normal range in both groups.

Since this study focused on the effects of the dental changes of the anterior teeth and the initial soft tissue profile variables on lip changes, the skeletal variables were not included as criteria. The ratio of the amount of retraction of the anterior teeth to lip movement is a key factor for the prediction of the soft tissue profile after orthodontic treatment. This ratio has been evaluated in subjects with different morphological, gender, and racial backgrounds using various reference points of the maxillary and mandibular incisors. Upper lip retraction was not significantly correlated

Table 4 Correlations between the changes of lip position and the hard and pre-treatment soft tissue variables in the horizontal (H) and vertical (V) planes.

	H-U-lip (mm)	H-L-lip (mm)	V-U-lip (mm)	V-L-lip (mm)
Hard tissues				
H-tU1 (mm)	0.40*	0.47**	−0.17	0.24
H-cU1 (mm)	0.52**	0.17	0.02	0.42*
H-tL1 (mm)	0.22	0.38*	−0.16	0.20
H-cL1 (mm)	0.40*	0.41*	−0.29	0.03
V-tU1 (mm)	−0.05	0.11	0.44**	0.60***
V-cU1 (mm)	−0.18	−0.11	0.27	0.49**
V-tL1 (mm)	−0.33	−0.17	0.43*	0.29
V-cL1 (mm)	−0.40*	−0.10	0.46**	0.26
U1–SN-7 (°)	−0.15	−0.37*	−0.10	−0.01
L1–Md (°)	−0.08	−0.09	0.04	−0.11
SNA (°)	−0.26	−0.04	−0.04	−0.11
SNB (°)	−0.30	−0.34	0.26	0.05
ANB (°)	0.00	0.22	−0.24	−0.12
Mandibular plane (°)	0.19	0.33	−0.28	−0.41*
Ramus plane (°)	0.01	0.10	0.23	0.12
Occlusal plane (°)	0.61***	0.10	−0.54**	0.05
Soft tissues				
Nasolabial angle (°)	0.00	0.21	0.41*	−0.07
Labiomental angle (°)	−0.27	0.06	0.21	0.10
E–Ls (mm)	0.12	0.41*	0.07	−0.03
E–Li (mm)	0.15	0.45*	−0.06	0.24
cU thickness (mm)	0.02	0.11	−0.15	−0.18
Ls thickness (mm)	0.26	−0.02	−0.46**	−0.19
cL thickness (mm)	−0.19	0.36*	0.26	−0.22
Li thickness (mm)	0.32	0.26	−0.02	0.31
Chin thickness (mm)	−0.05	−0.04	0.34*	−0.13
Sub–St (mm)	−0.09	0.18	0.23*	0.40*
St–Me (mm)	−0.09	0.17	−0.16	0.37*
Interlabial gap (mm)	0.44**	−0.25	−0.58***	0.58***

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 5 Stepwise multiple regression models for the horizontal (H) and vertical (V) measurements of the hard and soft tissue variables.

Dependent variables	R^2	Prediction equation			
		Constant	First	Second	Third
H-U-lip	0.54	0.32	0.26 (occlusal plane–SN)	0.45 (H-cU1)	
H-L-lip	0.51	0.07	0.38 (H-tU1)	−0.33 (pre-interlabial gap)	0.18 (pre-E line–Li)
V-U-lip	0.62	−6.54	−0.70 (pre-interlabial gap)	0.54 (V-tU1)	0.08 (pre-nasolabial angle)
V-L-lip	0.76	−7.37	0.66 (V-tU1)	0.64 (pre-interlabial gap)	0.14 (pre-St–Me)

Predictive equations: Y (dependent variable) = constant + (first) + (second) + (third). Independent variables for anterior teeth retraction: H-tU1, H-cU1, H-tL1, H-cL1, V-tU1, V-cU1, V-tL1, V-cL1, U1–SN-7, and L1–Md. Independent variables for skeletal changes: SNA, SNB, ANB, mandibular plane–SN, ramus plane–SN, and occlusal plane–SN. Independent variables for pre-treatment soft tissue: LFH, E–Ls, E–Li, cU thickness, Ls thickness, cL thickness, Li thickness, chin thickness, Sub–St, St–Me, interlabial gap, nasolabial angle, and labiomental angle. *R*, multiple correlation coefficient.

