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Pattern of lip retraction according to the presence of lip incompetence in patients with Class II malocclusion

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Objective: The aim of this retrospective study was to compare changes in hard tissue and soft tissue after the four first premolars were extracted with anterior teeth retraction according to the presence or absence of lip incompetence. **Methods:** Patients who underwent the four first premolars were extracted with anterior teeth retraction were divided into competent (n = 20) and incompetent lip (n = 20) groups. Cephalometric measurements for hard tissue and soft tissue changes were performed pre-treatment and post-treatment. **Results:** In the competent group, the upper and lower lips retreated by 2.88 mm and 4.28 mm, respectively, and in the incompetent group by 4.13 mm and 5.57 mm, respectively; the differences between the two groups were significant ($p < 0.05$). A strong positive correlation between retraction of the upper lip and upper incisors was observed in both groups ($p < 0.05$), whereas a correlation between retraction of the lower lip and lower incisors was only found in the incompetent group. A simple linear regression analysis showed that the pattern of lip retraction following the retraction of the anterior teeth was more predictable in the incompetent group than in the competent group. **Conclusions:** These findings suggest that the initial evaluation of lip incompetence in patients with skeletal Class II is essential for the accurate prediction of the soft tissue changes following retraction of the anterior teeth in premolar extraction treatment. Therefore, sufficient explanation should be provided during patient consultations.

Key words: Incompetence, Protrusion, Retraction, Soft tissue

INTRODUCTION

Orthodontic treatment aims not only to merely relocate the maxillomandibular dentition but also improve facial esthetics. Therefore, orthodontists should be able to predict the pattern of changes in the relationship between teeth and facial soft tissues when establishing a diagnosis and treatment plan.[1]

Numerous studies, which were conducted on the changes in the facial soft tissues attributed to orthodontic treatment, can help clinicians predict treatment outcomes. However, the association between hard and soft tissues remains controversial. Caplan and Shivapuja[2] reported that when the anterior teeth of adult patients with bimaxillary protrusion were retracted, the ratio of anterior teeth retraction to lip retraction were 1.75:1 and 1.2:1 in maxilla and mandibular, respectively. Sohn and Park[3] reported that the ratios of anterior teeth retraction to the lip retraction were 2.84:1 and 1.45:1 in maxilla and mandibular, respectively. However, some studies have found no significant association between the changes in dentition and soft tissue profile changes.[4,5] A systematic review implied that soft tissue changes were negligible, whereas individual variations in the response were large.[6]

Burstone[7] stated that one of the major problems in the creation of orthodontic treatment plans is determining the anterior-posterior positioning of the anterior teeth. It is also important to consider the shape of the surrounding soft tissues and position of the lips. Even young edentulous patients who lacked tooth support experienced a small amount of posterior lip compression. This is because even without the support of teeth,

a protruding look remains in cases of lip are fullness. Therefore, when establishing the location of the anterior teeth and formulating a treatment plan, the presence or absence of lip incompetence should be considered.

Lip incompetence has various causes, including imbalance of the maxillofacial structure, lip strain, short upper lip length, and increased anterior facial height.[8] Nevertheless, large retraction of the anterior teeth does not necessarily result in large posterior movement of the lips. Several studies have examined the changes in soft tissues following the retraction of the anterior teeth during orthodontic treatment in extraction cases. However, few studies have assessed the relationship between lip incompetence and patterns of lip retraction.

The aim of the present study was to 1) compare changes in hard tissue and soft tissue after the four first premolars were extracted with anterior teeth retraction according to the presence or absence of lip incompetence and 2) examine the correlation between them. We hypothesized that there would be no difference between the presence and absence of lip incompetence with respect to the soft tissue changes.

MATERIALS AND METHODS

Participants

Clinical records of patients treated with a fixed appliance in the Department of Orthodontics, Yonsei University Dental Hospital, Seoul, Korea, between August 2009 and May 2013 were screened. The inclusion criteria were: 1) female sex, 2) adult patients (aged > 17 years) with pre-treatment and post-treatment lateral cephalograms, 3) underwent extraction of the four first premo-
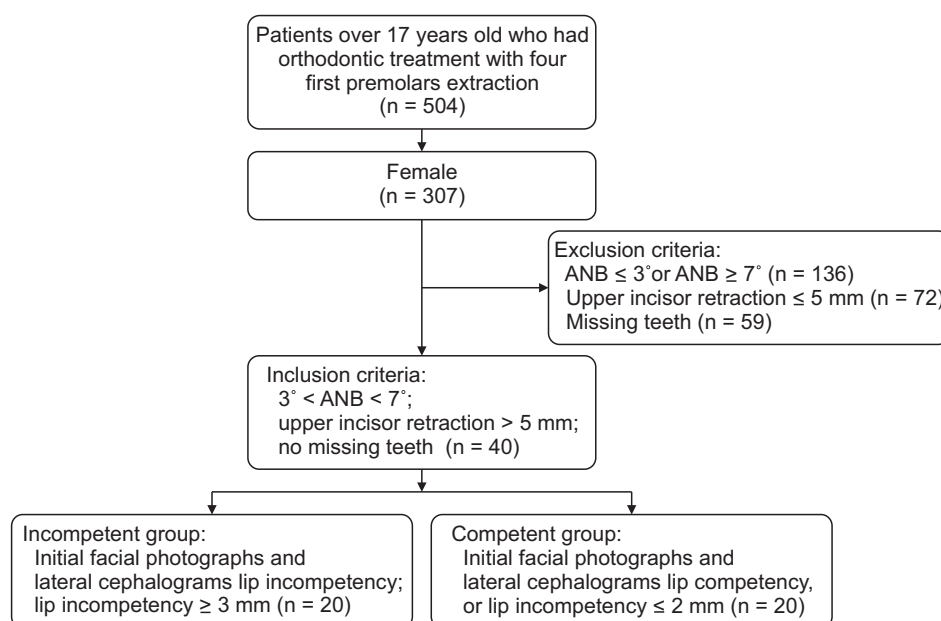

