Effects of maximum retraction of anterior teeth on third order torque of incisors and soft and hard tissue changes by conventional and self-ligating brackets

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ABSTRACT

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In recent times, the clinical application of mini-screws for maximum anchorage has allowed an increased amount of retraction in the anterior teeth, resulting in optimal changes in the facial profile. Maximum retractions of anterior teeth are performed frequently in Asians, given the large number of patients with dentoalveolar protrusion. However, how much torque is expressed by anterior brackets during retraction of anterior teeth, according to the bracket system used, under the same conditions remains not well understood. In addition, although there are experimental results that indicate that active-type self–ligating brackets are more advantageous for torque

control than passive-type self–ligating brackets, there are no clinical studies on the subject, indicating the need for testing whether actual improvements can be obtained in clinical settings.

The present study examined cases involving retraction of the anterior teeth after extraction of the maxillary first premolars or the maxillary first premolars and mandibular premolars for orthodontic treatment in Korean patients with lip protrusion. The objective was to compare (1) the patterns of anterior tooth movement when using conventional brackets versus self–ligating brackets, and (2) the characteristics of changes in hard and soft tissues based on the use of such brackets.

The participants in the present study consisted of 64 patients who visited the Department of Orthodontics at Yonsei University Dental Hospital with the chief complaint of lip protrusion, and who subsequently underwent a retraction procedure after extraction of the maxillary first premolars or the maxillary first premolars and mandibular premolars. The participants were divided into active clip metal (ACM), active clip ceramic (ACC), passive clip metal (PCM), and conventional metal (CM) groups, based on the brackets used. Pre- and post-treatment lateral cephalograms acquired from these participants were analyzed and the skeletal, dental, and soft tissue changes from pre- to post-treatment were compared among the groups, and the following results were found:

1. Incisal tip of the maxillary anterior teeth at post-treatment showed retraction of 7.32 mm, 7.59 mm, 7.18 mm, and 7.29 mm in ACM, ACC, PCM, and CM groups, respectively, with no significant differences among the four groups ($p > 0.05$).
2. During retraction of the maxillary anterior teeth, changes in U1 to SN (°) was 10.2°, 11.6°, 13.5°, and 12.1° in ACM, ACC, PCM, and CM groups, respectively, with no

significant differences among the four groups. Changes in IMPA (˚) also showed no significant differences among the four groups ($p > 0.05$).

3. No significant differences in treatment duration were found among the 4 groups ($p > 0.05$).
4. Both the upper lip to E-line (mm) and the lower lip to E-line (mm) were decreased post-treatment in all four groups, but there were no statistically significant differences ($p > 0.05$). Horizontal changes in soft tissues, such as Sn, A', Ls, Stms, Stmi, B', and Pog', were not significantly different among the four groups ($p > 0.05$).
5. In multiple linear regression analyses, ⊿ U1 to SN (˚) showed significantly positive linearity with only Δ VRP to U1t (mm) ($p < 0.01$).

The results above showed that the type of ligation used with the brackets did not affect the inclination of the anterior teeth after maximum retraction of the maxillary anterior teeth. The final tooth inclination was affected by the amount of retraction in the anterior teeth, according to the treatment goals and horizontal and vertical skeletal characteristics, more so than by the type of ligation used with the brackets.

Keywords: Anterior tooth retraction, Pattern of anterior tooth movement, Self-ligating bracket, Soft tissue changes, Torque

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I. INTRODUCTION

The self-ligating bracket was first introduced in 1935 by Dr. Jacob Stolzenberg, as an alternative to steel or elastomeric module ligatures and to enhance treatment efficiency (Stolzenberg, 1935), and thereafter, it has evolved into various forms for clinical use. There is an increasing trend for using self-ligating brackets given that they offer a shorter treatment time than conventional brackets, as they are easier to ligate (Eberting et al., 2001; Pandis et al., 2007), have less friction, and are advantageous to initial tooth alignment (S. Thomas et al., 1998) . Among the various advantages of self-ligating brackets, their fast ligation speed reportedly increases clinical efficiency (Maijer and Smith, 1990), but this is still contentious, as there have been contradictory reports on treatment duration and treatment efficiency due to low friction.

According to a study by Eberting et al., among both extraction and non-extraction patients, those who used self-ligating brackets had a treatment duration that was 6.33 months shorter than that of patients who used conventional brackets; the number of appointments also decreased by 6.93-fold (Eberting et al., 2001). However, two recent systematic reviews have stated that there was insufficient evidence to support the notion that, in both extraction and non-extraction cases, simply using self-ligating brackets for treatment, regardless of the self-ligating method used, reduced the number of appointments and shortened the treatment duration as compared to conventional brackets (Chen et al., 2010; Fleming and Johal, 2010). A summary of these study results indicates that it is not easy to find objective evidence of the effects of self-ligating brackets on treatment duration and efficiency.

Self-ligating brackets can be divided into either the passive or active self-ligating method, depending on the form of the self-ligature and whether force is applied to the arch wire. The type of bracket that has a spring clip that applies active force on the arch wire is referred to as active or interactive self-ligating brackets, which include SPEED™ (Strite Industries Ltd, Cambridge, Ontario, Canada) and Clippy-C™ (Tomy International Inc., Tokyo, Japan) brackets. On the other hand, passive-type self-ligating brackets have a self-ligating clip that does not push down on the arch wire; a primary example of this type of bracket is the Damon™ (Ormco, Glendora, CA, USA).

Laboratory studies on frictional characteristics of orthodontic brackets have reported that self-ligating brackets have reduced friction-resistance as compared to conventional brackets

(Henao and Kusy, 2005; Tecco et al., 2007) and that passive-type brackets produce less frictional resistance than active-type brackets (Budd et al., 2008; Kim et al., 2008). Another laboratory study (Susan Thomas et al., 1998) has also shown that the lowest friction was found in passive-type self-ligating brackets, and although active-type self-ligating brackets had more friction than the passive-type, and both types of brackets showed less friction than conventional brackets. Meanwhile, it has been reported that there were no significant differences in the frictional force between passive- and active-type self-ligating brackets in simulated dentition with moderate crowding (Matarese et al., 2008). Therefore, the results from different laboratory studies may vary, depending on various clinical conditions. Furthermore, it is unlikely that the observations of reduced friction and faster tooth movement found in laboratory studies would also be valid in the clinical situation. There have been no well-designed study specific for one type of bracket system, and no studies have used the same treatment process. Additionally, the results of clinical trials using a specialized method are not yet available; therefore, further clinical trials are needed on these topics.

Another area of interest for orthodontic outcomes is the expression of torque, due to the combination of brackets and wires. In studies related to torque expression from the anterior teeth (Badawi et al., 2008; Katsikogianni et al., 2015), it was found that active clips reduced the clearance between the arch wire and slot, exerting effective torque in an efficient manner. Based on such results, it is believed that using active-type self-ligating brackets on the anterior teeth can be helpful in extraction cases. However, the fact that these studies were conducted under laboratory conditions and that there are conflicting results on combinations of various slots and wire sizes (Chung et al., 2009) indicate the need for future clinical trials on these topics.

Meanwhile, results from clinical trials showed no differences in the expression of torque from the anterior teeth (Chung et al., 2009; Pandis et al., 2006). Pandis et al. investigated 105 patients using an *in vivo* method and found that comparisons of pre- and post-treatment angular measurements in cases treated with conventional brackets and passive clip brackets showed that self-ligating brackets delivered torque to maxillary incisors with an efficiency equivalent to those of conventional brackets for both extraction and non-extraction cases. However, this study was conducted using only passive-type brackets, and was therefore limited in terms of the comparisons of clinical outcomes that could be made according to bracket types.

