Soft tissue changes in Class II Division 1 malocclusion after camouflage treatment using maximum anchorage

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ABSTRACT

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The objective of the present study was to analyze soft tissue responses based on the degree of anterior retraction using maximum anchorage after extraction of maxillary and mandibular premolars for camouflage treatment in Korean Class II Division 1 malocclusion patients; and to identify the skeletal and dental variables that can predict such soft tissue responses.

57 participants were divided into two groups, a moderate retraction group (<8 mm) and a maximum retraction group (≥8.0 mm), based on the amount of maxillary incisor retraction from measurements of pre- and post-treatment lateral cephalograms. Skeletal, dental, and soft tissue changes from pre- to post-treatment were compared between the

two groups. Correlations between the soft tissue component of the upper and lower lips and hard tissue were examined and simple linear regression was used to determine the variables influencing soft tissue changes in the moderate and maximum retraction groups.

Due to changes in the maxillary and mandibular incisors, the incisal tips of the maxilla and mandible retracted by 5.3 mm and 4.4 mm, respectively, in the moderate group and 9.9 mm and 6.9 mm, respectively, in the maximum group, indicating statistically significant intergroup differences ($P < 0.001$). Upper (Ls) and lower (Li) lip retractions of 2.3 mm and 3.0 mm, respectively, were detected in the moderate group and 4.0 mm and 5.3 mm in the maximum group, also indicating statistically significant intergroup differences.

In the moderate group ($P < 0.001$), horizontal movement of the Ls was most strongly correlated with the movement of the cervical point of the maxillary incisor ($R^2=0.64$), and its influence ($\beta=0.942$) also appeared to be the highest. Horizontal movement of the Li was most highly correlated with the cervical point of the mandibular incisor ($R^2=0.79$), and the influences of the B point ($\beta=0.837$) and the cervical point of the mandibular incisor ($\beta=0.830$) appeared to be high. In the maximum group, no variables showed significant correlations or influence on the changes in the upper lip (Ls and Stms), so prediction was difficult. Posterior movement of the Li was highly correlated with the mandibular incisor tip ($R^2=0.51$) and cervical point ($R^2=0.46$), while the influences of the cervical point of the maxillary incisor ($\beta=0.503$) and cervical point of the mandibular

incisor (β=0.467) were highest, but these effects were weaker in the maximum group than in the moderate group.

For retraction of anterior teeth using skeletal anchorage, cervical point movement is necessary to increase lip retraction. However, periodic evaluation of the lip profile is needed during maximum retraction of anterior teeth due to the limitations in predicting soft tissue responses.

Key words : soft tissue changes, Class II Division 1 malocclusion, retraction of anterior teeth, camouflage treatment, maximum anchorage

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I. INTRODUCTION

The goals of orthodontic treatment are providing ideal mastication function and aesthetic improvements to facial and dental features. To achieve these goals, it is necessary to create a balance between soft tissues and skeletal elements, including the nose, the lips, and the jaw [1], and it is important to consider variability among individuals. [2]

With increasing public interest in facial aesthetics, there is an emphasis on establishing treatment goals based on soft tissue analysis. Holdaway [3, 4] reported that in the diagnosis of orthodontic treatment, both hard and soft tissue analysis are important, and Ackerman [5] emphasized that soft tissue analysis is a critical step during orthodontic decision making. Accordingly, various treatment methods for maximizing teeth alignment and facial improvements have recently been introduced. [6, 7]

Among the facial soft tissue changes resulting from orthodontic treatment, there is particular interest in changes in the position and the contour of the lips, [8] and various methods for predicting post-treatment soft tissue changes to establish a diagnosis and treatment plan have been reported. [9-12] These methods are used to acquire the basic information necessary to establish a goal-oriented treatment plan. Clinical studies have been conducted primarily on soft tissues changes in the upper and lower lips in patients treated with premolar extractions. [11, 13-20]

Studies in Asian populations that underwent premolar extraction found that, the ratios of upper and lower lip movements to the extent of anterior teeth retraction in Japanese patients with bimaxillary protrusion were 1:0.54 and 1:0.76, respectively. [21] In adult Japanese patients with Class II malocclusion, the ratio of movement between the cervical point of the maxillary incisor and the upper lip during anterior retraction treatment is reported as 1:0.45, while the ratio of movement between the maxillary incisor tip and the lower lip is reported as 1:0.38, [11] demonstrating somewhat low levels of soft tissue changes. Chio et al. [9] reported that in adult female patients with Class II Division 1 malocclusion, the ratios of movement between the upper and lower lips to the extent of anterior teeth retraction are 1:0.45 and 1:2.08, respectively, and that horizontal movement of the pogonion, followed by posterior movement of the maxillary incisal edge, have the greatest influence on the amount of posterior movement in the upper lip, indicating that movement via the jawbone has a more direct influence than the teeth. As such, varying responses have been reported according to gender, dentofacial morphology (malocclusion type), and ethnicity.

Lip thickness can be a major variable that influences soft tissue changes. Holdaway [3] reported that a very thin or a very thick basic upper lip can influence lip changes. Oliver [22] reported a strong correlation between osseous and soft tissue changes in thin basic upper lips, along with a strong correlation between soft tissue change and anterior movement in patients with high lip strain. Park et al. [16] did not detect a statistically significant correlation between teeth and lip movements in groups that had thin or thick basic upper lips prior to treatment. Lee et al. [23] studied soft tissue thickness with respect to gender and found that since males have thicker soft tissue than females in different facial areas, there is a gender-based difference. Therefore, clinically, pre-treatment assessment of soft tissue thickness warrants consideration for predicting treatment outcomes.

With recent advances in maximum anchorage, such as miniscrews, a significant amount of posterior movement by anterior teeth has become possible, which has expanded the boundaries of camouflage treatments for skeletal malocclusion. Orthodontic camouflage treatments using skeletal anchorage after extraction are widely used for patients with Class II Division 1 malocclusion showing anterior protrusion. When Class II malocclusion patients are treated with miniscrews for anchorage, the maxillary incisors show posterior retraction of 8.2 to 9.3 mm, [14, 24] and a range of tooth movement expanded in the envelope of discrepancy via improved tooth movement using traditional orthodontic treatments. However, unlike studies on dental changes following treatments using new skeletal anchors, studies on soft tissue responses are lacking. We hypothesized that soft tissue changes could differ when using maximum anchorage. Further, the ability

to predict soft tissue responses in these cases would be helpful for clinicians in predicting treatment outcome.

Therefore, in the present study, we analyzed soft tissue responses to retraction of the anterior teeth using maximum anchorage following extraction of the first maxillary and mandibular premolars for camouflage treatment in Korean patients with Class II Division 1 malocclusion, and identified the related skeletal and dental variables.

II. MATERIAL AND METHODS

The retrospective study group included 57 patients (23 males and 34 females, mean age 21.99 years) who had retraction of the incisors following implantation of miniscrews, after extraction of the maxillary and mandibular 1st premolars for camouflage treatment. They were selected among 3,300 total patients who visited the Department of Orthodontics, Yonsei University College of Dentistry between November 2005 and July 2012 for treatment of Class II Division 1 malocclusion. The patients were divided into a moderate retraction group (<8.0 mm) and a maximum retraction (≥8.0 mm) group according to the amount of retraction seen at the maxillary incisal edge. The inclusion criteria were as follows: Korean, older than 18 years, skeletal Class II Division 1 malocclusion (Class II canine and molar relationship), no missing teeth except for the third molars, extraction of 4 first premolars, and ANB angle > 4°. The exclusion criteria were previous orthodontic treatment and/or orthognathic surgery, the presence of a craniofacial anomaly and patients with anterior open bite. To minimize the effects of growth, patients older than 18 years were selected.

1. Measurements

Cranex3+ Ceph (Soredex, Milwaukee, Wisc), a cephalometric radiography system, was used to take the pre- and the post-treatment lateral cephalogram images from the natural head position, during which time the patients were asked to relax and naturally close their

lips. We used V-Ceph software (version 3.5; Cybermed, Seoul, Korea) to measure each variable. For the measurements, the horizontal reference plane (HRP) was established on Sella and oriented 7° inferior to the Sella-Nasion line, [25] while the vertical reference plane (VRP) passed through Sella and was perpendicular to the HRP. From the HRP and VRP, we measured and compared the perpendicular distances between each of the landmarks and the lip thicknesses before and after treatment. The cephalometric landmarks, reference planes, skeletal and dental measurements, soft tissue measurements, and abbreviations used in the present study are provided in Figure 1.