Figure 1. Flow diagram of patient selection. ANB, A point-nasion-B point.

lars to relieve lip protrusion, 4) skeletal Class II malocclusion (3.0° < A point-nasion-B point [ANB] < 7.0°), 5) > 5 mm retraction of the upper incisor edge, and 6) no missing teeth. The inclusion and exclusion criteria are shown in Figure 1.

Patients who met these criteria were assigned into two groups based on the presence or absence of lip incompetence. The presence of lip incompetence was defined as: 1) lip incompetence was shown in initial facial photographs at rest and lateral cephalogram, and 2) the amount of lip incompetence was equal to or greater than 3 mm on lateral cephalometric tracing.[9] The ab-

Table 1. Patient demographics

Variable	Competent group (n = 20)	Incompetent group (n = 20)	*p*-value
Female sex	20	20	
Age (yr)	27.57 ± 7.84	27.57 ± 6.99	NS*
Treatment duration (mo)	32.15 ± 6.23	34.00 ± 6.77	NS†

NS, not significant.
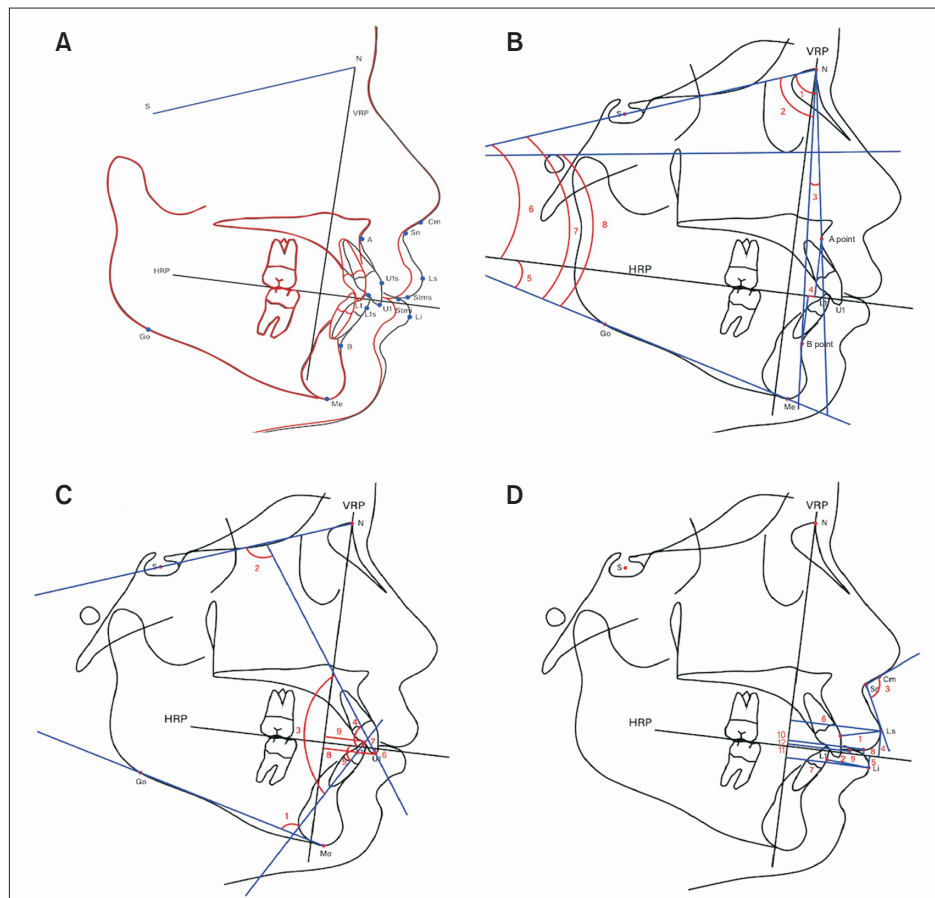*Wilcoxon signed-rank test. †Paired *t*-test.