With the development of self-ligating brackets, many laboratory studies have focused on torque control in conventional and self-ligating brackets, but clinical trials have been almost non-existent. Recently, the tendency for using absolute anchorage, such as mini-screws, has increased, which has led to more anterior tooth retraction, which has expanded the range of teeth movement. Moreover, retraction procedures are being performed, particularly among Asians, given the large number of extraction patients. However, no information is available on the levels of torque expressed by various bracket systems under the same retraction conditions. Moreover, although there are laboratory study results that indicate that active-type self-ligating brackets offer more advantageous torque control than passive-type self-ligating brackets, there are no clinical studies to support this, and thus, it is necessary to assess whether such improvements can be achieved in clinical settings.

Accordingly, the present study examined cases involving retraction of the anterior teeth after extraction of the maxillary first premolars or the maxillary first premolars and mandibular premolars for orthodontic treatment in Korean patients with lip protrusion. The objective was to compare (1) the patterns of anterior tooth movement when using conventional brackets versus self-ligating brackets and (2) the characteristics of changes in hard and soft tissues, based on the use of such brackets.

II. MATERIALS AND METHODS

1. Subjects

The present study was retrospectively conducted with the approval of Institutional Review Board (IRB) at Yonsei University Dental Hospital. Among a total of 1,282 patients who underwent completed orthodontic treatment at the Department of Orthodontics at Yonsei University Dental Hospital between January 2006 and January 2013, those who satisfied the criteria given below, based on measurement of the cephalometric radiographs, were included in the study. By excluding those who did not satisfy the inclusion criteria below, a total of 64 patients (16 males and 48 females) were selected to participate. The selection criteria were:

(1) Patients who were 16 years or older and whose pre- and post-treatment radiographs were available

(2) Patients who underwent extraction of the maxillary first premolars or the maxillary first premolars and mandibular premolars for the chief complaint of lip protrusion

(3) Patients with maxillary anterior teeth retraction of ≥ 5 mm, but ≤ 10 mm

(4) Patients with a pre-treatment ANB value of ≥ 2°, but ≤ 7°

(5) Patients with a pre-treatment U1 to SN value of ≥ 100°, but ≤ 125°

Among those who satisfied the above criteria, patients with the following conditions were excluded:

(1) Patients with maxillofacial deformities, such as cleft palate

(2) Patients who had undergone orthognathic surgery

(3) Patients with impacted teeth

(4) Patients with missing teeth except for the third molars

Based on the brackets used, the participants were divided into four groups; active clip metal (ACM, SPEED™), active clip ceramic (ACC, Clippy-C™), passive clip metal (PCM, Damon™), and conventional metal (CM, Micro-arch™) groups.

A total of 11 patients (6 males and 5 females) were assigned to ACM group and their mean age at the start of treatment was 20.8 years. A total of 13 patients (1 male and 12 females) were assigned to the ACC group and their mean age at the start of treatment was 22.1 years. A total of 19 patients (5 males and 14 females) were assigned to the PCM group and their mean age at the start of treatment was 22.4 years, while 21 patients (4 male and 17 females) were assigned to CM group; their mean age at the start of treatment was 23.4 years. Analysis of variance (ANOVA) was performed to compare the mean age of the four groups at the start of treatment; there were no statistically significant differences ($p > 0.05$; Table 1).

Table 1. Demographic features of subjects

	Group					
	ACM group Mean (±SD)	*ACC group Mean (±SD)*	*PCM group Mean (±SD)*	*CM group Mean (±SD)*	*Total Mean (±SD)*	*P value*
Ages (years)	20.8 (±4.0)	22.1 (±3.4)	22.4 (±5.9)	23.4 (±5.9)	22.4 (±5.1)	0.597
Male (N)	6	1	5	4	16	
Female (N)	5	12	14	17	48	
Total (N)	11	13	19	21	64	

ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal.

2. Measurements

A. Lateral cephalography

Pre- and post-treatment lateral cephalograms (T1 and T2, respectively) of the study participant were evaluated for changes. Lateral cephalography was performed at the Department of Radiology at Yonsei University Dental Hospital, using Cranex3+ (Soredex, Helsinki, Finland) with the head in its natural position and lips relaxed and closed naturally.

B. Lateral cephalometric measurements

The lateral cephalograms used during the participant selection process were acquired during the initial evaluation and the measurements were taken by a single person using V-Ceph^{TM} 5.5 (Osstem, Seoul, South Korea). The measurements were taken in units of 0.01 mm for length and 0.01° for angle.

The reference planes used during the measurements included a horizontal reference plane (HRP), which was 7° below the line from sella–nasion line to the sella (Burstone et al., 1978), and a vertical reference plane (VRP), which was the plane that bypassed the sella and was perpendicular to the HRP. The measurements were taken from T1, T2, and superimposed T1 and T2 lateral cephalograms. The major lateral cephalometric measurements used in the present study were as shown in Table 2 and Figure 1.

Table 2. Description of cephalometric measurements

Skeletal analysis	Dental analysis	Soft tissue analysis
SNA (˚)	U1 to SN (˚)	Upper lip to E-line (mm)
SNB (˚)	U1 to NA (mm. degree)	Lower lip to E-line (mm)
ANB (˚)	U1 to NB (mm, degree)	VRP to Sn (mm)
Wits (mm)	IMPA (˚)	VRP to A'(mm)
SN-GoMe (˚)	Interincisal Angle (˚)	VRP to Ls (mm)
Occlusal plane to GoMe (˚)	Overjet (mm)	VRP to Stms (mm)
FMA (˚)	Overbite (mm)	VRP to Stmi (mm)
VRP to A (mm)	VRP to U1t (mm)	VRP to Li (mm)
VRP to B (mm)	VRP to U1c (mm)	VRP to B'(mm)
VRP to Pog (mm)	VRP to L1t (mm)	VRP to Pog'(mm)
	VRP to L1c (mm)	
	HRP to U1t (mm)	
	HRP to L1t (mm)	

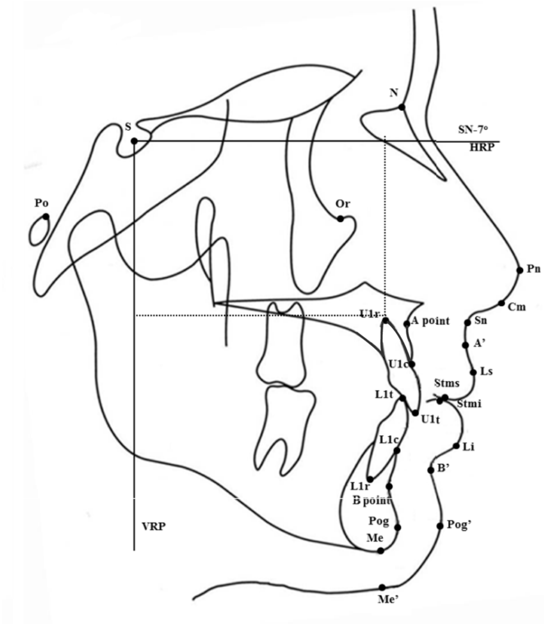

Figure 1. Landmarks, reference lines, and definitions of measurement for cephalometric analysis. Horizontal (HRP) and vertical (VRP) reference planes used to measure movements of individual landmarks: sella (S), nasion (N), A point (A), B point (B), pogonion (Pog), menton (Me), root apex of the maxillary central incisor (U1r), cervical point of the maxillary central incisor (U1c), tip of the maxillary central incisor (U1t), tip of the mandibular central incisor (L1t), cervical point of the mandibular central incisor (L1c), root apex of the mandibular central incisor (L1r), pronasale (Pn), collumela (Cm), subnasale (Sn), soft tissue A point (A'), labrale superioris (Ls), stomion superioris (Stms), stomion inferioris (Stmi), labrale inferioris (Li), soft tissue B point (B'), soft tissue pogonion (Pog'), soft tissue menton (Me').

C. Brackets and arch wires used

A total of four different types of brackets were used in the study and their types and characteristics are shown in Table 3 and Figure 2.