2. Reliability

All cephalometric radiographs were traced and digitized by the same examiner. Sixteen samples were randomly selected and retraced, and redigitized after a 1-week interval. Errors in locating and measuring values were calculated using intraclass correlation coefficients to determine reliability. The intraclass correlation coefficients were all ≥0.91, except for the occlusal plane to GoMe angle (0.76) and the over bite (0.84), indicating a lack of significant error in the measurements.

3. Statistical analysis

We used SAS version 9.2 (SAS Inc., Cary, NC) for the statistical evaluations. Two-sample t-tests were used to evaluate the differences in treatment-related changes between the moderate and the maximum retraction groups. Pearson's correlation coefficients were

calculated to assess the association between soft and hard tissue changes. A significance level of $p < 0.05$ was selected. Simple linear regression analysis was used to determine the variables that predicted soft tissue changes during orthodontic treatment at a significance level of $p < 0.05$.

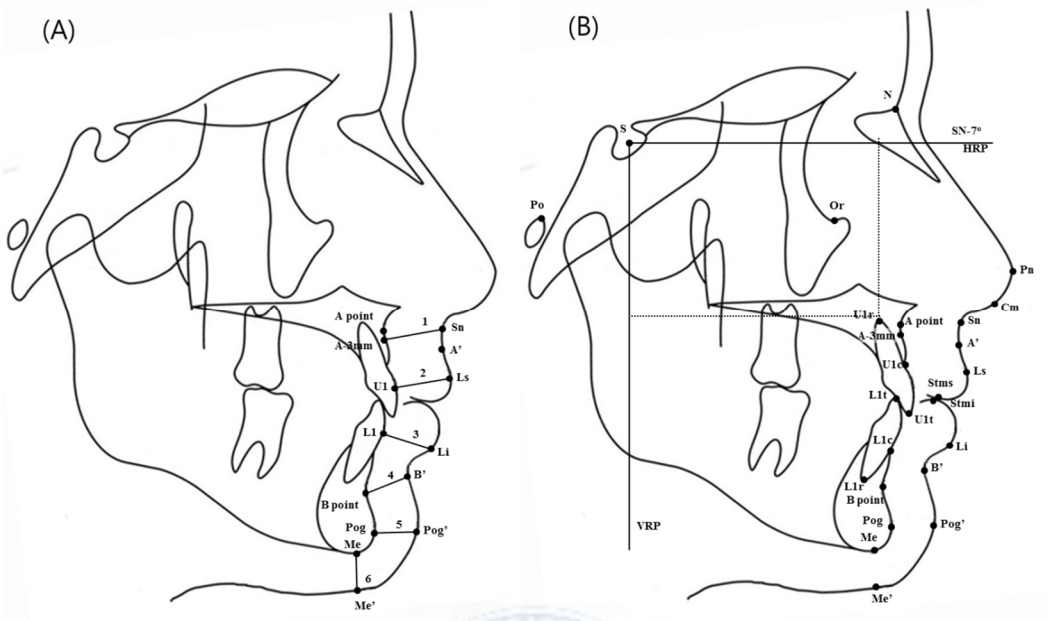

Fig 1. Landmarks, reference lines, and definitions of measurement for cephalometric analysis. **(A)** Lip thickness. 1, basic upper lip thickness (distance between Sn and A-3mm); 2, upper lip thickness (shortest distance between Ls and U1 surface); 3, lower lip thickness (shortest distance between Li and L1 surface); 4, basic lower lip thickness (distance between B' and B point); 5, horizontal chin thickness (distance between Pog' and Pog); 6, vertical chin thickness (distance between Me' and Me). 7, upper lip strain (difference between basic upper lip thickness and upper lip thickness). **(B)** Skeletal, dental and soft tissue landmarks, Horizontal (HRP) and vertical (VRP) reference planes used to measure movements of individual landmarks: S, sella; N, nasion; A, A point; A-3mm, 3mm below from A point; B, B point; Pog, pogonion; Me, menton; U1, maxillary central incisor; L1, mandibular central incisor; U1r, root apex of the maxillary central incisor; U1c, cervical point (cementoenamel junction) of the maxillary central incisor; U1t, tip (most anterior and inferior point) of the maxillary central incisor; L1t, tip (most anterior and superior point) of the mandibular central incisor; L1c, cervical point of the mandibular central incisor; L1r, root apex of the mandibular central Incisor; Pn, pronasale; Cm, collumela; Sn, subnasale; A', soft tissue A point; Ls, labrale superioris; Stms, stomion superioris; Stmi, stomion inferioris; Li, labrale inferioris; B', soft tissue B point; Pog', soft tissue pogonion; Me', soft tissue menton.

III. RESULTS

The mean pretreatment age of the subjects was 21.99 years (moderate group 22.35 years, maximum group 21.64 years), and the average treatment duration was 2.94 years (moderate group 2.91 years, maximum group 2.97 years), as shown in Table 1. Since we found no significant differences in the mean values of variables between male and female subjects in the pretreatment cephalometric analysis, the pooled data for the 57 subjects (28 subjects in moderate group, and 29 in maximum group) were evaluated to make the following statistical comparisons.

Table 1. Ages and treatment time of the subjects

	Group		*Total*
	Moderate retraction group Mean (±SD)	*Maximum retraction group Mean (±SD)*	*Mean(±SD)*
Ages (years)	22.35(±3.85)	21.64(±3.89)	21.99(±3.86)
Treatment duration (years)	2.91(±0.61)	2.97(±0.68)	2.94(±0.64)
Male (N)	9	14	23
Female (N)	19	15	34
Total (N)	28	29	57

Although there were no significant differences in pre-treatment skeletal characteristics between the moderate and the maximum groups ($p > 0.05$), we did detect significant differences in U1 to SN ($p < 0.01$), U1 to NA (angular) ($p < 0.01$), interincisal angle ($p < 0.01$), and U1 to NA (linear) ($p < 0.001$) between the groups (Table 2).

Table 2. Comparison of pre-treatment cephalometric characteristics between moderate and maximum retraction groups

	Moderate retraction group	*Maximum retraction group*	
Variable	*Mean (±SD)*	*Mean(±SD)*	*P value*
SNA (˚)	81.67 (±3.53)	81.45 (±3.66)	0.819
SNB (˚)	75.69 (±3.43)	75.72 (±3.75)	0.973
ANB difference (˚)	5.98 (±1.66)	5.73 (±1.59)	0.563
Wits (mm)	1.45 (±2.31)	2.69 (±2.43)	0.052
SN-GoMe (˚)	39.55 (±5.91)	39.74 (±5.88)	0.902
Occlusal plane to GoMe (˚)	19.03 (±4.33)	20.53 (±4.77)	0.221
FMA (˚)	30.86 (±5.61)	30.61 (±5.65)	0.868
U1 to SN (˚)	106.53 (±6.32)	112.28 (±6.39)	0.001**
U1 to NA (˚)	24.86 (±5.82)	30.83 (±6.98)	0.001**
U1 to NA (mm)	6.18 (±2.28)	8.67 (±2.37)	0.000***
L1 to NB (˚)	35.71 (±7.07)	38.90 (±5.41)	0.062
L1 to NB (mm)	11.68 (±3.41)	12.16 (±2.61)	0.547
IMPA (˚)	100.50 (±8.28)	103.48 (±7.97)	0.172
Interincisal angle (˚)	113.45 (±10.18)	104.54 (±9.24)	0.001**

U1 ; maxillary central incisor, L1 ; mandibular central incisor, * P<0.05, ** P<0.01, *** P<0.001

In terms of post-treatment skeletal changes, there were almost no horizontal changes in the B point of the moderate group, but there was posterior movement (1.2 mm) in the maximum group, resulting in a significant difference ($p < 0.01$). Changes in the occlusal plane angle exhibited a significant difference between groups (1.2° in the moderate group and 3.4°in the maximum group; $p < 0.01$) (Table 3).

In the maxillary incisors, U1 to SN, U1 to NA (°), and U1 to NA (mm) exhibited significantly greater changes in the maximum group than in the moderate group ($p < 0.001$). In the mandibular incisors, L1 to NB (mm) exhibited significantly greater changes in the maximum group than in the moderate group ($p < 0.05$) (Table 4).

The maxillary incisal tip and cervical point showed retractions of 5.3 mm and 4.2 mm, respectively, in the moderate group, and 9.9 mm and 6.2 mm, respectively, in the maximum group; the differences between the 2 groups were significant ($p < 0.001$). Horizontal changes in the mandibular incisors also differed significantly between the 2 groups ($p < 0.001$). The overjet was reduced by 0.6 mm in the moderate group and by 2.7 mm in the maximum group, and the differences were significant ($p < 0.01$) (Table 4).

The vertical changes in the maxillary and mandibular incisors were relatively small compared to the horizontal changes, and the vertical changes in the root apex of the maxillary incisor and the cervical point and root apex of the mandibular incisor differed significantly between the two groups ($p < 0.05$), but the magnitude of change was not particularly big (Table 4).

