Original Article

Factors influencing treatment efficiency: *A prospective cohort study*

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ABSTRACT

Objectives: The purpose of this cohort study was to evaluate the effect of self-ligating brackets (SB) and other related factors that influence orthodontic treatment time.

Materials and Methods: This was a two-armed prospective study. Consecutively treated patients who were recruited from a private practice were enrolled and asked to choose between SB and conventional brackets (CB). If the patient did not have a preference, that patient was randomly allocated. An identical archwire sequence was used, and all patients were treated by a single orthodontist. Treatment duration, number of bracket failures, poor oral hygiene, poor elastic wear, whether or not to orthodontic mini-implants (OMI) were used, OMI failure, extraction, American Board of Orthodontics Discrepancy Index, and arch length discrepancy were measured and statistically analyzed using *t*-tests, correlation analysis, and analysis of covariance (ANCOVA). Stepwise regression analysis was conducted to generate an equation to predict treatment duration.

Results: A total of 134 patients with an average age of 22.73 years were included. The average treatment duration was 28.63 months. ANCOVA showed no significant difference in treatment duration between CB and SB. Stepwise regression analysis could explain 64.6% of the variance in treatment duration using five variables.

Conclusions: SB did not exhibit a significant reduction in treatment time as compared with CB. Patient cooperation, extractions, and malocclusion severity had a significant impact on treatment duration. (*Angle Orthod.* 2021;91:1–8.)

KEY WORDS: Treatment duration; Self-ligating brackets; Patient's cooperation; Extraction

INTRODUCTION

Treatment duration is one of the topics of interest to both orthodontists and patients. If it is known exactly which factors affect treatment duration, the relevant factors can be adjusted for faster treatment. Various factors are expected to affect treatment duration.

Self-ligating brackets (SB) were devised with the expectation that a friction-free environment could allow better sliding mechanics and shorter treatment duration. Although laboratory studies have suggested that SB could reduce friction[1] and several early retrospective studies reported a reduction in treatment time,[2,3] recent systematic reviews (SRs) concluded that the treatment duration with SB was not shorter than with conventional brackets (CB).[4,5]

There has been controversy over whether extractions affect treatment duration. Many studies have reported that treatment duration was longer in extraction treatment,[6–9] but there were also studies that showed no difference.[10–12] Studies have shown that missed appointments,[8,13] bracket failure,[10,14] poor elastic wear,[8,10] and poor oral hygiene[8] can affect treatment duration.

Orthodontic mini-implants (OMI) have become very popular. Since previous studies of treatment duration were conducted before the widespread use of OMI, no studies have been performed on the effect of OMI on treatment duration. As OMI is often used for difficult treatment, OMI cases seem to have longer treatment durations. However, it is not easy to predict their effect on treatment duration because OMI can reduce the extraction rate[15] and the need for patient cooperation. If

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Table 1. Study Inclusion and Exclusion Criteria

Inclusion criteria
Started treatment between March 2008 and August 2009
Fully erupted dentition from the first molar forward
No history of orthodontic treatment
Desired comprehensive orthodontic treatment with ceramic brackets
Exclusion criteria
Tooth impaction other than the third molars
Jaw surgery combined treatment
Cleft lip and/or palate or other craniofacial anomalies
A complex medical or dental history

the OMI fails and replacement is performed, the treatment duration may be lengthened.

In some clinical settings, simple alignment cases are frequently treated by general practitioners, whereas more complex cases are treated by orthodontists. Under these conditions, the extraction rate or frequency of OMI use is likely to be high. The goals of this prospective cohort study were to compare the treatment efficiency of SB and CB and to identify the factors that affect orthodontic treatment duration in clinical settings with a high extraction rate and high frequency of OMI use.

MATERIALS AND METHODS

In this cohort study, patients were allocated to two groups, the SB group or CB group, and procedures were performed at a single private practice. In this office, more than 60% of the patients preferred ceramic brackets, so only patients treated with ceramic brackets were included. In the SB group, 0.022-inch slot Clippy-C (Tomy Inc, Tokyo, Japan) brackets were bonded; in the CB group, 0.022-inch slot Clarity (3M Unitek, Monrovia, Calif) brackets were used. The subjects were recruited from a sample of consecutive patients. The inclusion and exclusion criteria are shown in Table 1.