Table 3. Characteristics of brackets used in this study

Group	Type of ligation Bracket	Clip design	Slot size (inches)	Prescription	Manufacturer	Upper central incisor torque
	Self-ligating					
ACM	SPEED™	Active	018	Roth	Strite Industries, Canada	+12°
ACC	Clippy-C™	Active	018	Roth	Tomy Inc., Japan	+12°
PCM	Damon™	Passive	022	Standard	Ormco, USA	+12°
	Conventional					
CM	Micro-arch™		018	Roth	Tomy Inc., Japan	+12°

Three types of self-ligating brackets and one type of conventional bracket were studied. Self-ligating brackets included the SPEED™ (Strite Industries Ltd, Cambridge, Ontario, Canada) and Clippy-C™ (Tomy International Inc., Tokyo, Japan) active-type, and the Damon™ (SDS Ormco, Glendora, CA, USA) passive-type, while the conventional bracket used was the Micro-arch™ (Tomy International Inc., Tokyo, Japan).

For the tooth movement method, the sliding mechanics method, using the maxillary skeletal anchorage that is currently widely used, was selected. The wires used during anterior tooth retraction were .017 × .025 SS or .018 × .018 Hills dual geometry arch wire for the SPEED™ bracket and .017 × .025 SS for all the other brackets, except for the Damon™, where .019 × .025 SS was used. The initial arch wire used was .014 or .016 NiTi, while the finishing arch wire used was .016 × .022 TMA for all, except for the Damon™ bracket (.017 × .025 TMA).

Orthodontic treatments were performed by 3 full time faculty specialists from the Department of Orthodontics at Yonsei University Dental Hospital, each of whom had more than 10 years of orthodontic experience.

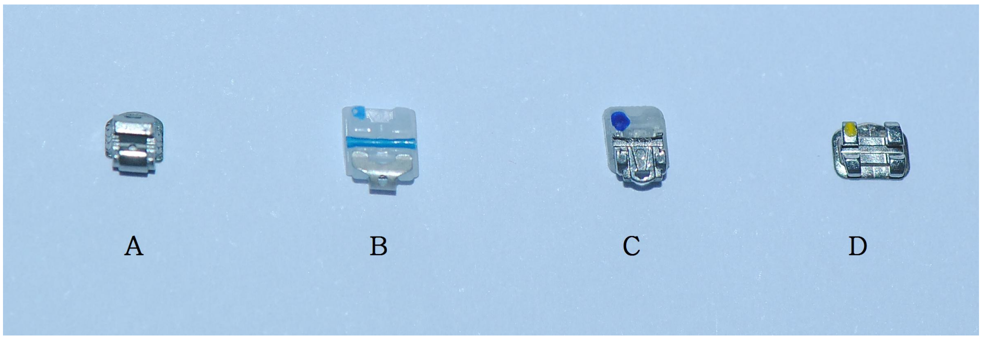

Figure 2. Different types of brackets (#11) used in this study. A. SPEED™ bracket (ACM group), B. Clippy-C™ bracket (ACC group), C. Damon™ bracket (PCM group), D. Micro-arch™ bracket (CM group).

D. Intra-examiner error and methodic error

To prevent intra-examiner error, all measurements and analyses were performed by the same examiner, and to verify intra-examiner error, two repeated measurements were made on 10 randomly selected participants, using the V-ceph 5.5 (Osstem Inc., Busan, Korea) program, with an accuracy of 0.01 mm.

E. Statistical analysis

The following statistical analyses were performed on the measured data, using SPSS 21.0 (SPSS Inc., Chicago, IL, USA) program. Normality test results showed that a normal distribution was satisfied, and consequently, parametric tests were used for comparisons. Statistical differences were accepted at a significance level of 95%.

(1) Intra-examiner error test (intraclass correlation coefficient)

(2) Comparisons of measurement items for each group (one-way ANOVA with post-hoc Scheffe test)

(3) Correlation analyses between measurement items (Pearson’s correlation analysis)

(4) Multiple linear regression analyses between measurement items (multiple linear regression analysis)

III. RESULTS

1. Intra-examiner error test

For assessment of the reliability of measurements in the present study, 10 participants were randomly selected from each group and were re-measured in 2-week intervals. The result of reliability testing by the intraclass correlation coefficient (ICC) showed that the agreement among measurements was high (≥ 0.9 in all cases).

2. Treatment time, the amount of arch length discrepancy (ALD) on maxillary dentition, and distribution of extraction according to dentition

The mean treatment duration was 3.0 years, and ACM, ACC, PCM, and CM groups showed no significant difference, with values of 2.9, 3.0, 3.0, and 3.1 years, respectively ($p > 0.05$). The mean amount of maxillary crowding was 2.7 mm, which was mild, and ACM, ACC, PCM, and CM groups were not significantly different, with values of 3.2, 2.4, 2.9, and 2.3 mm, respectively ($p > 0.05$). The mean amount of mandibular crowding was 3.6 mm. This was not significantly different in the ACM, ACC, PCM, and CM groups (3.3, 2.5, 4.0, and 4.0 mm, respectively; $p > 0.05$; Table 4).

Table 4. Treatment time, the amount of arch length discrepancy (ALD) on maxillary dentition, and distribution of extraction according to dentition

	Group					
	ACM group Mean (±SD)	*ACC group Mean (±SD)*	*PCM group Mean (±SD)*	*CM group Mean (±SD)*	*Total Mean (±SD)*	*P value*
Treatment time (years)	2.9 (±1.1)	3.0 (±0.5)	3.0 (±0.8)	3.1 (±0.9)	3.0 (±0.8)	0.941
ALD maxilla (mm)	3.2 (±2.9)	2.4 (±2.1)	2.9 (±3.8)	2.3 (±2.1)	2.7 (±2.8)	0.791
ALD mandible (mm)	3.3 (±3.6)	2.5 (±2.4)	4.0 (±3.8)	4.0 (±3.3)	3.6 (±3.4)	0.662
Mx & Mn ext (N)	10	10	15	19	54	
Mx ext (N)	1	3	4	2	10	
Total (N)	11	13	19	21	64	

ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal; ALD, Arch length discrepancy; Mx & Mn ext, extraction of upper first premolars and lower premolars; Mx ext, extraction of upper first premolars only.

3. Comparisons of measurement items among ACM, ACC, PCM, and CM groups

A. Statistical comparisons of pre-treatment measurement items

There were no significant differences among the four groups with respect to pre-treatment skeletal characteristics ($p > 0.05$). Among the skeletal characteristics, the mean value of Wits (mm) appeared to be in the order (highest to lowest) of ACM, PCM, ACC, and CM groups, and were statistically significantly different among groups ($p < 0.05$). However, Scheffe's multiple comparison test showed no inter-group differences (Table 5).

The pre-treatment maxillary anterior teeth angle U1 to SN in the ACM, ACC, PCM, and CM groups was 108.69˚, 108.42˚, 112.44˚, and 108.86˚, which showed no significant differences ($p > 0.05$; Table 6).

Table 5. Comparison of the skeletal variables between groups at pre-treatment (T1)

	ACM group (n = 11)		*ACC group (n = 13)*		*PCM group (n = 19)*		*CM group (n = 21)*		
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P value*
SNA (˚)	80.15	±3.17	81.31	±3.78	82.19	±3.82	80.22	±3.04	0.264
SNB (˚)	75.46	±3.96	76.34	±3.80	77.37	±3.73	76.14	±3.20	0.532
ANB difference (˚)	4.69	±1.16	4.97	±1.26[a]	4.82	±1.29	4.08	±1.28[a]	0.163
Wits (mm)	2.22	±2.43	0.36	±2.56	1.04	±2.88	-0.64	±2.71	0.037*
SN-GoMe (˚)	39.20	±6.38	37.76	±4.85	36.42	±4.46	38.01	±4.73	0.513
Occlusal plane to GoMe (˚)	20.75	±3.77	17.60	±2.88	18.32	±2.93	17.41	±3.59	0.052
FMA (˚)	29.70	±6.61	27.65	±3.92	27.26	±4.24	29.04	±3.65	0.412
VRP to A (mm)	70.04	±4.32	67.10	±4.30	69.07	±5.59	67.80	±4.31	0.395
VRP to B (mm)	57.99	±7.61	56.20	±7.00	59.19	±7.93	57.81	±6.83	0.732
VRP to Pog (mm)	56.44	±7.47	54.98	±8.12	59.17	±8.68	56.57	±7.53	0.510

VRP, vertical reference plane; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal; [a] Significantly different between the ACC group and the CM group ($p < 0.05$); *$p < 0.05$.