Basic upper lip thickness decreased in both groups after treatment, and there was no significant difference ($p > 0.05$). Upper lip thickness increased and upper lip strain decreased in both groups, but the changes in the maximum group were significantly greater than those seen in the moderate group ($p < 0.01$). There were no significant differences between the two groups with respect to changes in lower lip thickness and basic lower lip thickness ($p > 0.05$) (Table 5).

Horizontal changes in soft tissue, such as Sn, A', Ls, Stms, Stmi, and Li were significantly greater in the maximum group than in the moderate group ($p < 0.05$). In contrast, vertical changes were minimal and we observed no significant differences between the 2 groups ($p > 0.05$). In the moderate group, Ls and Li showed posterior movements of 2.3 mm and 3.0 mm, while in the maximum group, the movements were 4.0 mm and 5.3 mm, respectively (Table 5).

Table 3. Comparison of the skeletal pre- and post-treatment measurements and treatment changes between moderate and maximum retraction groups

	T1		*T2*		*T1-T2*		
	Moderate retraction group	*Maximum retraction group*	*Moderate retraction group*	*Maximum retraction group*	*Moderate retraction group*	*Maximum retraction group*	
Variable	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*P value*
SNA (˚)	81.67(±3.53)	81.45(±3.66)	81.00(±3.13)	80.44(±3.60)	0.66(±1.24)	1.01(±1.09)	0.262
SNB (˚)	75.69(±3.43)	75.72(±3.75)	75.64(±3.30)	75.13(±3.79)	0.05(±0.90)	0.59(±0.86)	0.024*
ANB difference (˚)	5.98(±1.66)	5.73(±1.59)	5.37(±1.90)	5.31(±1.46)	0.61(±1.22)	0.42(±1.22)	0.558
Wits (mm)	1.45(±2.31)	2.69(±2.43)	-0.03(±2.44)	-0.20(±2.92)	1.47(±2.41)	2.90(±3.30)	0.070
SN-GoMe (˚)	39.55(±5.91)	39.74(±5.88)	39.53(±6.12)	39.77(±5.81)	0.02(±1.33)	-0.03(±1.49)	0.903
Occlusal plane to GoMe (˚)	19.03(±4.33)	20.53(±4.77)	17.88(±4.50)	17.09(±4.23)	1.16(±1.85)	3.44(±3.46)	0.003**
FMA (˚)	30.86(±5.61)	30.61(±5.65)	30.41(±6.62)	30.50(±5.53)	0.45(±2.42)	0.11(±2.04)	0.562
VRP to A (mm)	69.15(±5.14)	70.20(±5.18)	68.44(±4.92)	68.93(±4.96)	0.71(±1.20)	1.27(±1.19)	0.085
VRP to B (mm)	55.96(±7.63)	57.39(±7.29)	56.01(±7.45)	56.18(±7.80)	-0.05(±1.72)	1.21(±1.54)	0.005**
VRP to Pog (mm)	55.06(±8.24)	55.84(±8.26)	55.40(±8.31)	55.48(±8.75)	-0.34(±2.01)	0.36(±1.79)	0.171
HRP to A (mm)	57.79(±5.08)	58.61(±4.28)	58.22(±4.88)	59.08(±4.41)	-0.43(±1.38)	-0.47(±1.75)	0.918
HRP to B (mm)	106.79(±9.23)	105.30(±7.78)	106.07(±10.15)	105.13(±8.04)	0.72(±2.74)	0.17(±1.84)	0.376
HRP to Pog (mm)	118.00(±8.54)	118.78(±8.43)	118.19(±8.31)	119.28(±8.50)	-0.19(±1.26)	-0.50(±1.48)	0.399

VRP ; vertical reference plane, HRP ; horizontal reference plane, * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Table 4. Comparison of the dental pre- and post-treatment measurements and treatment changes between moderate and maximum retraction groups

	T1		*T2*		*T1-T2*		
Variable	*Moderate retraction group Mean(±SD)*	*Maximum retraction group Mean(±SD)*	*Moderate retraction group Mean(±SD)*	*Maximum retraction group Mean(±SD)*	*Moderate retraction group Mean(±SD)*	*Maximum retraction group Mean(±SD)*	*P value*
U1 to SN (°)	106.53(±6.32)	112.28(±6.39)	100.31(±6.95)	96.83(±5.46)	6.22(±7.38)	15.45(±5.46)	0.000***
U1 to NA (°)	24.86(±5.82)	30.83(±6.98)	19.30(±6.76)	16.40(±4.80)	5.56(±8.08)	14.44(±5.62)	0.000***
U1 to NA (mm)	6.18(±2.28)	8.67(±2.37)	2.31(±1.81)	1.43(±1.25)	3.87(±2.45)	7.24(±2.55)	0.000***
L1 to NB (°)	35.71(±7.07)	38.90(±5.41)	28.47(±5.66)	30.63(±5.42)	7.24(±7.38)	8.27(±6.94)	0.589
L1 to NB (mm)	11.68(±3.41)	12.16(±2.61)	7.10(±2.82)	6.23(±1.92)	4.58(±2.62)	5.93(±2.41)	0.048*
IMPA (°)	100.50(±8.28)	103.48(±7.97)	93.33(±7.09)	95.76(±6.94)	7.17(±7.16)	7.71(±7.10)	0.775
Interincisal angle (°)	113.45(±10.18)	104.54(±9.24)	126.86(±8.57)	127.66(±6.69)	-13.41(±11.62)	-23.13(±9.15)	0.001***
VRP to U1t (mm)	74.74(±5.81)	78.18(±6.12)	69.45(±5.78)	68.27(±6.17)	5.28(±1.17)	9.91(±1.33)	0.000***
VRP to U1c (mm)	73.31(±5.36)	75.05(±5.43)	69.12(±5.48)	68.82(±5.59)	4.19(±1.18)	6.23(±1.31)	0.000***
VRP to U1r (mm)	63.64(±4.96)	64.55(±4.77)	61.70(±5.02)	61.96(±4.87)	1.94(±2.55)	2.59(±2.21)	0.307
VRP to L1t (mm)	70.75(±6.63)	72.46(±5.94)	66.36(±5.49)	65.59(±5.75)	4.39(±2.51)	6.87(±2.18)	0.000***
VRP to L1c (mm)	66.64(±7.16)	67.89(±6.61)	63.36(±6.23)	62.19(±6.65)	3.28(±2.08)	5.70(±1.58)	0.000***
VRP to L1r (mm)	55.69(±7.32)	56.34(±6.65)	53.69(±6.69)	52.23(±7.33)	2.00(±1.99)	4.11(±1.96)	0.000***
HRP to U1t (mm)	85.07(±6.20)	85.89(±5.62)	84.48(±6.07)	85.81(±5.53)	0.59(±1.14)	0.08(±1.46)	0.148
HRP to U1c (mm)	72.10(±6.08)	72.93(±5.30)	71.59(±6.08)	72.83(±5.47)	0.51(±1.05)	0.10(±1.45)	0.230
HRP to U1r (mm)	59.80(±5.38)	61.64(±5.06)	59.84(±5.23)	60.44(±5.47)	-0.04(±1.47)	1.20(±2.08)	0.013*
HRP to L1t (mm)	82.68(±6.34)	83.22(±5.56)	81.21(±6.03)	82.81(±5.53)	1.47(±1.89)	0.41(±2.14)	0.053
HRP to L1c (mm)	91.91(±6.48)	92.21(±6.11)	90.78(±6.20)	92.12(±5.79)	1.13(±1.54)	0.09(±1.51)	0.013*
HRP to L1r (mm)	98.91(±7.00)	98.81(±6.63)	98.77(±6.76)	99.65(±6.46)	0.14(±1.48)	-0.84(±1.58)	0.019*
overjet (mm)	4.40(±1.92)	6.11(±2.78)	3.80(±0.55)	3.37(±0.83)	0.61(±2.13)	2.74(±2.65)	0.001**
overbite (mm)	1.54(±1.49)	1.56(±1.84)	2.40(±0.81)	2.19(±0.81)	-0.86(±1.48)	-0.63(±1.92)	0.629

VRP ; vertical reference plane, HRP ; horizontal reference plane, U1t ; tip of the maxillary central incisor, U1c ; cervical point of the maxillary central incisor, U1r ; root apex of the maxillary central incisor, L1t ; tip of the mandibular central incisor, L1c ; cervical point of the mandibular central incisor, L1r ; root apex of the mandibular central incisor, $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$

Table 5. Comparison of the soft tissue pre- and post-treatment measurements and treatment changes between moderate and maximum retraction groups