The Seoul National University Dental Hospital Institutional Review Board approved this study. All patients and parents received written and verbal information about the study, and informed consent was obtained in accordance with the Declaration of Helsinki.

According to the mean and standard deviation of treatment time in a previous study that compared the treatment duration of extraction and nonextraction treatment,[15] the sample size was estimated using the Sample Size Determination Program version 2.0.1 (Seoul National University Dental Hospital, Seoul, Korea). A sample size of 53 patients in each group was required to have 90% power at $\alpha = .05$. Considering a possible dropout rate of 10% during the trial, more than 59 patients per group was needed. Assuming that there might be a difference between groups of about 20% in the patient allocation process described, a sample size of more than 133 patients was planned.

If the patient wanted ceramic brackets, typodonts (Figure 1) with two types of brackets were presented. The patient was informed that CB has been used for a long time, whereas SB has been recently developed and that the seller claims that the treatment period is shorter than the CB, but this has not been verified. The differences in shape and wire-holding mechanism were also explained. Each patient was asked to choose one of the two bracket types; if the patient did not have a

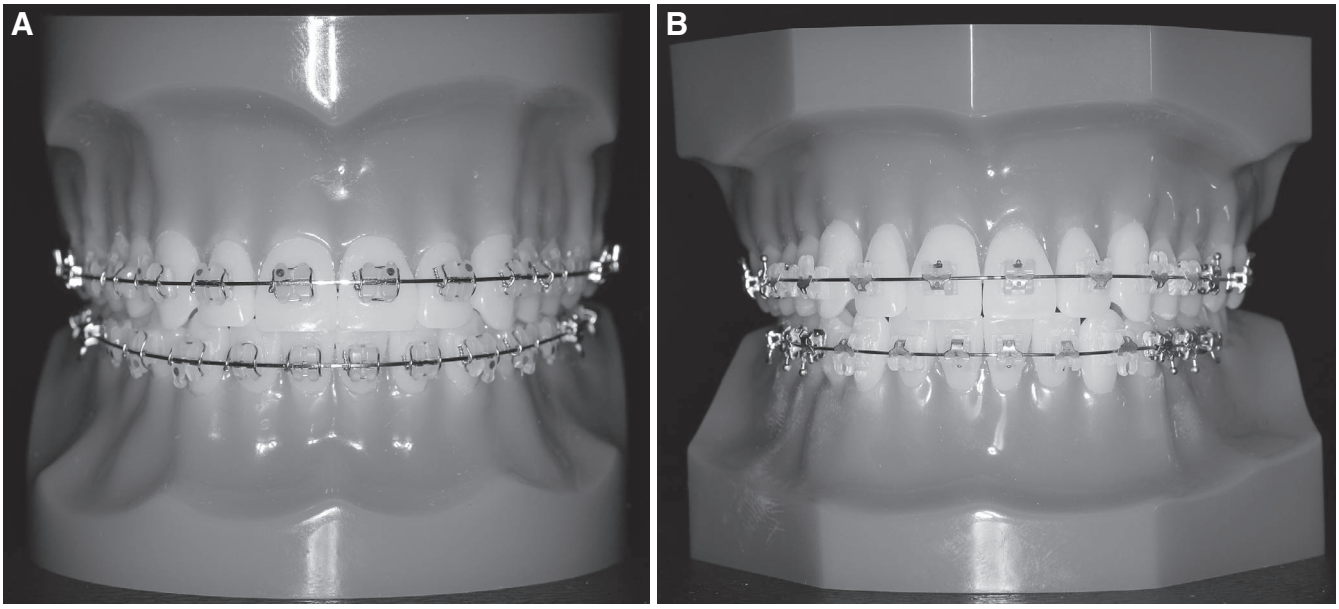

Figure 1. Typodonts with two types of brackets. (A) Clarity (CB). (B) Clippy-C (SB).