Table 6. Comparison of the dental variables between groups at pre-treatment (T1)

Variable	*ACM group (n = 11)* *Mean*	*SD*	*ACC group (n = 13)* *Mean*	*SD*	*PCM group (n = 19)* *Mean*	*SD*	*CM group (n = 21)* *Mean*	*SD*	*P value*
U1 to SN (˚)	108.69	±5.83	108.42	±4.57	112.44	±5.76	108.86	±5.03	0.093
U1 to NA (˚)	28.54	±4.95	27.11	±3.62	30.25	±5.96	28.64	±5.04	0.394
U1 to NA (mm)	8.46	±1.77	7.80	±1.29	8.62	±2.22	8.09	±2.37	0.690
L1 to NB (˚)	36.12	±7.00	37.52	±3.06	32.84	±4.93	35.30	±5.56	0.094
L1 to NB (mm)	11.60	±3.04	11.08	±1.58	10.07	±1.63	10.11	±2.13	0.146
IMPA (˚)	101.48	±7.03	103.43	±4.49	99.06	±6.91	101.17	±6.39	0.298
Interincisal angle (˚)	110.65	±9.24	110.41	±4.16	112.09	±7.26	111.98	±8.01	0.888
Overjet (mm)	4.76	±2.16	4.74	±2.22	6.38	±2.46	4.60	±2.01	0.059
Overbite (mm)	1.25	±1.54	1.18	±1.95	2.11	±1.17	1.29	±1.17	0.183
VRP to U1t (mm)	77.14	±5.41	74.14	±5.47	77.40	±6.55	74.66	±5.74	0.296
VRP to U1c (mm)	74.88	±4.62	71.75	±4.76	74.00	±6.13	72.15	±4.95	0.348
VRP to L1t (mm	72.71	±6.52	69.81	±6.32	71.41	±7.17	70.49	±6.43	0.721
VRP to L1c (mm)	67.54	±6.35	64.74	±6.96	67.43	±7.57	65.90	±6.53	0.666
HRP to U1t (mm)	86.44	±5.49	83.10	±4.09	83.15	±3.77	82.50	±4.24	0.102
HRP to L1t (mm)	84.30	±5.78	80.82	±3.81	80.30	±4.04	80.15	±3.78	0.057

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; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal.

Table 7. Comparison of the soft tissue variables between groups at pre-treatment (T1)

	ACM group (n = 11)		*ACC group (n = 13)*		*PCM group (n = 19)*		*CM group (n = 21)*		
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P value*
Upper lip to E-line (mm)	2.08	±2.30	1.79	±1.97	1.75	±1.57	1.15	±2.14	0.585
Lower lip to E-line (mm)	4.33	±2.89	3.95	±2.30	3.71	±1.33	3.37	±1.88	0.627
VRP to Sn (mm)	85.20	±4.88	80.48	±3.81	83.28	±6.45	81.85	±5.13	0.153
VRP to A' (mm)	85.62	±5.66	80.55	±4.26	83.92	±6.79	82.11	±5.34	0.137
VRP to Ls (mm)	89.58	±5.20	84.46	±5.36	87.60	±6.90	85.41	±5.99	0.142
VRP to Stms (mm)	83.57	±7.17	78.64	±5.48	81.90	±6.71	79.41	±5.87	0.166
VRP to Stmi (mm)	81.23	±6.02	77.71	±6.52	80.24	±7.14	78.28	±5.86	0.442
VRP to Li (mm)	83.36	±5.78	79.27	±8.28	80.59	±8.26	79.90	±6.41	0.492
VRP to B' (mm)	73.99	±6.37	71.74	±7.53	74.64	±8.08	73.05	±6.90	0.609
VRP to Pog' (mm)	70.91	±7.83	69.06	±7.63	72.10	±8.58	70.30	±7.80	0.550

VRP, vertical reference plane; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal.

B. Statistical comparisons of post-treatment measurement items

There were no significant differences among the four groups with respect to post-treatment skeletal and soft tissue characteristics ($p > 0.05$). Among the dental characteristics, statistically significant differences were seen in HRP to U1t (mm) values ($p < 0.05$), but Scheffe's multiple comparison test results showed no inter-group differences (Table 9).

Table 8. Comparison of the skeletal variables between groups at post-treatment (T2)

	ACM group (n = 11)		*ACC group (n = 13)*		*PCM group (n = 19)*		*CM group (n = 21)*		
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*P value*
SNA (˚)	79.74	±3.47	80.37	±3.74	81.76	±3.97	79.93	±3.52	0.369
SNB (˚)	75.03	±3.81	76.04	±3.80	77.51	±4.18	75.65	±2.91	0.267
ANB difference (˚)	4.70	±1.39	4.33	±1.74	4.26	±1.63	4.28	±1.57	0.887
Wits (mm)	1.10	±2.39	-0.98	±2.75	-0.41	±2.94	0.14	±1.79	0.204
SN-GoMe (˚)	39.22	±6.50	37.83	±5.03	36.55	±4.92	38.29	±4.28	0.530
Occlusal plane to GoMe (˚)	18.89	±4.16	16.32	±3.51	17.33	±3.76	17.79	±3.29	0.377
FMA (˚)	30.08	±7.08	27.64	±4.41	27.68	±4.65	29.45	±3.45	0.406
VRP to A (mm)	69.48	±5.05	66.22	±4.46	68.67	±6.06	67.42	±4.58	0.391
VRP to B (mm)	57.08	±7.45	56.06	±7.47	59.64	±9.13	56.94	±6.10	0.552
VRP to Pog (mm)	56.25	±8.18	55.11	±8.62	59.81	±9.74	56.22	±6.95	0.391

VRP, vertical reference plane; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal.

Table 9. Comparison of the dental variables between groups at post-treatment (T2)

Variable	*ACM group (n = 11)* Mean	SD	*ACC group (n = 13)* Mean	SD	*PCM group (n = 19)* Mean	SD	*CM group (n = 21)* Mean	SD	*P value*
U1 to SN (˚)	98.53	±6.46	96.85	±4.58	98.96	±5.65	96.81	±5.43	0.559
U1 to NA (˚)	18.79	±6.60	16.49	±4.08	17.19	±7.04	16.88	±5.81	0.801
U1 to NA (mm)	2.09	±1.51	2.12	±1.84	2.48	±1.74	1.99	±1.52	0.813
L1 to NB (˚)	24.80	±3.94	27.32	±5.15	26.42	±8.01	23.82	±4.52	0.313
L1 to NB (mm)	6.14	±2.61	5.51	±2.41	5.69	±2.24	5.02	±1.89	0.577
IMPA (˚)	90.58	±5.98	93.47	±6.42	92.42	±10.78	89.89	±5.75	0.543
Interincisal angle (˚)	131.70	±7.68	131.87	±6.22	132.12	±13.53	135.02	±7.83	0.694
Overjet (mm)	3.86	±0.53	3.06	±0.60	3.37	±1.05	3.19	±0.72	0.079
Overbite (mm)	2.61	±0.76	1.72	±0.74	2.01	±1.04	2.12	±0.98	0.139
VRP to U1t (mm)	69.82	±5.30	66.56	±5.56	70.22	±7.16	67.37	±5.62	0.260
VRP to U1c (mm)	70.03	±5.27	66.80	±4.87	70.41	±7.06	67.72	±5.29	0.251
VRP to L1t (mm)	66.66	±5.00	64.02	±5.26	67.33	±6.72	64.75	±5.53	0.333
VRP to L1c (mm)	63.54	±5.96	60.63	±6.12	64.23	±7.94	61.75	±5.90	0.421
HRP to U1t (mm)	86.57	±5.07	82.35	±3.97	82.90	±4.12	82.02	±4.51	0.046*
HRP to L1t (mm)	83.16	±5.11	79.93	±3.87	80.24	±4.42	79.22	±4.14	0.116

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; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal; $^{*}p < 0.05$.