	T1		*T2*		*T1-T2*		
	Moderate retraction group	*Maximum retraction group*	*Moderate retraction group*	*Maximum retraction group*	*Moderate retraction group*	*Maximum retraction group*	
Variable	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*Mean(±SD)*	*P value*
Basic upper lip thickness (mm)	14.97(±1.86)	14.64(±1.69)	14.41(±1.93)	13.99(±1.64)	0.56(±0.58)	0.65(±0.62)	0.570
Upper lip thickness (mm)	13.24(±2.17)	12.63(±1.64)	14.97(±2.49)	15.44(±1.86)	-1.73(±1.29)	-2.81(±1.61)	0.007**
Upper lip strain (mm)	1.73(±2.02)	2.01(±2.13)	-0.56(±1.90)	-1.45(±1.99)	2.29(±1.16)	3.46(±1.58)	0.002**
Lower lip thickness (mm)	14.81(±1.76)	15.31(±1.73)	15.49(±2.33)	15.66(±1.80)	-0.68(±1.68)	-0.35(±1.90)	0.498
Basic lower lip thickness (mm)	17.08(±2.88)	16.34(±2.22)	15.29(±2.58)	14.66(±2.03)	1.79(±1.69)	1.68(±1.78)	0.811
Horizontal chin thickness (mm)	15.43(±3.52)	14.55(±3.10)	15.09(±3.11)	14.25(±2.99)	0.34(±2.92)	0.30(±1.56)	0.954
Vertical chin thickness (mm)	7.27(±1.96)	7.51(±1.60)	8.03(±2.51)	8.31(±1.94)	-0.76(±1.23)	-0.80(±0.96)	0.891
Nasolabial angle (°)	99.33(±11.63)	96.2(±10.13)	103.98(9.48±)	103.15(±8.89)	-4.65(±6.18)	-6.95(±6.52)	0.177
Mentolabial sulcus angle (°)	142.43(11.59±)	141.67(14.23±)	139.50(9.00±)	138.48(±15.98)	2.92(±12.66)	3.19(±13.13)	0.938

VRP ; vertical reference plane, HRP ; horizontal reference plane, * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Table 5. Continued

	T1		*T2*		*T1-T2*		
Variable	*Moderate retraction group* *Mean(±SD)*	*Maximum retraction group* *Mean(±SD)*	*Moderate retraction group* *Mean(±SD)*	*Maximum retraction group* *Mean(±SD)*	*Moderate retraction group* *Mean(±SD)*	*Maximum retraction group* *Mean(±SD)*	*P value*
VRP to Sn (mm)	83.93(±6.24)	84.11(±5.30)	83.10(±6.23)	82.78(±5.32)	0.82(±0.84)	1.32(±0.95)	0.040*
VRP to A' (mm)	83.62(±6.09)	83.93(±5.16)	82.38(±6.39)	82.09(±5.28)	1.23(±0.86)	1.84(±0.80)	0.007**
VRP to Ls (mm)	87.81(±6.31)	89.42(±6.01)	85.53(±6.86)	85.42(±5.60)	2.28(±1.73)	4.00(±1.68)	0.000***
VRP to Stms (mm)	79.94(±6.24)	83.01(±6.65)	76.35(±6.97)	76.13(±5.97)	3.59(±2.24)	6.88(±2.32)	0.000***
VRP to Stmi (mm)	78.92(±6.23)	81.45(±5.91)	74.94(±6.31)	74.69(±6.73)	3.98(±2.07)	6.76(±1.76)	0.000***
VRP to Li (mm)	82.08(±7.89)	83.97(±6.79)	79.04(±7.67)	78.62(±7.07)	3.04(±2.20)	5.34(±1.62)	0.000***
VRP to B' (mm)	72.61(±7.67)	73.43(±7.70)	70.70(±7.83)	70.34(±8.03)	1.91(±2.20)	3.09(±2.22)	0.050
VRP to Pog' (mm)	69.71(±8.99)	69.79(±8.17)	69.74(±8.90)	69.03(±8.30)	-0.03(±2.79)	0.76(±2.20)	0.238
HRP to Sn (mm)	56.61(±5.24)	57.05(±4.44)	57.24(±5.02)	58.04(±4.61)	-0.64(±1.03)	-0.99(±0.86)	0.160
HRP to A' (mm)	59.83(±5.58)	59.62(±4.56)	60.54(±5.26)	60.95(±4.73)	-0.71(±1.17)	-1.33(±1.35)	0.067
HRP to Ls (mm)	71.76(±7.60)	72.47(±5.25)	72.73(±6.69)	74.13(±5.72)	-0.96(±1.54)	-1.66(±1.50)	0.089
HRP to Stms (mm)	82.27(±7.29)	82.97(±5.55)	82.58(±6.90)	83.51(±5.37)	-0.31(±1.22)	-0.54(±1.44)	0.534
HRP to Stmi (mm)	83.54(±6.79)	84.32(±6.63)	82.73(±6.92)	84.04(±5.69)	0.81(±2.06)	0.28(±2.34)	0.370
HRP to Li (mm)	95.64(±7.10)	96.30(±7.11)	94.44(±7.79)	95.20(±6.54)	1.20(±2.68)	1.10(±2.52)	0.883
HRP to B' (mm)	104.08(±9.38)	104.27(±8.23)	103.33(±9.48)	103.11(±7.77)	0.75(±2.59)	1.16(±2.02)	0.512
HRP to Pog' (mm)	114.84(±10.51)	116.20(±8.51)	114.92(±9.64)	116.54(±8.04)	-0.08(±3.58)	-0.34(±2.68)	0.753

VRP ; vertical reference plane, HRP ; horizontal reference plane, * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Pearson's correlation between soft tissue of the upper lip and hard tissue

In the moderate group, the horizontal movement of the Ls was significantly positively correlated with the horizontal U1c movement (0.64) ($p < 0.001$), U1t movement ($p < 0.01$), and vertical U1c movement, U1t movement ($p < 0.05$), in descending order of effect size. The horizontal movement of the Stms showed the strongest positive correlation with the horizontal movement of the U1t ($p < 0.001$), while the horizontal movement of A' was positively correlated only with the horizontal movement of the U1c ($p < 0.05$) (Table 6).

In the maximum group, positive correlations were observed in the horizontal movement of A' only with the horizontal movements of U1c and L1c ($p < 0.01$) (Table 6).

Pearson's correlation between soft tissue of the lower lip and hard tissue

In the moderate group, horizontal movement of the Li was significantly positively correlated with horizontal movements of the L1c (0.79) ($p < 0.001$), B point, L1t, Pog, and U1t, in descending order with respect to strength ($p < 0.01$). Horizontal movement of the Stmi exhibited the strongest positive correlation with horizontal movement the U1t ($p < 0.001$), while horizontal movement of the B' showed strong, significant positive correlations with horizontal movements of the Pog and B point ($p < 0.001$) (Table 6).

In the maximum group, horizontal movement of the Li was significantly positively correlated with horizontal movements of the L1t (0.51) ($p < 0.01$), L1c, B point, Pog, and U1c, in descending order with respect to strength ($p < 0.05$). Horizontal movement of the

Stmi showed the strongest positive correlation with horizontal movement of the Pog, and this correlation was significant ($p < 0.05$), while horizontal movements of the B' and Pog' exhibited the strongest positive correlations with the horizontal movement of B point and Pog, both of which were significant ($p < 0.001$) (Table 6).