Figure 2. Cephalometric landmarks and reference planes. **A**, Reference planes for treatment changes. **B**, Skeletal measurements. 1, SNA (deg); 2, SNB (deg); 3, ANB (deg) 4, Wits appraisal, AO-BO (mm); 5, Occlusal plane to GoMe (deg); 6, Occlusal plane to SN (deg); 7, SN-GoMe (deg); 8, FMA (deg). **C**, 1, IMPA (deg); 2, U1 to SN (deg); 3, Interincisal angle (deg); 4, U1 to HRP (deg); 5, L1 to HRP (deg); 6, U1 to HRP (mm); 7, L1 to HRP (mm); 8, U1 to VRP (mm); 9, L1 to VRP (mm). **D**, 1, Upper lip thickness; 2, Lower lip thickness; 3, Nasolabial angle (deg); 4, Ls to HRP (mm); 5, Li to HRP (mm); 6, Ls to VRP (mm); 7, Li to VRP (mm); 8, Stms to HRP (mm); 9, Stmi to HRP (mm); 10, Stms to VRP (mm); 11, Stmi to VRP (mm); 12, Stms to Stmi (mm).
S, sella; N, nasion; A, point A; B, point B; Go, gonion; Me, menton; U1s, upper central incisor surface; L1s, lower central incisor surface; U1, upper central incisor edge; L1, lower central incisor edge; Sn, subnasale; Cm, columella; Ls, labrale superioris; Li, labrale inferioris; Stms, stomion superius; Stmi, stomion inferius; HRP, horizontal reference plane; VRP, vertical reference plane; SNA, sella-nasion-A point; SNB, sella-nasion-B point; ANB, A point-nasion-B point; FMA, Frankfort-mandibular plane angle; IMPA, incisor-mandibular plane angle.

Table 2. Comparison of the skeletal changes between the competent and incompetent groups

Variable	T1 Competent group	T1 Incompetent group	T1 p-value	T2 Competent group	T2 Incompetent group	T2 p-value	T2-T1 Competent group	T2-T1 p-value	T2-T1 Incompetent group	T2-T1 p-value	Intergroup comparison, p-value
Skeletal											
SNA (°)	82.11 ± 3.55	82.48 ± 3.27	0.732	80.74 ± 3.79	81.98 ± 3.34	0.280	−1.37 ± 1.70	0.002**,c	−0.50 ± 1.01	0.039*,c	0.059
SNB (°)	76.34 ± 3.19	76.41 ± 2.98	0.945	76.11 ± 3.45	76.34 ± 3.11	0.823	−0.24 ± 1.08	0.339	−0.07 ± 1.05	0.764	0.904
ANB (°)	5.76 ± 1.63	6.07 ± 1.53	0.787	4.53 ± 1.76	5.60 ± 2.15	0.094	−1.23 ± 1.69	0.004**,c	−0.47 ± 1.21	0.108	0.110
Wits appraisal (mm)	1.56 ± 1.86	1.21 ± 3.47	0.693	−0.63 ± 2.28	−0.12 ± 3.27	0.576	−2.18 ± 2.56	0.001**,c	−1.33 ± 2.61	0.034*,c	0.303
Occlusal plane to GoMe (°)	17.89 ± 3.59	19.81 ± 2.93	0.072	15.14 ± 4.30	17.59 ± 3.08	0.063	−2.75 ± 3.35	0.002**,c	−2.21 ± 3.04	0.004**,c	0.659
SN-GoMe (°)	37.91 ± 4.65	40.16 ± 2.87	0.073	37.23 ± 5.10	39.78 ± 2.91	0.060	−0.68 ± 1.46	0.053	−0.38 ± 1.41	0.242	0.518
Occlusal plane to SN (°)	20.01 ± 4.74	20.35 ± 3.32	0.796	22.09 ± 4.07	21.77 ± 4.49	0.816	2.07 ± 3.14	0.008**,c	1.42 ± 3.38	0.076	0.738
FMA (°)	29.11 ± 5.79	32.23 ± 4.10	0.057	28.27 ± 5.73	32.29 ± 4.13	0.015*,a	−0.85 ± 2.88	0.204	0.06 ± 2.02	0.892	0.255
Dental											
IMPA (°)	101.45 ± 5.92	101.05 ± 5.15	0.725	94.92 ± 4.89	90.02 ± 6.66	0.012*,a	−6.53 ± 5.59	<0.001***,d	−11.03 ± 6.82	<0.001***,c	0.104
U1 to SN (°)	106.48 ± 7.98	109.42 ± 5.34	0.200	98.76 ± 6.89	97.41 ± 4.68	0.474	−7.72 ± 5.41	<0.001***,c	−12.00 ± 5.65	<0.001***,c	0.126
Interincisal angle (°)	110.08 ± 20.67	109.39 ± 6.13	0.247	129.12 ± 7.52	132.64 ± 7.97	0.159	19.04 ± 20.75	<0.001***,d	23.25 ± 7.89	<0.001***,c	0.402
U1 to HRP (°)	53.50 ± 4.99	50.23 ± 3.83	0.877	60.80 ± 5.12	61.90 ± 5.04	0.296	7.30 ± 5.34	<0.001***,c	11.67 ± 5.76	<0.001***,c	0.910
L1 to HRP (°)	60.69 ± 5.33	59.16 ± 5.22	0.430	68.32 ± 5.77	70.74 ± 7.96	0.993	7.63 ± 6.81	<0.001***,c	11.58 ± 7.35	<0.001***,c	0.993
U1 to HRP (mm)	1.14 ± 0.69	0.87 ± 0.68	0.433	1.63 ± 1.06	2.15 ± 1.50	0.209	0.49 ± 1.00	0.043*,c	1.28 ± 1.59	0.002**,d	0.065
L1 to HRP (mm)	1.08 ± 0.69	0.83 ± 0.69	0.455	1.24 ± 0.99	1.75 ± 1.50	0.209	0.31 ± 1.47	0.896	1.12 ± 1.91	0.029*,d	0.142
U1 to VRP (mm)	25.28 ± 5.95	28.04 ± 4.78	0.120	17.49 ± 6.04	19.33 ± 4.93	0.298	−7.79 ± 1.48	<0.001***,c	−8.71 ± 1.67	<0.001***,d	0.072
L1 to VRP (mm)	19.16 ± 6.52	22.89 ± 5.52	0.058	13.12 ± 5.80	15.23 ± 4.53	0.207	−6.04 ± 1.68	<0.001***,c	−7.65 ± 2.47	<0.001***,d	0.074
Soft tissue											
Upper lip thickness (mm)	12.76 ± 2.07	12.30 ± 2.07	0.491	15.16 ± 2.42	14.17 ± 2.35	0.060	2.40 ± 2.20	<0.001***,c	1.87 ± 1.20	<0.001***,d	0.350
Lower lip thickness (mm)	15.60 ± 2.32	15.64 ± 1.72	0.946	15.84 ± 2.20	15.54 ± 1.65	0.583	0.25 ± 2.04	0.595	−0.10 ± 1.52	0.737	0.565
Nasolabial angle (°)	102.27 ± 9.91	93.22 ± 12.03	0.008**,b	113.42 ± 11.35	106.14 ± 11.95	0.028*,a	11.15 ± 8.99	<0.001***,c	12.91 ± 6.45	<0.001***,d	0.480
Ls to HRP (mm)	10.16 ± 2.71	12.65 ± 2.96	0.007**,a	8.62 ± 2.55	10.67 ± 2.80	0.020*,a	−1.54 ± 1.47	<0.001***,c	−1.98 ± 2.34	0.001**,a	0.482
Li to HRP (mm)	5.12 ± 2.13	6.97 ± 2.80	0.024*,a	5.49 ± 2.12	5.79 ± 2.37	0.676	0.37 ± 1.61	0.315	−1.17 ± 3.02	0.098	0.053