Table 10. Comparison of the soft tissue variables between groups at post-treatment (T2)

Variable	*ACM group (n = 11)* Mean	SD	*ACC group (n = 13)* Mean	SD	*PCM group (n = 19)* Mean	SD	*CM group (n = 21)* Mean	SD	*P value*
Upper lip to E-line (mm)	-0.66	±3.26	-1.11	±2.12	-1.23	±1.73	-1.29	±1.86	0.878
Lower lip to E-line (mm)	0.14	±2.85	-0.21	±2.40	-0.78	±1.50	-1.20	±1.68	0.281
VRP to Sn (mm)	84.40	±5.91	79.96	±3.55	82.67	±6.87	81.24	±4.80	0.218
VRP to A' (mm)	83.48	±5.78	78.88	±4.16	82.14	±7.54	80.36	±4.88	0.211
VRP to Ls (mm)	86.31	±6.20	81.57	±4.88	84.62	±7.89	82.40	±5.50	0.215
VRP to Stms (mm)	78.81	±7.32	74.01	±5.63	77.97	±8.31	74.69	±6.04	0.178
VRP to Stmi (mm)	75.67	±5.94	72.17	±5.80	75.59	±7.36	73.19	±5.79	0.346
VRP to Li (mm)	78.55	±6.30	75.30	±7.24	78.63	±8.71	76.15	±6.25	0.492
VRP to B' (mm)	71.71	±7.17	69.55	±7.25	73.08	±8.78	70.90	±6.63	0.609
VRP to Pog' (mm)	69.94	±7.61	68.47	±8.46	72.47	±9.21	69.71	±7.15	0.550

VRP, vertical reference plane; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal.

C. Statistical comparisons of the amount of change between pre- and post-treatment

Changes in Wits (mm) showed a significantly higher value in the PCM group than in the CM group ($p < 0.01$; Table 11).

All maxillary and mandibular anterior teeth tips and cervical points had retracted by post-treatment. Maxillary anterior teeth tips and cervical points had retracted by 7.32 and 4.85 mm, 7.59 and 4.95 mm, 7.18 mm, 3.59 mm, and 7.29 and 4.43 mm in the ACM, ACC, PCM and CM groups, respectively, and there were no significant differences among the four groups ($p > 0.05$).

Vertical changes in the maxillary and mandibular anterior teeth were small compared to the horizontal changes, and there were no significant changes among the four groups ($p > 0.05$).

During maxillary anterior tooth retraction, changes in U1 to SN (˚) were 10.16˚, 11.57˚, 13.48˚, and 12.06˚ in the ACM, ACC, PCM, and CM groups, respectively, showing no significant differences among the four groups. Changes in IMPA (˚) also showed no significant differences among the four groups ($p > 0.05$; Table 12).

Both the upper lip to E-line (mm) and the lower lip to E-line (mm) had decreased in all four groups by post-treatment, but there were no statistically significant differences ($p > 0.05$). The horizontal changes in soft tissues, such as Sn, A', Ls, Stms, Stmi, B', and Pog', were not significantly different among the four groups ($p > 0.05$), whereas Li retracted by 4.81 mm, 3.97 mm, 1.96 mm, and 3.75 mm in the ACM, ACC, PCM and CM groups, respectively. The ACM group showed a significantly greater change than did the PCM group ($p < 0.01$; Table 13).

Table 11. Comparison of the changes in skeletal variables between groups during the treatment period (T1-T2)

Variable	*ACM group (n = 11)* Mean	SD	*ACC group (n = 13)* Mean	SD	*PCM group (n = 19)* Mean	SD	*CM group (n = 21)* Mean	SD	*P value*
Δ SNA (˚)	0.41	±1.07	0.94	±1.09	0.42	±0.56	0.29	±0.98	0.237
Δ SNB (˚)	0.42	±0.95	0.31	±0.86	-0.14	±1.14	0.49	±0.95	0.225
Δ ANB difference (˚)	-0.01	±1.29	0.63	±1.04	0.56	±0.90	-0.20	±1.17	0.072
Δ Wits (mm)	1.12	±1.97	1.33	±1.67	1.44	±2.20[a]	-0.78	±2.37[a]	0.005[†]
Δ SN-GoMe (˚)	-0.02	±1.18	-0.07	±0.73	-0.13	±1.30	-0.29	±1.91	0.955
Δ Occlusal plane to GoMe (˚)	1.86	±1.81	1.28	±2.12	0.99	±2.74	-0.38	±2.79	0.076
Δ FMA (˚)	-0.04	±2.64	0.01	±1.55	-0.41	±1.73	-0.41	±2.19	0.933
Δ VRP to A (mm)	0.56	±1.33	0.88	±1.07	0.40	±0.70	0.38	±1.04	0.520
Δ VRP to B (mm)	0.91	±1.93	0.14	±1.57	-0.45	±2.05	0.87	±1.92	0.120
Δ VRP to Pog (mm)	0.18	±2.14	-0.12	±1.50	-0.65	±1.80	0.36	±2.54	0.484

VRP, vertical reference plane; [a] Significantly different between the PCM group and CM group ($p < 0.05$); ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal; Δ, difference between T1 and T2; [†]$p < 0.01$.

Table 12. Comparison of the changes in dental variables between groups during the treatment period (T1-T2)

Variable	ACM group (n = 11) Mean	SD	ACC group (n = 13) Mean	SD	PCM group (n = 19) Mean	SD	CM group (n = 21) Mean	SD	P value
Δ U1 to SN (˚)	10.16	±6.65	11.57	±3.23	13.48	±5.36	12.06	±5.92	0.440
Δ U1 to NA (˚)	9.75	±7.26	10.62	±3.28	13.06	±5.38	11.77	±6.14	0.426
Δ U1 to NA (mm)	6.37	±2.13	5.68	±1.98	6.13	±1.19	6.10	±2.60	0.866
Δ L1 to NB (˚)	11.32	±8.05	10.20	±5.35	6.41	±8.63	11.47	±6.29	0.133
Δ L1 to NB (mm)	5.46	±2.88	5.58	±2.81	4.38	±3.13	5.08	±2.15	0.598
Δ IMPA (˚)	10.90	±7.79	9.96	±5.67	6.64	±8.46	11.28	±6.24	0.197
Δ Interincisal angle (˚)	-21.05	±11.35	-21.46	±5.95	-20.03	±12.74	-23.04	±10.45	0.847
Δ Overjet (mm)	0.91	±2.17	1.68	±2.37	3.00	±2.60	1.41	±2.04	0.071
Δ Overbite (mm)	-1.36	±1.48	-0.54	±1.69	0.10	±1.57	-0.83	±1.34	0.072
Δ VRP to U1t (mm)	7.32	±1.41	7.59	±1.61	7.18	±1.35	7.29	±1.26	0.879
Δ VRP to U1c (mm)	4.85	±1.99	4.95	±1.57	3.59	±1.99	4.43	±1.05	0.088
Δ VRP to L1t (mm)	6.05	±2.27	5.79	±2.32	4.08	±2.87	5.74	±2.11	0.081
Δ VRP to L1c (mm)	4.00	±1.47	4.11	±2.07	3.20	±2.15	4.15	±1.92	0.423
Δ HRP to U1t (mm)	-0.13	±1.52	0.75	±1.35	0.25	±1.46	0.47	±1.76	0.555
Δ HRP to L1t (mm)	1.14	±2.10	0.89	±2.15	0.06	±1.76	0.93	±1.79	0.376

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; ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal.