Table 6. Pearson's correlation coefficients between soft tissue component of upper and lower lips and hard tissue for moderate and maximum retraction groups

soft tissue variables	*Hard tissue variables*									
	Moderate retraction group					*Maximum retraction group*				
VRP to Sn	VRP to A	VRP to L1c	VRP to U1c	VRP to B						
	0.43*	0.41*	0.39*	0.38*						
VRP to A'	VRP to U1c					VRP to L1c	VRP to U1c	VRP to B	VRP to U1t	VRP to Pog
	0.42*					0.48**	0.48**	0.42*	0.41*	0.39*
VRP to Ls	VRP to U1c	VRP to U1t	HRP to U1c	HRP to U1t						
	0.64***	0.52**	0.38*	0.37*						
VRP to Stms	VRP to U1t	VRP to U1c	HRP to U1t							
	0.74***	0.57**	0.38*							
VRP to Stmi	VRP to U1t	VRP to L1c	VRP to L1t	VRP to U1c	VRP to B	VRP to Pog	VRP to U1t	VRP to B	VRP to U1c	
	0.73***	0.62***	0.58**	0.39*	0.38*	0.45*	0.44*	0.43*	0.39*	
VRP to Li	VRP to L1c	VRP to B	VRP to L1t	VRP to Pog	VRP to U1t	VRP to L1t	VRP to L1c	VRP to B	VRP to Pog	VRP to U1c
	0.79***	0.66***	0.64***	0.63***	0.56**	0.51**	0.46*	0.43*	0.42*	0.41*
VRP to B'	VRP to Pog	VRP to B	VRP to L1c			VRP to B	VRP to Pog	VRP to U1c	VRP to L1c	
	0.73***	0.66***	0.52**			0.71***	0.63***	0.45*	0.41*	
VRP to Pog'	VRP to Pog	VRP to L1c	VRP to B	VRP to L1t		VRP to Pog	VRP to B	VRP to L1c		
	0.53**	0.46*	0.46*	0.42*		0.86***	0.83***	0.48**		

VRP ; vertical reference plane, HRP ; horizontal reference plane, U1t ; tip of the maxillary central incisor, U1c ; cervical point of the maxillary central incisor, L1t ; tip of the mandibular central incisor, L1c ; cervical point of the mandibular central incisor * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Simple linear regression between soft tissue of the upper lip and hard tissue

In the moderate group, horizontal movement of the Ls was influenced the most by horizontal movement of the U1c (0.94; $p < 0.001$), followed by vertical movement of the U1c and horizontal movement of the U1t ($p < 0.05$). Horizontal movement of the Stms was significantly influenced by horizontal movements of the U1c and U1t ($p < 0.01$) (Table 7).

In the maximum group, the influences of the horizontal movement of the U1c and U1t were significant for horizontal movement of the A' ($p < 0.05$), but no variables significantly influenced horizontal movements of the Sn, Ls, or Stms ($p > 0.05$) (Table 7).

Simple linear regression of soft tissue of the lower lip on hard tissue

In the moderate group, horizontal movement of the B point had the biggest influence on horizontal movement of the Li (0.84; $p < 0.001$), followed in order of effect size by horizontal movements of the L1c, U1t, Pog, and L1t ($p < 0.01$). Horizontal movement of the U1t had the greatest influence on horizontal movement of the Stmi (0.88; $p < 0.001$) (Table 8).

In the maximum group, horizontal movement of the U1c had the greatest influence on horizontal movement of the Li (0.50), followed in order of effect size by horizontal movements of the L1c, B point, Pog, and L1t ($p < 0.05$). Horizontal movement of the U1t had the greatest influence on horizontal movement of the Stmi (0.58; $p < 0.05$) (Table 8).

Table 7. Simple linear regression between soft tissue component of upper lip and hard tissue for moderate and maximum retraction groups

Variables		*Moderate retraction group*					*Maximum retraction group*					
		Unstandardized coefficient					*Unstandardized coefficient*					*Comparison P value*
Dependent	*Independent*	*Beta*	*Intercept*	*SE*	*t*	*P value*	*Beta*	*Intercept*	*SE*	*t*	*P value*	
VRP to Sn	VRP to A	0.305	0.606	0.124	2.46	0.021*	0.102	1.194	0.153	0.67	0.508	0.309
	VRP to B	0.188	0.834	0.089	2.12	0.044*	0.135	1.160	0.115	1.17	0.251	0.717
	VRP to Pog	0.152	0.876	0.077	1.98	0.058	0.145	1.272	0.098	1.48	0.151	0.958
	VRP to U1t	0.130	0.136	0.093	1.40	0.175	0.254	-1.198	0.129	1.98	0.058	0.434
	VRP to U1c	0.275	-0.330	0.129	2.13	0.043*	0.226	-0.087	0.132	1.72	0.098	0.795
	VRP to L1t	0.099	0.390	0.063	1.57	0.128	0.104	0.610	0.081	1.27	0.214	0.962
	VRP to L1c	0.168	0.273	0.072	2.32	0.029*	0.173	0.338	0.110	1.57	0.129	0.967
VRP to A'	VRP to A	0.231	1.067	0.133	1.74	0.093	0.212	1.576	0.123	1.72	0.097	0.915
	VRP to B	0.058	1.236	0.097	0.60	0.557	0.220	1.579	0.091	2.43	0.022*	0.230
	VRP to Pog	0.024	1.241	0.083	0.29	0.778	0.175	1.782	0.079	2.20	0.037*	0.198
	VRP to U1t	0.131	0.540	0.095	1.38	0.179	0.246	-0.593	0.106	2.32	0.028*	0.429
	VRP to U1c	0.308	-0.056	0.129	2.39	0.024*	0.291	0.033	0.103	2.82	0.009**	0.919
	VRP to L1t	0.033	1.089	0.067	0.49	0.627	0.106	1.119	0.068	1.56	0.131	0.450
	VRP to L1c	0.045	1.084	0.080	0.56	0.578	0.241	0.470	0.085	2.82	0.009**	0.108
VRP to Ls	VRP to A	0.351	2.027	0.275	1.28	0.213	0.290	3.637	0.266	1.09	0.286	0.873
	VRP to B	-0.018	2.277	0.197	-0.09	0.928	0.017	3.983	0.209	0.08	0.936	0.903
	VRP to Pog	-0.031	2.267	0.169	-0.18	0.858	-0.115	4.045	0.179	-0.64	0.525	0.732
	VRP to U1t	0.527	-0.505	0.170	3.10	0.005**	0.443	-0.389	0.228	1.95	0.062	0.769
	VRP to U1c	0.942	-1.670	0.220	4.28	0.000***	0.345	1.856	0.237	1.46	0.157	0.074
	VRP to L1t	0.166	1.550	0.131	1.26	0.217	0.152	2.961	0.145	1.04	0.306	0.942
	VRP to L1c	0.187	1.662	0.159	1.18	0.250	0.087	3.510	0.203	0.43	0.673	0.698
	HRP to U1t	0.570	1.939	0.277	2.06	0.050*	-0.015	4.005	0.221	-0.07	0.945	0.107
	HRP to U1c	0.627	1.956	0.298	2.10	0.045*	-0.065	4.011	0.222	-0.29	0.771	0.070
VRP to Stms	VRP to A	0.224	3.432	0.364	0.62	0.543	0.598	6.120	0.359	1.67	0.107	0.467
	VRP to B	0.271	3.606	0.249	1.09	0.287	0.003	6.874	0.290	0.01	0.991	0.486
	VRP to Pog	0.337	3.707	0.208	1.62	0.117	-0.115	6.919	0.249	-0.46	0.648	0.168
	VRP to U1t	0.964	-1.499	0.174	5.55	<.0001***	0.501	1.910	0.323	1.55	0.132	0.197
	VRP to U1c	1.075	-0.911	0.305	3.52	0.002**	0.200	5.631	0.338	0.59	0.559	0.065
	VRP to L1t	0.284	2.348	0.166	1.71	0.099	0.137	5.938	0.204	0.67	0.507	0.577
	VRP to L1c	0.370	2.376	0.198	1.87	0.073	0.151	6.015	0.281	0.54	0.594	0.523
	HRP to U1t	0.744	3.149	0.357	2.08	0.047*	0.006	6.878	0.306	0.02	0.984	0.129

VRP ; vertical reference plane, HRP ; horizontal reference plane, U1t ; tip of the maxillary central incisor, U1c ; cervical point of the maxillary central incisor, L1t ; tip of the mandibular central incisor, L1c ; cervical point of the mandibular central incisor $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$

Table 8. Simple linear regression between soft tissue component of lower lip and hard tissue for moderate and maximum retraction groups