Table 2. Continued

Variable	T1			T2			T2-T1				
	Competent group	Incompetent group	p-value	Competent group	Incompetent group	p-value	Competent group	p-value	Incompetent group	p-value	Intergroup comparison, p-value
Ls to VRP (mm)	33.97 ± 6.22	37.31 ± 4.90	0.174	32.01 ± 6.20	33.18 ± 5.06	0.517	−2.88 ± 1.46	<0.001***,c	−4.13 ± 1.76	<0.001***,a	0.019*,a
Li to VRP (mm)	34.28 ± 6.51	37.56 ± 6.02	0.038*,b	30.00 ± 6.49	31.98 ± 5.44	0.321	−4.28 ± 1.60	<0.001***,c	−5.57 ± 2.23	<0.001***,d	0.030*,a
Stms to HRP (mm)	2.19 ± 1.56	4.24 ± 2.28	0.002**,a	1.94 ± 1.79	2.60 ± 1.96	0.314	−0.24 ± 1.16	0.364	−1.64 ± 2.36	0.011*,d	0.052
Stmi to HRP (mm)	1.95 ± 1.57	2.07 ± 1.25	0.583	1.78 ± 1.34	2.11 ± 1.79	0.883	−0.17 ± 1.15	0.525	0.04 ± 1.40	0.888	0.445
Stms to VRP (mm)	28.23 ± 8.25	32.23 ± 5.02	0.049	26.64 ± 6.33	27.49 ± 4.87	0.639	−1.59 ± 5.25	0.005**,d	−4.75 ± 1.57	<0.001***,a	0.002**,d
Stmi to VRP (mm)	27.48 ± 8.31	30.81 ± 5.70	0.152	24.90 ± 6.23	25.95 ± 5.12	0.561	−2.58 ± 5.08	0.002**,d	−4.85 ± 2.18	<0.001***,d	0.063
Stms to Stmi (mm)	0.33 ± 0.11	4.12 ± 1.57	<0.001***,b	0.28 ± 0.18	0.34 ± 0.25	0.416	−0.04 ± 0.19	0.953	−3.78 ± 1.54	<0.001***,d	<0.001***,d