Table 13. Comparison of the changes in soft tissue variables between groups during the treatment period (T1-T2)

Variable	*ACM group (n = 11)* Mean	SD	*ACC group (n = 13)* Mean	SD	*PCM group (n = 19)* Mean	SD	*CM group (n = 21)* Mean	SD	*P value*
Δ Upper lip to E-line (mm)	2.74	±1.91	2.91	±2.01	2.99	±1.43	2.45	±1.52	0.755
Δ Lower lip to E-line (mm)	4.19	±1.81	4.16	±1.79	4.49	±1.57	4.57	±1.79	0.881
Δ VRP to Sn (mm)	0.81	±1.31	0.52	±0.97	0.61	±0.88	0.61	±1.21	0.932
Δ VRP to A' (mm)	2.14	±0.74	1.67	±1.27	1.78	±1.33	1.76	±1.40	0.812
Δ VRP to Ls (mm)	3.28	±2.46	2.89	±1.41	2.98	±1.69	3.00	±1.76	0.960
Δ VRP to Stms (mm)	4.77	±3.35	4.63	±1.60	3.93	±3.19	4.73	±1.81	0.738
Δ VRP to Stmi (mm)	5.56	±2.35	5.54	±2.00	4.65	±2.10	5.09	±2.27	0.618
Δ VRP to Li (mm)	4.81	±1.68[a]	3.97	±1.97	1.96	±2.18[a]	3.75	±2.01	0.002†.
Δ VRP to B' (mm)	2.28	±2.92	2.19	±2.25	1.56	±2.03	2.15	±2.15	0.787
Δ VRP to Pog' (mm)	0.97	±2.12	0.59	±2.43	-0.37	±2.25	0.58	±2.56	0.424

VRP, vertical reference plane; [a] Significantly different between the ACM group and the PCM group ($p < 0.05$); ACM, Active clip metal; ACC, Active clip ceramic; PCM, Passive clip metal; CM, Conventional metal; † $p < 0.01$.

D. Correlation analysis between measurement items

Pearson correlation analysis was performed to examine whether skeletal and dental variables were correlated with the final angle of the maxillary and mandibular central incisors at post-treatment and angular differences from pre- to post-treatment.

Post-treatment U1 to SN (˚) showed significantly negative correlations with the following, in the order of; post-treatment SN-GoMe (˚) ($p < 0.01$), post-treatment ANB difference (˚) ($p < 0.05$), and Δ VRP to U1t (mm), which is the amount of retraction of the maxillary anterior teeth tips from pre- to post-treatment ($p < 0.05$).

Δ U1 to SN (˚) showed a significantly positive correlation only with Δ VRP to U1t (mm) ($p < 0.01$), while no significant correlation was found in IMPA T2(˚) and Δ IMPA (˚) ($p > 0.05$) (Table 14).

Table 14. Pearson's correlation coefficients between U1 to SN (˚) T2, Δ U1 to SN (˚) and Δ VRP to U1t (mm), SN-GoMe T2 (˚), ANB difference T2 (˚)

	Δ VRP to U1t (mm)	**ANB T2 (˚)**	**SN-GoMe T2 (˚)**
U1 to SN T2 (˚)	-0.28*	-0.32*	-0.34†
Δ U1 to SN (˚)	0.35†	0.07	-0.15
IMPA T2 (˚)	-0.08	0.23	-0.20
Δ IMPA (˚)	0.21	-0.21	-0.18

VRP, vertical reference plane; U1t, tip of the maxillary central incisor; Δ, difference between T1 and T2; *$p < 0.05$; †$p < 0.01$.

E. Multiple linear regression analysis between measurement items

Analyses were performed by applying the dependent variables U1 to SN T2 (˚) and Δ U1 to SN (˚) and the independent variables used in the correlation analysis to the multiple linear regression analysis, while the group factor (ACM, ACC, PCM, and CM) was also included in the linear regression analysis as a dummy variable. The significance of each model is shown in Table 15, while the significance of each independent variable included in the models is shown in Table 16. The stepwise method was used to select the optimal model, and since the dummy variable was eliminated by the stepwise method, it was clear that the group had no effect (Table 16).

The explanatory power (adjusted R^2) of the regression model that explains U1 to SN T2 (˚) and Δ U1 to SN (˚) was 0.20 and 0.13, respectively. Although these values were not very high, it was highly significant ($p = 0.001$ and $p = 0.011$, respectively; Table 15).

In the multiple linear regression analysis, all three independent variables were selected by the stepwise method, and U1 to SN T2 (˚) showed significantly negative linearity with SN-GoMe T2 (˚), ANB difference T2 (˚), and Δ VRP to U1t (mm) ($p < 0.05$). In the final model for Δ U1 to SN (˚), all three independent variables were selected by the stepwise method, but SN-GoMe T2 (˚) and ANB difference T2 (˚) did not show significant linearity with the model, while only Δ VRP to U1t (mm) showed significantly positive linearity ($p < 0.01$; Table 16).

Table 15. Stepwise multivariate regression model fit test for angulation of the upper incisor

Dependent variables	**F value**	***P* value**	**R^2**	**Adjusted R^2**
U1 to SN T2 (˚)	6.367	0.001†	0.241	0.204
Δ U1 to SN (˚)	4.049	0.011*	0.168	0.127

*$p < 0.05$; †$p < 0.01$.

Table 16. Results of multiple linear regression for angulation of the upper incisor

Dependent variables		**B**	**S.E.**	**Beta**	**t**	***P* value**
U1 to SN T2 (˚)	Constant	120.069	5.627		21.337	0.000
	Δ VRP to U1t (mm)	-1.076	0.453	-0.268	-2.377	0.021*
	SN-GoMe T2 (˚)	-0.281	0.129	-0.257	-2.186	0.033*
	ANB difference T2 (˚)	-0.872	0.411	-0.249	-2.122	0.038*
Δ U1 to SN (˚)	Constant	7.682	5.849		1.313	0.194
	Δ VRP to U1t (mm)	1.467	0.471	0.368	3.116	0.003†
	SN-GoMe T2 (˚)	-0.221	0.134	-0.203	-1.651	0.104
	ANB difference T2 (˚)	0.455	0.427	0.131	1.066	0.291

B: Unstandardized coefficients; S.E.: Standard error; Beta: Standardized coefficients; VRP, vertical reference plane; U1t, tip of the maxillary central incisor; *$p < 0.05$; †$p < 0.01$.

IV. DISCUSSION

Self-ligating brackets involve simple methods of ligating and removing the wire, which can reduce the chair time during patient admission, and because they do not require additional ligature material, they can also reduce the discomfort felt by the patient when wearing the bracket (Eberting et al., 2001; Pringle et al., 2009). Although self-ligating brackets have become popular owing to various benefits, there have been no clinical trials on torque expression in self-ligating brackets. The present study examined cases involving retraction of anterior teeth after extraction of the maxillary first premolars or the maxillary first premolars and mandibular premolars for the chief complaint of lip protrusion, and compared the patterns of tooth movement when using conventional versus when using self-ligating brackets, as well as to compare the characteristics of changes in hard and soft tissues based on use of such brackets.

The amount of retraction in the maxillary anterior teeth was 7.32, 7.59, 7.18, and 7.29 mm in the ACM, ACC, PCM, and CM groups, respectively, with no significant differences ($p > 0.05$). Inter-group comparison at pre-treatment showed no horizontal or vertical differences in the skeletal structure, while the inclination and protrusion of the maxillary anterior teeth also did not show differences. Therefore, differences in the amount of retraction in the maxillary anterior teeth did not occur due to these factors.

The amount of retraction in the mandibular anterior teeth was 6.05, 5.79, 4.08, and 5.74 mm in the ACM, ACC, PCM, and CM groups, respectively, showing no statistically significant differences among the four groups ($p > 0.05$). However, the amount of retraction was found to be the lowest in the PCM group. This is believed to be because the PCM group had the largest pre-treatment overjet (6.38 mm) and the smallest IMPA (99.06˚).