with incisor tip position but with the cervical point of the maxillary incisor. Ramos *et al.* (2005) reported that upper lip retraction is significantly correlated with maxillary incisor retraction, measured at the cervical point. The incisal edge or the most anterior point of the incisor has been used as the most common landmark. However, previous studies (Rudee, 1964; Talass *et al.*, 1987; Ramos *et al.*, 2005) revealed that the correlation coefficients using this point have a weaker contribution ratio for the upper lip. The ratio of maxillary incisor retraction to upper lip retraction was 2.22:1, although the contribution ratio of this parameter was 28 per cent in the present study. Talass *et al.* (1987) attributed upper lip change at labrale superious to lip thickness and dental variables ($R = 0.69$). Moreover, Stalpers *et al.* (2007) found that overjet reduction and initial upper lip thickness could explain 15 per cent of the variation in upper lip position. Therefore, the contribution ratios of the parameters predicting upper lip position in previous investigations

were relatively low. Considering that the contribution ratios using stepwise multiple regression models were 54 per cent for the upper lip and 51 per cent for the lower lip in the present study, it was difficult to predict the post-treatment position of the upper and lower lip with confidence using a limited number of parameters. On the other hand, upper and lower lip positions could be explained using all the hard and soft tissue variables utilized in the present study and which reached a greater than 96 per cent level of confidence.

A previous study investigated bimaxillary dentoalveolar protrusion subjects (Yasutomi *et al.*, 2006). The ratio of maxillary incisor retraction to upper lip retraction was 1.85:1 (R^2 = 0.31), while retraction in Class II division 1 cases was 2.22:1 as shown in the present study. The ratio for the lower lip was 1.32:1 in bimaxillary protrusion cases, while it was 2.63 in the present study. This was 1.11:1–1.23:1 in Caucasians, in Class II division 1 cases. These varying ratios in Caucasians 2.24:1–2.93:1 for the upper lip were similar to those of Japanese Class II division 1 patients. A change in the upper lip of African Americans (1.75:1) was relatively larger than that in both Caucasians and Japanese. Therefore, pre-treatment morphology and ethnicity could affect the change in lip position relative to the amount of incisor retraction.

Interestingly, the vertical positions of the lips, especially the lower lip, were highly predictable based upon changes of the vertical positions of the maxillary incisor tip, the pre-treatment interlabial gap, and stomion to soft tissue menton distance. The maxillary incisor tip had the greatest contribution among all parameters employed in the present study. As shown in previous research (Rudee, 1964; Roos, 1977; Perkins and Staley, 1993; Caplan and Shivapuja, 1997), the horizontal position of the lower lip followed the movement of the mandibular incisors; however, the vertical lip positions could be primarily directed by the maxillary incisor tip but not the mandibular incisors based on present results.

The current study demonstrated the significant relationships between lip changes and orthodontic movement of the anterior teeth in conjunction with the initial soft tissue variables in both the horizontal and vertical planes. Considering the weak predictability in determining post-treatment upper and lower lip position, however, the results should be interpreted with caution. Moreover, to correctly predict post-treatment change, each subject must be carefully observed by evaluating the individual soft tissue patterns. Additional research on soft tissue adaptation to changes of the hard tissues in different dentofacial morphologies, such as Class II division 2 or Class III cases, would therefore appear to be warranted.

Conclusions

Based on the findings of the present study, the following conclusions were reached:

1. It is relatively difficult to predict lip position after retraction of the incisors using a limited number of hard and soft tissue parameters, such as the maxillary incisor cervical point. However, the horizontal positions of upper and lower lips can be predicted by utilizing the multiple parameters identified in this study.
2. The vertical positions of the lips could be explained by three parameters with a higher than 62 per cent confidence.
3. The amount of change in lip position after retraction of the anterior teeth may differ among different ethnicities, genders, and/or types of malocclusions.

The variables to predict both lip positions found in the present study may be beneficial for orthodontists for both making an accurate diagnosis and also for treatment planning.

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