Values are presented as mean ± standard deviation.
T1, pre-treatment; T2, post-treatment; S, sella; N, nasion; A, point A; B, point B; Go, gonion; Me, menton; FMA, Frankfort horizontal and mandibular planes; IMPA, incisor-mandibular plane angle; U1, upper central incisor edge; L1, lower central incisor edge; HRP, horizontal reference plane; VRP, vertical reference plane; Stms, stomion superius; Stmi, stomion inferius.
*p < 0.05; **p < 0.01; ***p < 0.001. aIndependent t-test. bMann–Whitney U test. cPaired t-test. dWilcoxon signed rank test. Type 1 error was corrected using Bonferroni correction.

sence of lip incompetence was defined as follows: lip competency was shown in initial facial photographs at rest and lateral cephalograms, or the amount of lip incompetence was equal to or less than 2 mm on lateral cephalometric tracing. At the end of orthodontic treatment, lip incompetence should be in the range of 0 ± 2 mm.

The competent group comprised 20 female patients (27.57 ± 7.84 years), with an average treatment time of 32.15 ± 6.23 months. The incompetent group comprised 20 female patients (27.57 ± 6.99 years), with an average treatment time of 34.00 ± 6.77 months (Table 1). The retraction duration of the competent and incompetent groups were 18.10 ± 2.83 months and 18.75 ± 2.51 months, respectively with no significant intergroup difference.

The waiver for informed consent was obtained by the Institutional Review Board of Yonsei Dental Hospital. This study conformed to the tenets of the Declaration of Helsinki on medical protocols and ethics and was approved by the institutional review board of the Yonsei University Dental Hospital (IRB 2-2020-0012).

Methods

The lateral cephalograms, pre-treatment and post-treatment (T1 and T2, respectively) were obtained using a Rayscan Alpha (Ray Co., Ltd., Hwaseong, Korea) in the natural head and relaxed lips position. The V-ceph program (Osstem Inc., Seoul, Korea) was used for digitalization of the cephalometric tracing and Adobe Illustrator 24.0 (Adobe System, San Jose, CA, USA) (Figure 2). Measurements and reference planes were set based on the analysis methods of Trisnawaty et al.[10] and Lee et al.[11] The sella-nasion (SN) superimposition method was used to align the pre- and post-treatment tracing. The occlusion plane at T1 was defined as the horizontal reference plane (HRP). The vertical reference plane (VRP) was set as the plane passing through the nasion point perpendicular to the HRP (Figure 2).

Reliability

All lateral cephalometric assessments and measurements were performed by a single investigator (MLF). After a two-week interval, 20 samples were randomly selected and retraced by the same examiner. The intraclass correlation coefficient was greater than 0.90, indicating a high reliability.

Statistical analysis

Using G*Power 3 (Dusseldorf, Germany), we determined a sample size of 20 patients in each group ($p < 0.05$, 80% power, 0.5 effect size). The independent t-test and Mann–Whitney U test were used to compare the differences in variables between T1 and T2, and

analyze treatment changes (T2–T1) between the two groups. And the paired *t*-test and Wilcoxon signed-rank test were performed to compare the differences in variables within the groups. To correct for excessive type 1 errors, Bonferroni correction was applied to compensate for multiple comparisons, resulting in a significance level of $p < 0.49$ (IBM SPSS Statistics Version 21). Pearson's correlation coefficients were calculated to identify the association between the lip profile changes and other variables. Multiple regression analysis was used to determine the variables that predicted soft tissue changes, using retraction of the upper and lower lips as a dependent variable.

RESULTS

Table 1 showed the demographic characteristics of the sample population. No significant differences in the age or treatment duration were observed between the competent and incompetent groups. The means and standard deviations for skeletal, dental, and soft tissue measurements in both groups at T1, T2, and T2–T1 are shown in Table 2. There was no significant difference in skeletal measurements and dental measurements between the two groups at T1, excluding the angle between the Frankfort horizontal and mandibular planes at T2. No statistically significant differences were found between the two groups in the skeletal changes after treatment (Table 2).

No significant intergroup difference in the extent of retraction and vertical movement of the upper and lower incisior was observed. The extent of retraction of the upper and lower incisors were -7.79 ± 1.48 mm and -6.04 ± 1.68 mm, respectively in the competent group ($p < 0.001$), and -8.71 ± 1.67 mm and -7.65 ± 2.47 mm, respectively in the incompetent group ($p < 0.001$).

The labrale superioris (Ls) and labrale inferioris (Li) moved more posteriorly and horizontally in the incompetent group compared to in the competent group ($p < 0.05$). In addition, the vertical movements of the stomion superius (Stms) and stomion inferius (Stmi) demonstrated no significant differences. However, a greater decrease in the Stms horizontal movement was observed following treatment in the incompetent group

compared to in the competent group ($p = 0.002$) (Table 2). The mean ratio of both, in the competent group, when the anterior teeth were retracted, the ratios of anterior teeth retraction to lip retraction were 2.70:1 and 1.42:1 in the maxilla and mandible, respectively in the competent group, and 2.11:1 and 1.37:1 in the maxilla and mandible, respectively in the incompetent group (Table 3).