Camouflage treatment on Class II malocclusion patients in the present study revealed that the amount of retraction of the maxillary anterior teeth was smaller than the 9.3 mm found in the group in which skeletal anchorage was used in a previous study by Kuroda et al. (Kuroda et al., 2009), yet bigger than the 6.3 mm found when traditional anchorage was used for maxillary anterior tooth retraction. In another study (Solem et al., 2013), the amount of retraction was reported to be 5.6 mm in the group in which skeletal anchorage was used and 4.2 mm in the group in which traditional anchorage was used, which indicated that the amount of retraction of the maxillary anterior teeth was higher in the present study. It is believed that these differences in the amount of retraction arose from the characteristics of the type of anchorage used and the treatment goals based on the initial degree of protrusion and inclination of the maxillary anterior teeth. In the present study, there were no significant differences among the four groups in terms of changes in U1 to SN (˚) during maxillary anterior tooth retraction, and there were also no significant differences among the four groups with respect to IMPA (˚) ($p > 0.05$). This is believed to be due to the similar pre-treatment skeletal characteristics in all four groups.

Post-treatment U1 to SN T2 (˚) values were 98.53˚, 96.85˚, 98.96˚, and 96.81˚ in the ACM, ACC, PCM, and CM groups, respectively. These values were lower than the normal standard values, which can also be interpreted as the result of camouflage treatment on skeletal Class II malocclusion.

Maxillary incisor torque plays an important role in creating a proper anterior guide, Class I molar relationship, and an aesthetic smile line. Less torque on the anterior teeth blocks the distal movement of the maxillary anterior teeth, while anterior teeth that show inadequate inclination decrease the dental arch space. Moreover, anterior teeth torque affects the overjet, as well as the intercusp relationships of the molars (Chung et al., 2009).

Effective torque refers to the minimum effective force that can uphold the tooth when rectangular wires are inserted into the anterior tooth region for tipping (Sebanc et al., 1984), and can be influenced by the bracket slot profile or ligature method. Typical effective torque in clinical applications is known to be 0.5–2 Ncm (Burstone, 1982; Gmyrek et al., 2002). In a laboratory study that compared different combinations of various bracket designs and wires (Katsikogianni et al., 2015), the SPEED™ bracket, an active type self-ligating bracket, showed highly effective torque (35.4 Nmm) with .016 × .022 SS wire. According to that study, conventional brackets had less capability for creating torque than self-ligating brackets, while the active-type self-ligating brackets showed superior torque effectiveness to that of passive-type self-ligating brackets.

In a prospective study that observed changes in the maxillary incisor torque from pre- to post-treatment in extraction cases (Pandis, 2006), using passive-type self-ligating brackets resulted in a decrease in U1 to SN (˚), by 6.9˚ from pre- to post-treatment, while using conventional brackets resulted in similar decrease of 6.3˚. Thus, in extraction cases, self-ligating brackets did not exceed the ability of conventional brackets to deliver torque to the maxillary anterior teeth. Their results, which showed that self-ligating brackets have a similar torque expression efficiency as conventional brackets, were consistent with the results of the present study. Yet, in the present study, the change in U1 to SN (˚) was larger when using conventional brackets and self-ligating brackets, with a decrease of 12.1˚ for both, which is believed to be the result of the larger mean anterior teeth retraction (7.3 mm). Furthermore, in another study that performed camouflage treatment in a case of extraction for bimaxillary protrusion (Solem et al., 2013), the decrease in the maxillary anterior tooth angle was 13.2˚ in the group that experienced greater retraction and that used skeletal anchorage. In contrast, it was 9.8˚ in the group that used traditional anchorage, which was similar to the results of the present study.

In the present study, variation in Δ U1 to SN (˚) appeared to be smallest in the ACC group, while the other three groups showed relatively larger variations. The reason for the large variation can be attributed to differences in treatment mechanics, the amount of crowding in the anterior teeth, and the angular difference in the central incisor at the start of treatment. There was large variation in Δ IMPA (˚), which is believed to be the result of large differences in the initial angular values if the mandibular anterior teeth among the groups, due to dental compensation.

Both the upper and lower lips retracted along with tooth movement in all four groups, but there were no inter-group differences ($p > 0.05$). It is believed that this was due to the similar amount of retraction in the maxillary anterior teeth among the groups, and the final tooth angles after retraction showing no differences between the groups. In a study that used traditional anchorage after extraction, Ls and Li showed retraction of 2.5–3.2 and 3.4–3.5 mm, respectively, and in the present study, amount of Ls retraction was similar to this value in all groups. Li retraction in the ACC and CM groups was similar or larger than that of previous studies, but it was larger in the ACM group (4.8 mm) and smaller in the PCM group, with a significant difference between these two groups ($p < 0.05$). Horizontal movement of Li may be correlated with dental variables, such as L1 cervical, L1 tip, and U1 tip, and skeletal variables, such as B point and Pog; therefore, the results are believed to be based on these factors.

In order to achieve a favorable outcome in extraction treatment, angles in the maxillary and mandibular anterior teeth must be properly maintained during treatment. Therefore, correlation analysis was performed to determine the relationship between the variables of interest and the final mandibular central incisor angle at post-treatment and the angular changes from pre- to post-treatment. Since there were no significant inter-group differences, the four groups were combined for the analysis. Post-treatment U1 to SN (˚) did not show differences based on the bracket used, but showed a significantly negative correlation with post-treatment SN-GoMe (˚) ($p < 0.01$), post-treatment ANB difference (˚) ($p < 0.05$), and Δ VRP to U1t (mm) ($p < 0.05$), while Δ U1 to SN (˚) showed a significantly positive correlation with only Δ VRP to U1t (mm) ($p < 0.01$). Therefore, the values for SN-GoMe T2 (˚) and ANB difference T2 (˚) increased, U1 to SN T2 (˚) became smaller, and the amount of maxillary anterior tooth retraction increased, U1 to SN T2 (˚) became smaller. Thus, Δ U1 to SN (˚) increases as the amount of maxillary anterior tooth retraction becomes greater.

In the multiple linear regression analysis, U1 to SN T2 (˚) showed significantly negative linearity with SN-GoMe T2 (˚), ANB difference T2 (˚), and Δ VRP to U1t (mm) ($p < 0.05$), while Δ U1 to SN (˚), the angular change in maxillary anterior teeth from pre- to post-treatment, showed significantly positive linearity with only Δ VRP to U1t (mm) ($p < 0.01$). Moreover, to determine whether the group factor had an influence on the maxillary central incisor, an analysis was performed with the group factor added as a dummy variable in the linear regression model. Because the group factor was eliminated by the stepwise method, it was determined to have no effect on maxillary central incisor angles. Based on the results mentioned above, it was determined that the type of bracket does not affect the angle or position of the anterior teeth, while the final tooth angles are affected more by the amount of anterior tooth retraction, according to the treatment goal, and horizontal and vertical skeletal characteristics than by the type of bracket.

When the amount of tooth retraction increases, if maxillary anterior teeth torque is maintained or is inclined steeply toward the lingual side, it can deviate from the maxillary alveolar bone to come into contact with the palatal or labial cortical bone, causing root resorption (Guo et al., 2011; Liou and Chang, 2010). Therefore, treatment mechanics need to be applied to allow the roots to settle within a range that is not beyond the envelope of discrepancy, by controlling the root angulation according to the amount of retraction.

Studies on treatment duration have reported varying results, where Eberting et al. have reported that, in comparison to conventional brackets, self-ligating brackets shortened the treatment duration by approximately 6.33 months (Eberting et al., 2001). However, with the exception of the early studies by Eberting et al., most studies (Chen et al., 2010; Fleming and Johal, 2010) reported that there were no significant differences in treatment duration between self-ligating and conventional brackets. In a study by Pandis et al. (Pandis et al., 2010), it was reported that, for non-extraction treatment and addressing initial anterior tooth crowding, there was no significant differences in treatment duration between passive and active self-ligating brackets, regardless of the degree of crowding. These results were consistent with the findings in the present study. However, the study by Pandis et al. was conducted on non-extraction patients and the duration for completing alignment of six maxillary anterior teeth was observed, which was different from the present study. The present study compared the duration of treatment of patients who underwent extraction for improvement of Class II malocclusion maxillary protrusion with mild crowding; no inter-group differences were observed ($p > 0.05$). Accordingly, it was confirmed that, with respect to extraction treatment duration, the initial degree of lip protrusion, amount of crowding, and dental and skeletal characteristics are important, whereas the type of bracket used does not have any marked influence.