Variables		*Moderate retraction group*					*Maximum retraction group*					*Comparison P value*
		Unstandardized coefficient					*Unstandardized coefficient*					
Dependent	*Independent*	*Beta*	*Intercept*	*SE*	*t*	*P value*	*Beta*	*Intercept*	*SE*	*t*	*P value*	
VRP to Stmi	VRP to A	0.356	3.723	0.331	1.07	0.293	0.255	6.439	0.282	0.91	0.373	0.818
	VRP to B	0.454	4.000	0.218	2.08	0.047*	0.495	6.165	0.198	2.50	0.019*	0.892
	VRP to Pog	0.348	4.096	0.189	1.84	0.077	0.447	6.604	0.169	2.65	0.013*	0.701
	VRP to U1t	0.884	-0.696	0.162	5.47	<.0001***	0.582	1.000	0.230	2.53	0.018*	0.281
	VRP to U1c	0.688	1.093	0.315	2.18	0.038*	0.517	3.540	0.238	2.17	0.039*	0.664
	VRP to L1t	0.474	1.897	0.132	3.60	0.001**	0.202	5.374	0.151	1.34	0.191	0.180
	VRP to L1c	0.619	1.943	0.152	4.06	0.000***	0.277	5.185	0.207	1.34	0.193	0.187
VRP to Li	VRP to A	0.655	2.571	0.336	1.95	0.062	0.154	5.149	0.261	0.59	0.560	0.243
	VRP to B	0.837	3.082	0.189	4.43	0.000***	0.450	4.801	0.182	2.47	0.020*	0.148
	VRP to Pog	0.691	3.275	0.166	4.17	0.000***	0.380	5.209	0.158	2.41	0.023*	0.183
	VRP to U1t	0.714	-0.734	0.210	3.40	0.002**	0.296	2.413	0.228	1.30	0.205	0.190
	VRP to U1c	0.544	0.758	0.349	1.56	0.131	0.503	2.209	0.216	2.33	0.028*	0.919
	VRP to L1t	0.558	0.591	0.132	4.22	0.000***	0.380	2.733	0.123	3.10	0.005**	0.333
	VRP to L1c	0.830	0.312	0.128	6.47	<.0001***	0.467	2.681	0.174	2.68	0.013*	0.098
VRP to B'	VRP to A	0.511	1.550	0.346	1.47	0.152	0.311	2.694	0.356	0.87	0.390	0.689
	VRP to B	0.848	1.958	0.188	4.51	0.000***	1.028	1.847	0.194	5.29	<.0001***	0.509
	VRP to Pog	0.797	2.188	0.147	5.43	<.0001***	0.786	2.809	0.185	4.24	0.000***	0.961
	VRP to U1t	0.470	-0.569	0.235	2.00	0.056	0.161	1.497	0.321	0.50	0.621	0.437
	VRP to U1c	0.148	1.295	0.364	0.41	0.689	0.764	-1.671	0.291	2.63	0.014*	0.189
	VRP to L1t	0.312	0.545	0.161	1.94	0.063	0.295	1.060	0.188	1.57	0.128	0.945
	VRP to L1c	0.551	0.104	0.177	3.11	0.005**	0.571	-0.165	0.247	2.31	0.029*	0.947
VRP to Pog'	VRP to A	0.216	-0.183	0.455	0.47	0.639	0.422	0.230	0.348	1.21	0.236	0.720
	VRP to B	0.751	0.010	0.282	2.66	0.013*	1.183	-0.664	0.153	7.72	<.0001***	0.194
	VRP to Pog	0.735	0.223	0.231	3.18	0.004**	1.052	0.390	0.123	8.58	<.0001***	0.242
	VRP to U1t	0.281	-1.516	0.316	0.89	0.381	0.097	-0.197	0.319	0.30	0.763	0.690
	VRP to U1c	0.189	-0.822	0.462	0.41	0.685	0.465	-2.133	0.310	1.50	0.145	0.616
	VRP to L1t	0.463	-2.060	0.198	2.34	0.028*	0.225	-0.780	0.190	1.18	0.247	0.393
	VRP to L1c	0.621	-2.070	0.233	2.66	0.013*	0.666	-3.031	0.235	2.84	0.009**	0.896

VRP ; vertical reference plane, HRP ; horizontal reference plane, U1t ; tip of the maxillary central incisor, U1c ; cervical point of the maxillary central incisor, L1t ; tip of the mandibular central incisor, L1c ; cervical point of the mandibular central incisor $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$

IV. DISCUSSION

Although previous studies have examined the responses of the Ls and the Li to posterior movement of the maxillary and mandibular incisors in orthodontic treatments involving premolar extraction, they have used traditional anchorage to estimate various soft tissue responses during maxillary incisal retraction, based on skeletal and dental characteristics of the subjects. [9-11, 17, 18, 26, 27] In our retrospective study, we used maximum anchorage for the treatment of Class II Division 1 malocclusion to examine how soft tissues respond in cases with very large retractions in the anterior region. Soft tissue responses were compared between the moderate and the maximum retraction groups, with the hypothesis that soft tissue responses differ when using maximum anc horage.

The amount of retraction in the maxillary incisors was significantly higher in the maximum group than the moderate group ($p < 0.001$). In the pre-treatment comparison of skeletal components between the groups, significant differences in the ANB angles were not observed, but much greater degrees of labioversion and protrusion of the maxillary incisors were observed in the maximum group compared to the moderate group, resulting in differences in the amount of **retrac tion** in the maxillary incisal region. For the camouflage treatment of Class II malocclusion patients, the amount of retraction in the maxillary teeth of the maximum group was similar that observed in a previous study by Kuroda et al. [14] in which 9.3 mm of retraction was detected in a group with skeletal anchorage. Considering that the retraction of the maxillary incisal region that occurs

when Class II malocclusion patients are treated with traditional anchorage is 5.6–6.3 mm, [9, 14] the amount of retraction in the maxillary incisal region increased noticeably.

Mandibular incisor retraction was significantly higher in the maximum group than the moderate group (4.4 mm and 6.9 mm in the moderate and maximum groups, respectively; $p < 0.001$). The measurements in the present study were higher than the 4.8 mm of retraction observed in the group treated with skeletal anchorage in the Kuroda et al. [14] study, and this difference is attributed to the smaller pre-treatment overjet in the present study (6.1 mm compared to 7.0 mm). In other studies that used traditional anchorage after premolar extraction, the amount of retraction in the mandibular teeth is 3.1–3.3 mm, [11, 14, 17] demonstrating that the retraction of the mandibular incisors in the present study was nearly twice as extensive.

Horizontal changes in the A point during posterior movement of the maxillary incisors were 1.3 mm in the maximum group and 0.7 mm in the moderate group, but the differences were not statistically significant. Baumrind et al. [28] indicated that posterior movement of the A point occurs according to posterior movement of the maxillary incisor, but another study indicated that movements of the maxillary incisal root apex and A point are weakly correlated. [29] Because there were no significant differences between the groups in maxillary incisal root movement compared to crown movement, no differences in changes in the A point between the groups were observed in the present study.

However, during posterior movement of the mandibular incisors, the B point in the maximum group moved posteriorly by 1.2 mm but only 0.05 mm in the moderate group,

and this difference was statistically significant ($p < 0.01$). This difference in the B point observed between the groups was due to the significant difference in the amount of mandibular incisal root movement between the moderate and maximum groups (2.0 mm and 4.1 mm, respectively).

In both groups, the upper and lower lips retracted along with tooth movement, but the movement was significantly greater in the maximum group than the moderate group ($p < 0.001$). A study that used traditional anchorage after extraction reported Ls and Li retractions of 2.5–3.2 mm and 3.4–3.5 mm, respectively, which were similar to the retractions of 2.3 mm and 3.0 mm in the moderate group observed in the present study, but smaller than those of the maximum group (4.0 mm and 5.3 mm). Because the amount of tooth movement in the maximum group was greater than that observed in previous studies, the amount of soft tissue movement was also greater.

In terms of vertical movements of soft tissue variables, in both groups, the Sn, A', Ls, and Stms of the upper lip moved inferiorly, while the Li and Stmi of the lower lip moved superiorly. However, the magnitude of change was minimal and there were no significant differences between the groups ($p > 0.05$). Vertical changes in soft tissue were minor, since the correlations based on tooth movement were also relatively low, and this was consistent with the results of a previous study that reported that the variables have low predictive ability. [13]

There were no major changes in the basic upper lip thickness in the two groups following treatment, and post-treatment upper lip thickness and lip strain did show

significant differences between the groups ($p < 0.01$). Upper lip thickness increased by 1.7 mm in the moderate group and by 2.8 mm in the maximum group, while upper lip strain was reduced by 2.3 mm in the moderate group and by 3.5 mm in the maximum group, indicating greater changes in the maximum group. The increased thickness of the upper lip was consistent with the results of previous studies, [10, 11, 20] but the magnitude of change in the maximum group was relatively large. The reduction in lip strain may be a result of the recovery of upper lip thickness owing to hard tissue retraction.