The relationship between incisor and lip retraction is shown in Table 4. A strong positive correlation was observed between the posterior movement of the Ls (Ls to VRP) and upper central incisor retraction (U1 to VRP) ($p < 0.01$) in both groups, especially the incompetent group (r = 0.767). In contrast, a positive correlation between the posterior movement of the Li (Li to VRP) and the lower central incisor (L1 to VRP) was only observed in the incompetent group (r = 0.837; $p < 0.01$). Moreover, in the incompetent group the positive correlation was observed between the posterior movement of Ls with the change in the thickness of the upper lip.

Multiple regression analysis was performed to identify the variables that could significantly predict changes in the soft tissues of the lips. Retraction of the upper lip was mostly influenced by the retraction of the upper incisors In the competent group (competent group: β = 0.660; $p < 0.001$/incompetent group: β = 0.477; $p < 0.05$). However, the posterior movement of the Li was most influenced by the lower central incisor, which was only observed in the incompetent group (Table 5).

DISCUSSION

This study evaluated the change of lip-facial profile following the retraction of anterior teeth in skeletal Class II malocclusion, with the hypothesis that there was no difference in soft tissue changes between the presence or absence of lip incompetence. To avoid potential confounding effects influencing the changes in the lip

Table 3. Ratio of the amount of incisor retraction to lip retraction

Variable	Competent group	Incompetent group
U1:Ls	2.70:1	2.11:1
L1:Li	1.42:1	1.37:1

U1, upper central incisor; L1, lower central incisor; Ls, labrale superioris; Li, labrale inferioris.

Table 4. Pearson's correlation coefficients between the soft tissue and dental changes

Variable	Competent group	Incompetent group
Ls to VRP	U1 to VRP 0.579**	U1 to VRP 0.767**
	Upper lip thickness 0.010	Upper lip thickness 0.691*
Li to VRP	L1 to VRP 0.223	L1 to VRP 0.837**
	Lower lip thickness 0.332	Lower lip thickness 0.273

U1, upper central incisor; L1, lower central incisor; Ls, labrale superioris; Li, labrale inferioris; VRP, vertical reference plane.
*$p < 0.05$; **$p < 0.01$.

Table 5. Multiple regression models for the lips and anterior teeth of the competent and incompetent group

Variable		Competent group					Incompetent group				
Dependent	Independent	B	SE	β	t	p-value	B	SE	β	t	p-value
Ls to VRP	U1 to VRP	0.654	0.137	0.660	4.782	< 0.001***	0.503	0.223	0.477	2.258	0.042*
	L1 to VRP	0.089	0.157	0.102	0.563	0.583	0.046	0.137	0.065	0.337	0.742
	U1 to SN	−0.037	0.051	−0.136	−0.715	0.487	−0.018	0.062	−0.057	−0.287	0.779
	Upper lip thickness (initial)	0.165	0.283	0.235	0.585	0.566	0.242	0.231	0.285	1.046	0.310
	Lower lip thickness (initial)	−0.317	0.253	−0.503	−1.254	0.227	−0.152	0.278	−0.149	−0.548	0.591
	Stms to Stmi	0.203	1.108	0.031	0.183	0.858	0.136	0.176	0.120	0.777	0.451
Li to VRP	U1 to VRP	0.244	0.248	0.257	0.981	0.344	0.043	0.315	0.032	0.135	0.895
	L1 to VRP	0.301	0.232	0.363	1.294	0.218	0.555	0.194	0.617	2.859	0.013*
	U1 to SN	−0.083	0.076	−0.321	−1.090	0.296	−0.041	0.088	−0.105	−0.471	0.646
	Upper lip thickness (initial)	−0.032	0.281	−0.048	−0.114	0.910	−0.120	0.299	−0.111	−0.400	0.694
	Lower lip thickness (initial)	−0.096	0.251	−0.160	−0.382	0.707	−0.052	0.359	−0.040	−0.145	0.887
	Stms to Stmi	1.445	1.638	0.231	0.882	0.394	0.235	0.248	0.163	0.947	0.361

SE, standard error; Ls, labrale superioris; Li, labrale inferioris; U1, upper central incisor; L1, lower central incisor; VRP, vertical reference plane; S, sella; N, nasion; Stms, stomion superius; Stmi, stomion inferius.
*$p < 0.05$; ***$p < 0.001$.

facial profile, many factors were considered, such as dentofacial morphology, age, sex, and soft tissue thickness (Aniruddh et al.[12]). Additionally, lip growth reportedly continues until around 17 years of age[13]; thus, many individuals with lip incompetence at 13 years may develop spontaneous lips-together posture at rest by 17 years of age. Therefore, this study included adult female patients aged > 17 years with no significant between-group differences in the dentofacial morphology or soft tissue thickness (Tables 1 and 2).