For addressing protruding lips, retraction of the anterior teeth after premolar extraction is a common treatment method. The finding that the degree of soft tissue retraction is more closely correlated with movement of the cervical region than with the incisal margin of the dental crown (Hayashida et al., 2011; Roos, 1977) indicates that, for uncontrolled or controlled tipping, fewer soft tissue changes may occur, due to the relatively smaller movement of the cervical region than bodily movement. Therefore, soft tissue changes can be enhanced only by controlling the torque during anterior teeth retraction.

For added torque control, the present study, in some cases, used a long lever arm on the labial side or applied a compensatory curve for vertical control during the treatment. If it was imperative to apply the proper torque for retraction of anterior teeth, a full size wire and lever arm was used, or additional torque was applied to the arch wire or bracket. High torque is required for extraction in patients with protruding lips, Class II division 2 malocclusion, and Class II malocclusion requiring significant amount of retraction. When various self-ligating systems are used, a variety of brackets need to be prescribed to accommodate the varying degrees of malocclusion, for which the use of wires suitable for each system is recommended.

To control for the various conditions, efforts were made to unify the extraction conditions and the amount of retraction. However, because the present study was a retrospective clinical trial, it was limited by the treatment system-related issues, such as anchorage, lever arm, and wire control, as well as having different slot sizes for active and passive clips, and the involvement of three specialists. Moreover, each group had a small sample size, and thus, additional testing through a prospective study that includes more participants under better controlled conditions is deemed necessary.

The final positions of post-treatment anterior teeth and final hard and soft tissue positions based on those tooth positions were compared to pre-treatment positions. The treatment outcomes can be affected by the soft tissue conditions of each individual patient, such as lip thickness and tension. Therefore, studies that take into account various conditions, including those mentioned above, which can influence the treatment outcome, are needed in future. Moreover, the present study did not include all of the variables as independent variables during the regression analyses. Therefore, if more factors are included as independent variables, the explanatory power of the model can be increased.

V. CONCLUSION

The present study was conducted on 64 patients who underwent extraction of the maxillary first premolars or the maxillary first premolars and mandibular premolars and subsequent anterior teeth retraction for orthodontic treatment of lip protrusion. The patients were divided into the ACM, ACC, PCM, and CM groups, based on the brackets used. The four groups were compared for skeletal, dental, and soft tissue changes from pre- to post-treatment and the following results were obtained.

1. Incisal tip of the maxillary anterior teeth at post-treatment showed a retraction of 7.32 mm, 7.59 mm, 7.18 mm, and 7.29 mm in the ACM, ACC, PCM, and CM groups, respectively, with no significant differences among the four groups ($p > 0.05$).

2. During retraction of the maxillary anterior teeth, changes in U1 to SN (˚) was 10.16˚, 11.57˚, 13.48˚, and 12.06˚ in the ACM, ACC, PCM, and CM groups, respectively, with no significant differences among the four groups. Changes in IMPA (˚) also showed no significant differences among the four groups ($p > 0.05$).

3. No significant differences were found when treatment duration was compared between each group ($p > 0.05$).

4. Both the upper lip to E-line (mm) and the lower lip to E-line (mm) were decreased post-treatment in all four groups, but there were no statistically significant differences ($p >$

0.05). Horizontal changes in soft tissues, such as Sn, A', Ls, Stms, Stmi, B', and Pog', were not significantly different among the four groups ($p > 0.05$).

5. In the multiple linear regression analysis, Δ U1 to SN (°) showed significantly positive linearity with only Δ VRP to U1t (mm) ($p < 0.01$).

The results above showed that the type of ligation used with the brackets did not affect the anterior tooth angles during maximum retraction of the anterior teeth and the final teeth angles were affected by the amount of retraction in the anterior teeth, according to treatment goals and horizontal and vertical skeletal characteristics, to a greater extent than by the type of ligation used with the brackets.

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국문 요약

전치부 최대견인시 결찰 방식에 따른 상악 전치부 이동 양상 및 치료 효과

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최근 miniscrew 등의 절대 고정원의 이용범위가 커져 전치부 후방 이동 양이 증가되면서 치아 이동 범위가 확대되었다. 또한 동양인들의 경우 발치 환자가 많아 견인을 많이 시행하는데, 같은 조건에서 견인을 시행하였을 경우, 어떠한 시스템의 브라켓이 어느 정도의 torque 를 발현시킬 수 있을 지에 대해서는 알려진 바가 적다. 그리고 능동형 자가결찰 브라켓이 수동형 자가결찰 브라켓에 비해 torque 조절에 유리하다는 실험실적인 결과는 있지만 임상적인 수준에서의 연구는 없기 때문에 임상적으로도 실제 개선점을 주는지에 대한 검증이 필요하다.

본 연구의 목적은 한국인 돌출 환자의 교정치료를 위해 상악 제 1 소구치나 상악 제 1 소구치와 하악 소구치를 발치하고 전치부를 후방 견인한 경우에 대해, (1) 전통적인 브라켓과 자가결찰 브라켓의 전치부 치아 이동 양상을 비교하며 (2) 이에 따른 경조직과 연조직의 변화에 대한 특성을 비교하는 것이다.

연세대학교 치과대학병원 교정과에 내원하여 돌출을 주소로 상악 제 1소구치나 상악 제 1소구치와 하악 소구치를 발치하고 최대 고정원을 이용하여 전치부를 후방 견인한 64명을 사용한 브라켓을 기준으로 ACM (Active clip metal) group, ACC (Active clip ceramic) group, PCM (Passive clip metal) group, CM (Conventional metal) group으로 나누어 치료 전과 후의 골격적, 치성, 연조직 변화에 대해 네 그룹을 비교하여 다음과 같은 결과를 얻었다.

1. 치료 후 상악 전치 tip은 ACM group에서 7.32 mm, ACC group에서 7.59 mm, PCM group에서 7.18 mm, CM group에서 7.29 mm 견인되어 네 그룹간에 유의한 차이가 없었다 ($p > 0.05$).
2. 상악 전치의 후방이동 시 U1 to SN (°)의 변화는 ACM group에서 10.16°, ACC group에서 11.57°, PCM group에서 13.48°, CM group에서 12.06°로 네 그룹에서 유의한 차이가 없었으며, IMPA (°)의 변화 또한 네 그룹간에 유의한 차이가 없었다 ($p > 0.05$).
3. 각 그룹간의 치료기간 비교에 있어서 유의한 차이가 없었다 ($p > 0.05$).
4. Upper lip to E-line (mm) 과 Lower lip to E-line (mm)는 치료 후 네 그룹 모두 감소하였으나 유의한 차이는 없었다 ($p > 0.05$). Sn, A', Ls, Stms, Stmi, B', Pog' 등의 연조직의 수평적 변화는 네 그룹간 유의성 있는 차이를 보이지 않았다 ($p > 0.05$).

5. 다중선형회귀 분석에서 Δ U1 to SN (°)는 Δ VRP to U1t (mm)하고만 유의한 양의 선형성이 있었다 ($p < 0.01$).

이상의 결과로 브라켓의 결찰 방식은 상악 전치부 최대견인시 전치부의 각도에 영향을 주지 않았으며 최종 치아의 각도는 브라켓의 종류보다는 수평, 수직적인 골격 특성과 치료목표에 따른 전치부의 견인량에 영향을 받는다는 것을 알 수 있었다.

핵심이 되는 말: 연조직 변화, 자가결찰 브라켓, 전치부 견인, 전치부 치아 이동 양상, 토오크