Generally, the amount of movement is maximal at the incisal tip and its measurement is simple; hence, there is a tendency to use the incisal tip or the anteriormost point as a landmark for the incisor during posterior movement. In the present study, two landmarks were used, the incisal tip and cervical point, to evaluate the correlation and regression coefficients for soft tissue variables. [30]

Horizontal movement of the upper lip was not correlated with skeletal variables in the moderate group, but was correlated with dental variables. Horizontal movement of the Ls was more highly correlated with horizontal movement of the U1c than with that of the U1t, consistent with previous results, [11, 30] while horizontal movement of the Stms was highly correlated with horizontal movement of the U1t. In the regression analysis, both Ls and Stms were influenced the most by horizontal movement of the U1c, whereas the posterior movement of the upper lip (Ls, Stms) was influenced by both the horizontal and vertical movements of the maxillary incisor (U1t, U1c). Based on these results, as more posterior

movement and intrusion of the maxillary incisors occurs, the retraction in the upper lips also increases. These findings are different from the results of an existing study [9] that indicated posterior movement of the Ls is influenced, in order, by horizontal movement of the Pog and posterior movement of the maxillary incisal edge, and that jawbone movement had a more direct influence than teeth movement. However, our results were consistent with previous results indicating that horizontal movement of the maxillary incisal cervical point have the biggest influence on posterior movement of the Ls. [10, 11]

Unlike the moderate group, none of the skeletal or dental variables was significantly correlated with horizontal movements of the Ls and Stms in the maximum group. In the regression analysis, the prediction of soft tissue changes was also difficult. Horizontal movement of the A' was influenced significantly, in order, by the U1c and U1t, but the degree of influence was low, consistent with the results of existing previous study that reported an influence of the posterior movements of the maxillary incisal tip and root apex. [9]

In the maximum group, pre-treatment upper lip strain and large protrusion of the maxillary incisor can influence the upper lip response. Holdaway [3] reported that when the basic upper lip thickness and the upper lip thickness in the vermilion border are equivalent, upper lip movement is equal to that of the teeth; when the basic upper lip thickness is very thin or thick, the movement pattern of the upper lip is not proportional to the tooth movement pattern. Ramos [30] reported that in cases with a large overjet from extreme upper incisor proclination prior to treatment, the amount of retraction in the

maxillary incisal cervical point is smaller than that of the maxillary incisal tip and shows less lip change; more normal incisor inclinations are associated with translatory movement by the teeth and more lip change. In the present study, pre-treatment lip strain was larger in the maximum group than in the moderate group, and it is believed that the amount of upper lip retraction with respect to the amount of tooth retraction was offset by the greater relief in lip strain following the treatment. Moreover, the incisal region protruded more in the maximum group prior to the treatment and the amount of maxillary incisal cervical point retraction was smaller than that of the tip when compared to the moderate group, resulting in a reduced lip response.

In the moderate group, horizontal movement of the lower lip was significantly correlated with not only horizontal movements of dental variables, but also with horizontal movements of skeletal variables. The horizontal movement of the Li was highly correlated with dental variables such as the L1c, L1t, and U1t, and with skeletal variables such as the B point and Pog. Major influences of these variables were also detected based on the regression analysis. Horizontal movements of the Stmi were highly correlated and influenced by those of the U1t and B point based on the regression analysis; hence, movement of the lower lip and maxillary teeth also had a major influence.

Although the horizontal movements of the lower lip in the maximum group were also correlated with horizontal movements of the dental and skeletal variables, most of these correlations were lower than those observed in the moderate group. Based on the regression analysis, the U1c and L1c had large influences on the horizontal movements of

the Li, but these influences were smaller than those observed in the moderate group. These findings indicate that in the maximum group, the soft tissue responses to increases in the amount of mandibular incisal retraction are not proportional to the amount of mandibular incisal retraction. Unlike the upper lip, the thickness changes from pre- to post-treatment were not particularly large in the lower lip; hence, a reduction in the amount of soft tissue retraction based on strain relief cannot be inferred, and skeletal variables, such as the B point and Pog, exert an influence on the degree of soft tissue response in addition to the dental variables.

Hodges et al. [10] reported that among dental variables, the mandibular incisal cervical point has the greatest influence on posterior movement of the Li, consistent with the results observed for the moderate group in the present study. Meanwhile, Hayashida et al. [11] stated that lower lip changes are not correlated with skeletal variables. Because angular measurements, such as SNA and SNB, were used as skeletal variables, the results differed from those of the present study, which used linear measurements. Moreover, it was also reported that the maxillary incisal edge has the greatest influence on horizontal movement of the lower lip, but the degree of such influence was lower than that observed in the present study, and skeletal variables were not evaluated.

Horizontal movements of the B' and Pog' were highly correlated with skeletal variables in both the moderate and maximum groups. Based on the regression analysis, horizontal movements of the B' and Pog' were influenced, in order, by the B point and Pog in both groups, but the influence of skeletal variables was stronger in the maximum group. This

was consistent with the results of an existing study indicating that movement of the B' is directly influenced by the B point, [9] and that in the lower anterior face, moving inferiorly from the lower lip, the influence of skeletal variables becomes greater than that of dental variables.

Varying results have been reported from numerous studies on the ratio of tooth number to soft tissue movements following premolar extraction. The differences among studies can be attributed to differences in dentofacial morphology, age, gender, ethnicity, and study methodology.[9, 11, 18, 21, 26, 31, 32] In the present study, the ratio of the unit change in hard tissue to the unit change in soft tissue, obtained from regression analyses, was 1:0.53 ($p < 0.01$) for the amount of movement between the maxillary incisal tip and Ls in the moderate group, and the amount of movement between the mandibular incisal tip and Li exhibited a ratio of 1:0.56 ($p < 0.001$). In the maximum group, the amount of movement between the maxillary incisal tip and Ls had a ratio of 1:0.44, but was not significant ($p = 0.062$), and the amount of movement between the mandibular incisal tip and Li exhibited a ratio of 1:0.38 ($p < 0.01$). Although both teeth and soft tissues exhibited greater changes in the maximum group, the ratio of the amount of soft tissue movement to the amount of tooth retraction was lower in the maximum group, but this difference was not significant among groups ($p > 0.05$). When the teeth were maximally retracted using maximum anchorage, the upper lip changes were difficult to predict based on dental and skeletal variables alone. Although the lower lip was influenced by all of the dental and skeletal variables, those influences appeared to be smaller in the maximum group than in the moderate group.

Furthermore, studies on the ratio of soft tissue movement to tooth movement have a tendency to use the incisal tip or anteriormost point as a landmark for the incisor. [11, 21, 30] These previous studies and our study indicate that the cervical point is highly correlated and has a major influence on changes in the upper and lower lips. This signifies that the degree of soft tissue retraction can vary depending on how much torque is maintained during incisor retraction. As tooth retraction increases, soft tissue changes do not match those of the hard tissue, and factors other than the hard tissue variables can play a role; hence, evaluation of soft tissue changes via periodic imaging is necessary.

There are a few limitations of the present study. First, owing to individual variability in soft tissues of the musculonervous system, it was difficult to determine the accuracy of lip posture during imaging. Although lip strain should be considered in either soft tissue analysis or lip thickness evaluation, it does show not only differences between individuals, but also temporal differences within individuals; accordingly, these variables could not be controlled or quantified. The sample size of each group was too small to overcome these limitations; hence, the scientific and statistical power to evaluate the effect of each variables was insufficient. Moreover, consideration of the envelope of discrepancy is also needed when retraction increases. Dental root [24] and cortical bone resorption [33] due to contact between the dental root and the palatal side cortical bone can occur during maximum retraction of the incisal region, but the present study did not consider any such intergroup differences. As such, the morphological characteristics of the palatal side cortical bone for each individual must also be examined. In addition, There is a lack of

research methodology to categorize continuous variables such as the amount of retraction. Further studies using complementary research methods are needed.

V. CONCLUSIONS

1. The maxillary and mandibular incisal tips showed retractions of 5.3 mm and 4.4 mm, respectively, in the moderate group, and 9.9 mm and 6.9 mm, respectively, in the maximum group; the differences among groups were significant ($p < 0.001$).

2. The Ls and Li showed retractions of 2.3 mm and 3.0 mm, respectively, in the moderate group, and 4.0 mm and 5.3 mm in the maximum group; these differences among groups were significant ($p < 0.001$).

3. In the moderate group, the Ls and Stms retractions in the upper lip were correlated with and influenced by the dental variables only, whereas the Li and Stmi retractions in the lower lip were correlated with and influenced by both dental and skeletal variables ($p < 0.05$).

4. In the maximum group, no dental or skeletal variables were significantly correlated with or influenced by upper lip retraction ($p > 0.05$); however, similar to the moderate group, lower lip retraction was correlated with and influenced by both dental and skeletal variables($p < 0.05$), although these effects were weak ($R^2 \leq 0.51$, $\beta \leq 0.58$).

5. In the moderate group, the cervical point had a greater influence on the posterior movements of the Ls and Li than did the incisal tip ($p < 0.01$).

6. Both teeth and soft tissues showed more extensive changes in the maximum group, but the ratio of the amount of soft tissue movement to tooth retraction was lower in the maximum group. The differences between the 2 groups were not significant ($p > 0.05$).