Various superimposition methods have been developed using different reference planes.[14,15] Among them, Bjork's method is regarded as highly reproducible. However, Bjork's method is incompatible with computer-based cephalometrics. The SN superimposition method has been widely used as a computer-compatible superimposition method. Little or no difference in the accuracy and reproducibility was observed in subsequent studies on the differences between the Bjork's and SN superimposition methods.[14,16]

An occlusal plane with good reproducibility was set as the horizontal reference line, whereas the VRP was set as the plane passing through the nasion and perpendicular to the HRP. In clinical practice, a relaxed lip position is less reliable in cephalogram testing, unless electromyography is used. Nevertheless, the use of such positions should not be avoided if clinically helpful information can be obtained.[7]

Many studies have reported the ratio of lip retraction to the corresponding retraction of the anterior teeth, and most have reported lower lip retraction to be more sensitive than incisor retraction.[2,17,18] Considering the reason for the poor response of the posterior movement of the upper lip to incisor retraction, Burstone[7] mentioned that in evaluating the soft tissue profile, individual variations in the thickness and length should be considered. Hershey[4] reported that the original force per unit area exerted by the lips, variations in the soft tissue, and changes in the intercanine width, which may alter the tension of the buccinator mechanism, should be considered. In the present study, both groups revealed that the movement of the lower lip was more sensitive than that of the upper lip (Table 2). In both groups, the upper and lower lips were retracted along with tooth movement, but the movement was significantly greater in the incompetent group than in the competent group. There was a significant difference in the horizontal movement of the soft tissue point Stms ($p < 0.01$); however, no significant difference was found in the soft tissue point Stmi between groups (Tables 2 and 3).

In our study, the upper lip thickness significantly increased after treatment in both groups (Table 2). There was no significant correlation between the extent of movement of the upper and lower anterior teeth (Table

3). The amount of change in the thickness of the upper lip was similar to that reported in previous studies.[19,20] Increased lip thickness may have been caused by lip eversion.

In this study, a strong and significant positive correlation was observed between the upper lip movement and that movement of the upper anterior teeth, in which Pearson's correlation coefficient was 0.579 in the competent group and 0.767 in the incompetent group. Whereas, the positive correlation between the movement of the lower lip and that of the lower incisor movement was only observed significantly in the incompetent group with r = 0.837 (Table 4).

Multiple regression analysis was conducted to determine the predictability of lip changes after retraction of the anterior teeth accompanied by premolar extraction.[18,19] A positive correlation between the Li posterior movement and the lower incisor was observed only in the incompetent group. Multiple regression analysis demonstrated that predicting the soft tissue changes was challenging even in the competent group. These results indicated that the soft tissue response to an increase in the amount of lower incisor retraction in the competent group was not proportional to the amount of lower incisor retraction. The coefficient of determination for predicting the upper and lower lip based on the retraction of upper and lower incisors respectively were 0.59 and 0.70 in the incompetent group, showing a moderate to high predictability of the lip-profile change, which was higher than that in the competent group (Figure 3A and B). Therefore, the retraction pattern of the lip-facial profile following the retraction of the anterior teeth seems to be more predictable in the incompetent group than in the competent group.

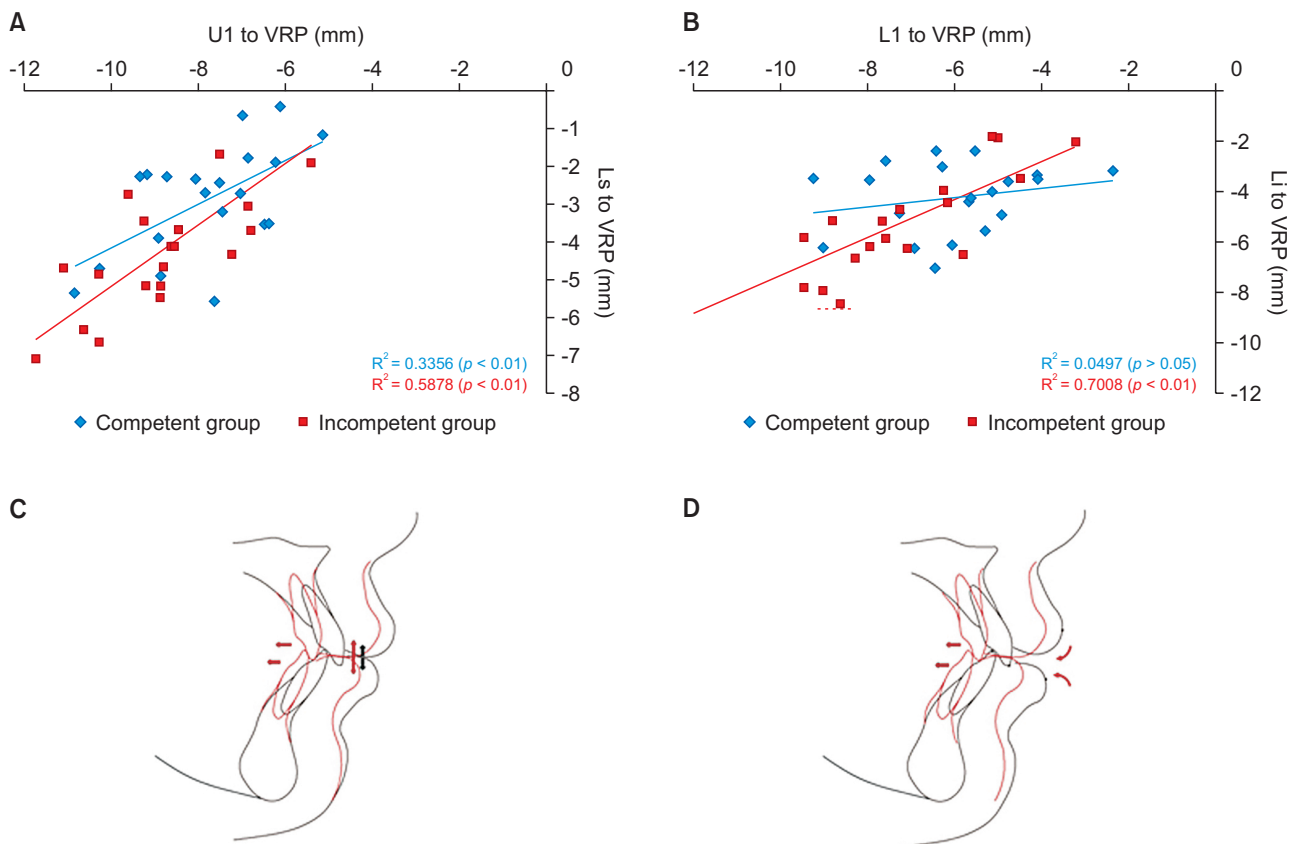The difference between the two groups may not be attributed to the effect of the initial lip thickness but

Figure 3. Scatter plot of the hard tissue versus soft tissue changes in both group and comparison of treatment changes between the two groups. **A**, U1 to VRP versus Ls to VRP in both groups. **B**, L1 to VRP versus Li to VRP in both groups. **C**, Lip retraction pattern in the competent group (vertical arrows indicate mutual lip pressure that may resist posterior displacement of the lips according to incisor retraction, indicated by horizontal arrows). **D**, Lip retraction pattern in the incompetent group (curved arrows represent free lip retraction without resistance).
U1, upper central incisor edge; VRP, vertical reference plane; Ls, labrale superioris; L1, lower central incisor edge; Li, labrale inferioris.

to interference between the upper and lower lips in the competent group.[7] In the competent group, inherent contact between the upper and lower lips may resist lingual displacement of the lips due to retraction of the incisors. In contrast, subsequent retraction may have occurred without resistance in the incompetent group (Figure 3C and D).

Bloom[20] indicated that it is possible to use methods such as regression analysis or scatter plots, because a high correlation exists between the amount of change in the hard and soft tissues. Therefore, simple regression analysis was used to determine the measure of hard tissue changes that had the most influence on the soft tissue changes. The intergroup difference in the pattern of lip retraction following to the retraction of anterior teeth and the difference in the regression analysis indicated that it is essential to evaluate the initial presence of lip incompetence. Changes in the lip facial profile caused by hard-tissue reconstruction were limited and less predictable in the competent group than in the incompetent group. Thus, sufficient explanation should be provided to patients during consultation.

This study has the following implications for developing treatment plans for patients who are dissatisfied with soft tissue esthetics: 1) Since the factors associated with good esthetic outcomes vary among individuals, this study revealed that little or no posterior lip movement is achieved after posterior retraction of the anterior teeth, after the extraction of the premolars in patients with lip competence, through accurate goal setting and reference to previous studies. Therefore, our findings would assist in determining whether extraction is necessary for orthodontic treatment in relieving lip protrusion. 2) In patients with lip incompetence, extraction treatment seems to be beneficial in terms of lip-facial profile improvement, in which a significant posterior movement of the lips follows the retraction of anterior teeth, enabling the prediction of whether esthetic improvement of facial appearance would be significant. To our knowledge, this is the first clinical study to highlight the importance of evaluating lip incompetence.

However, this study has a few limitations that should be considered when applying the results. This study analyzed changes in the teeth and lips in two dimensions, using lateral cephalograms, but more progressive studies recommend the use of three-dimensional analysis tools.

CONCLUSIONS

Orthodontic treatment with premolar extraction in skeletal Class II patients brought greater retraction of the upper and lower lips in incompetent group than that in the competent group ($p < 0.05$). And significantly positive correlation relationship between the amount of

upper incisor and lip retraction. These findings suggest that the initial evaluation of lip incompetence is essential for the accurate prediction of soft tissue change following to the retraction of the anterior teeth in premolar extraction cases. The extent of the soft tissue changes was limited in the competent group; therefore, sufficient explanation should be provided during patient consultations.

AUTHOR CONTRIBUTIONS

Conceptualization: KJL. Data curation: MLF. Formal analysis: MLF. Funding acquisition: KJL. Investigation: KJL, MLF. Methodology: MLF, KJL. Project administration: KJL. Resources: KJL, YJC. Software: MLF, KJL. Supervision: KJL. Validation: YJC, SHC. Visualization: MLF. Writing–original draft: MLF. Writing–review & editing: KJL, SHC.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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