REFERENCES

1. Tweed, C., *Evolutionary trends in orthodontics, past, present, and future.* Am J Orthod, 1953. **39**: p. 81-108.
2. Cha, K.S., *Soft-tissue thickness of South Korean adults with normal facial profiles.* Korean J Orthod, 2013. **43**(4): p. 178-85.
3. Holdaway, R.A., *A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part I.* Am J Orthod, 1983. **84**(1): p. 1-28.
4. Holdaway, R.A., *A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part II.* Am J Orthod, 1984. **85**(4): p. 279-93.
5. Ackerman, J.L. and W.R. Proffit, *Soft tissue limitations in orthodontics: treatment planning guidelines.* Angle Orthod, 1997. **67**(5): p. 327-36.
6. Gkantidis, N., et al., *Effectiveness of non-conventional methods for accelerated orthodontic tooth movement: A systematic review and meta-analysis.* J Dent, 2014. **42**(10): p. 1300-19.
7. Lee, K.J., et al., *Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism.* Am J Orthod Dentofacial Orthop, 2010. **137**(6): p. 830-9.
8. Burcal, R.G., D.M. Laskin, and T.P. Sperry, *Recognition of profile change after simulated orthognathic surgery.* J Oral Maxillofac Surg, 1987. **45**(8): p. 666-70.
9. Chio, J.H., J.W. Lee, and K.S. Cha, *Soft tissue profle change prediction in maxillary incisor retraction based on cephalometrics.* Korean J Orthod, 1997. **27**(1): p. 65-78.
10. Hodges, A., et al., *Prediction of lip response to four first premolar extractions in white female adolescents and adults.* Angle Orthod, 2009. **79**(3): p. 413-21.
11. Hayashida, H., et al., *Effects of retraction of anterior teeth and initial soft tissue variables on lip changes in Japanese adults.* Eur J Orthod, 2011. **33**(4): p. 419-26.
12. Kim, H.H., et al., *Three-dimensional assessment of upper lip positional changes according to simulated maxillary anterior tooth movements by white light scanning.* Korean J Orthod, 2014. **44**(6): p. 281-93.

13. Kang, C.S., K.H. Kim, and K.C. Choy, *The vertical changes of the lip and perioral soft tissue resulting from incisor retraction.* Korean J Orthod, 2000. **30**(2): p. 185-196.
14. Kuroda, S., et al., *Class II malocclusion treated with miniscrew anchorage: comparison with traditional orthodontic mechanics outcomes.* Am J Orthod Dentofacial Orthop, 2009. **135**(3): p. 302-9.
15. Leonardi, R., et al., *Soft tissue changes following the extraction of premolars in nongrowing patients with bimaxillary protrusion. A systematic review.* Angle Orthod, 2010. **80**(1): p. 211-6.
16. Park, S.H., et al., *The effect of lip thickness on lip profile change after orthodontically treated patients with 4 first bicuspid extraction.* Korean J Orthod, 2002. **32**(5): p. 355-360.
17. Scott Conley, R. and C. Jernigan, *Soft tissue changes after upper premolar extraction in Class II camouflage therapy.* Angle Orthod, 2006. **76**(1): p. 59-65.
18. Solem, R.C., et al., *Three-dimensional soft-tissue and hard-tissue changes in the treatment of bimaxillary protrusion.* Am J Orthod Dentofacial Orthop, 2013. **144**(2): p. 218-28.
19. Trisnawaty, N., et al., *Effects of extraction of four premolars on vermilion height and lip area in patients with bimaxillary protrusion.* Eur J Orthod, 2013. **35**(4): p. 521-8.
20. Zierhut, E.C., et al., *Long-term profile changes associated with successfully treated extraction and nonextraction Class II Division 1 malocclusions.* Angle Orthod, 2000. **70**(3): p. 208-19.
21. Yasutomi, H., et al., *Effects of retraction of anterior teeth on horizontal and vertical lip positions in Japanese adults with the bimaxillary dentoalveolar protrusion.* Orthodontic Waves, 2006. **65**(4): p. 141-147.
22. Oliver, B.M., *The influence of lip thickness and strain on upper lip response to incisor retraction.* Am J Orthod, 1982. **82**(2): p. 141-9.
23. Lee, Y.J., *Perioral soft tissue evaluation of skeletal Class II division 1 : A cephalometric study*, in *College of dentistry*. 2013, Yonsei university.

24. Liou, E.J. and P.M. Chang, *Apical root resorption in orthodontic patients with en-masse maxillary anterior retraction and intrusion with miniscrews.* Am J Orthod Dentofacial Orthop, 2010. **137**(2): p. 207-12.
25. Burstone, C.J., *Cephalometrics for orthognathic surgery.* J Oral Surg, 1978. **36**(4): p. 269-277.
26. Rudee, D.A., *Proportional profile changes concurrent with orthodontic therapy.* American Journal of Orthodontics, 1964. **50**(6): p. 421-434.
27. Talass, M.F., L. Talass, and R.C. Baker, *Soft-tissue profile changes resulting from retraction of maxillary incisors.* Am J Orthod Dentofacial Orthop, 1987. **91**(5): p. 385-94.
28. Baumrind, S., et al., *Distal displacement of the maxilla and the upper first molar.* Am J Orthod, 1979. **75**(6): p. 630-40.
29. Hwang, C.J. and J.R. Moon, *The limitation of alveolar bone remodeling during retraction of the upper anterior teeth.* Korean J Orthod, 2001. **31**(1): p. 97-105.
30. Ramos, A.L., et al., *Upper lip changes correlated to maxillary incisor retraction--a metallic implant study.* Angle Orthod, 2005. **75**(4): p. 499-505.
31. Caplan, M.J. and P.K. Shivapuja, *The effect of premolar extractions on the soft-tissue profile in adult African American females.* Angle Orthod, 1997. **67**(2): p. 129-36.
32. Roos, N., *Soft-tissue profile changes in class II treatment.* Am J Orthod, 1977. **72**(2): p. 165-75.
33. Guo, Q.Y., et al., *Three-dimensional evaluation of upper anterior alveolar bone dehiscence after incisor retraction and intrusion in adult patients with bimaxillary protrusion malocclusion.* J Zhejiang Univ Sci B, 2011. **12**(12): p. 990-7.

국문요약

한국인 II급 1류 부정교합에서 절대고정원을 이용한 절충치료 후 연조직 변화

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김 가 영

본 연구는 한국인 II급 1류 부정교합 환자의 절충치료를 위해 상악과 하악의 소구치 발치 후 절대고정원을 이용해 전치부를 견인한 경우에 대해 연조직의 반응을 분석하고 이와 관련된 골격성 및 치성 변수를 예측하고자 하였다.

교정 치료를 완료한 57명에 대해 치료 전과 후의 측모두부규격 방사선사진을 계측하여 상악 전치 견인량을 기준으로 moderate retraction group(<8 ㎜)과 maximum retraction group(≥8.0 ㎜)으로 나누어 치료 전과 후의 골격적, 치성, 연조직 변화에 대해 비교하였다. 연조직의 변화와 경조직 변화 사이의 상관성을 분석하고 단순 선형 회귀분석을 시행하였다.

상악과 하악 전치의 절단연은 moderate retraction group에서 각각 5.3 ㎜, 4.4 ㎜ 견인되었고 maximum retraction group에서는 9.9 ㎜, 6.9 ㎜ 견인되어

두 그룹간에 유의한 차이가 있었다(P<0.001). 상순과 하순은 moderate retraction group에서 Ls는 2.3 mm, Li는 3.0 mm 견인되었고 maximum retraction group에서 Ls는 4.0 mm, Li는 5.3 mm 견인되어 두 그룹간 유의한 차이를 보였다(P<0.001). Moderate retraction group에서 Ls의 수평이동은 상악 전치 치경부와 상관성이 가장 높았고(R^2=0.64) 그 영향도(β=0.942) 가장 크게 나타났다. Li의 수평이동은 하악 전치 치경부와의 상관성이 가장 높았고(R^2=0.79), B point(β=0.837)와 하악 전치 치경부(β=0.830)의 영향이 크게 나타났다. Maximum retraction group에서는 상순의 변화에 유의성 있는 상관성을 보이거나 영향을 미치는 변수가 없어 예측이 어려웠다. Li의 수평이동은 하악 전치 절단연(R^2=0.51)과 치경부(R^2=0.46)와의 상관성이 높았고, 상악 전치 치경부(β=0.503)와 하악 전치 치경부(β=0.467)의 영향이 가장 크게 나타났으나 moderate retraction group과 비교해서 그 정도는 약하게 나타났다.

골성 고정원을 이용하여 전치부의 후방이동이 클 경우 연조직의 반응을 예측하는데 어려움이 있다. Class II Division 1 부정교합 환자의 연조직 치료목표 달성을 위하여 치료과정 중에 주기적인 측모 방사선 촬영 등을 통해 전치의 치경부 후방 이동량과 개별적인 연조직 반응을 평가해야 한다.

핵심이 되는 말 : 연조직 변화, II급 1류 부정교합, 전치부 견인, 절충치료, 절대 고정원