Table 2. Comparison of Plaque Index and Modified Plaque Index

	Plaque Index	Modified Plaque Index
Target surface	Buccal, lingual, mesial, and distal surfaces of six teeth (#12, 16, 24, 32, 36, 44)	Labial surface of 12 anterior teeth
Evaluation	Poor hygiene: Average score $\geq$2 points	Poor hygiene: Four or more teeth $\geq$2 points
Scoring criteria	0: following air drying, plaque is not visible nor cannot be wiped out with an explorer 1: following air drying, plaque is not visible but can be wiped out with an explorer 2: plaque is visible along the gingival margin with or without air drying 3: thick plaque is visible along the gingival margin	

preference, the bracket type was chosen randomly with a coin toss. Only 15 patients chose one of the two bracket types, whereas the others received a random allocation.

After allocation, conventional bonding adhesive (Transbond XT, 3M Unitek, Monrovia, Calif) was used to bond the brackets. Arch leveling and alignment were performed with a predetermined archwire sequence: .014-inch nickel-titanium (NiTi), .016-inch NiTi, .018-inch NiTi, .016 $\times$ .022-inch NiTi, .019 $\times$ .025-inch NiTi, and .019 $\times$ .025-inch stainless steel. Each subject was reviewed at approximately 4-week intervals. For patients who required OMI, they (Mplant U2, Biomaterials Korea Inc, Seoul, Korea) were placed during the leveling stage.

The following parameters were recorded and analyzed:

- American Board of Orthodontics Discrepancy Index (ABO-DI) and arch length discrepancy (ALD; Hays-Nance analysis)
- Extractions (or previous extraction tooth space)
- Bracket failure, bracket fracture, poor elastic wear, missed appointments, and OMI failure
- Oral hygiene (evaluated at each visit) using the modified plaque index (Table 2 shows a comparison of the plaque index[16] and modified plaque index)
- When additional appliances (eg, headgear, Hyrax expander, Forsus) were used, they were recorded and used as confounding variables

It was not possible for the operator to be blinded to the appliance type during treatment. After debonding, all identifiable patient information on the study casts and x-rays were replaced with a random study identification number at the administrative office. All lateral cephalograms were traced and digitized by a single investigator, and cephalometric values were calculated using V-ceph software (Osstem Implant Co, Seoul, Korea).

Statistical Analysis

The data were analyzed using SPSS 17.0 (SPSS, Chicago, Ill), with statistical significance set at $\alpha = .05$. Descriptive analysis was performed to evaluate the baseline characteristics of the sample and confounding variables. After log transformation of treatment duration, the normality assumption was confirmed by the Shapiro-Wilk test.

The effects of nominal variables on treatment duration were analyzed using independent *t*-test, and the effects of continuous variables were analyzed by correlation analysis. Using significant variables in *t*-test and correlation analysis, analysis of covariance (ANCOVA) was used to compare the treatment duration of the bracket systems, and stepwise regression analysis was performed to generate an equation to predict treatment duration.

To assess intraexaminer reliability, the ABO-DI and ALD of 28 randomly selected cases were remeasured at 4-week intervals, and the intraclass correlation coefficient (ICC) based on a two-way mixed-effect model was calculated.

RESULTS

During the study period, 321 patients started orthodontic treatment. Among them, 184 patients decided to use ceramic brackets; 139 patients were allocated, and a final total of 134 patients were analyzed (Figure 2).

The descriptive statistics are shown in Tables 3 and 4. The baseline characteristics and clinical features of the two groups were similar. The average age of the patients was 22.73 years, and the mean ABO-DI was 21.81. The reliability test using ICC revealed strong intraexaminer reliability (ABO-DI = .997, ALD-maxilla = .995, ALD-mandible = .997). The average treatment duration was 28.63 months, the extraction rate was 71.6%, and OMIs were used in 70.1% of patients. In the SB group, four patients used Forsus, three used headgear, and two used a Hyrax expander. In the CB group, six patients used Forsus, one used both a Hyrax and headgear, two used headgear, and one used a Hyrax.

Among the nominal variables, only extractions showed a significant difference in the *t*-test (Table 5). In the correlation analysis, age, OMI failure, and ALD-maxilla did not show a significant correlation (Table 6). ALD-mandible was not used in the ANCOVA because it may have interactions with the ABO-DI. When the effects of confounding variables were covaried out, the

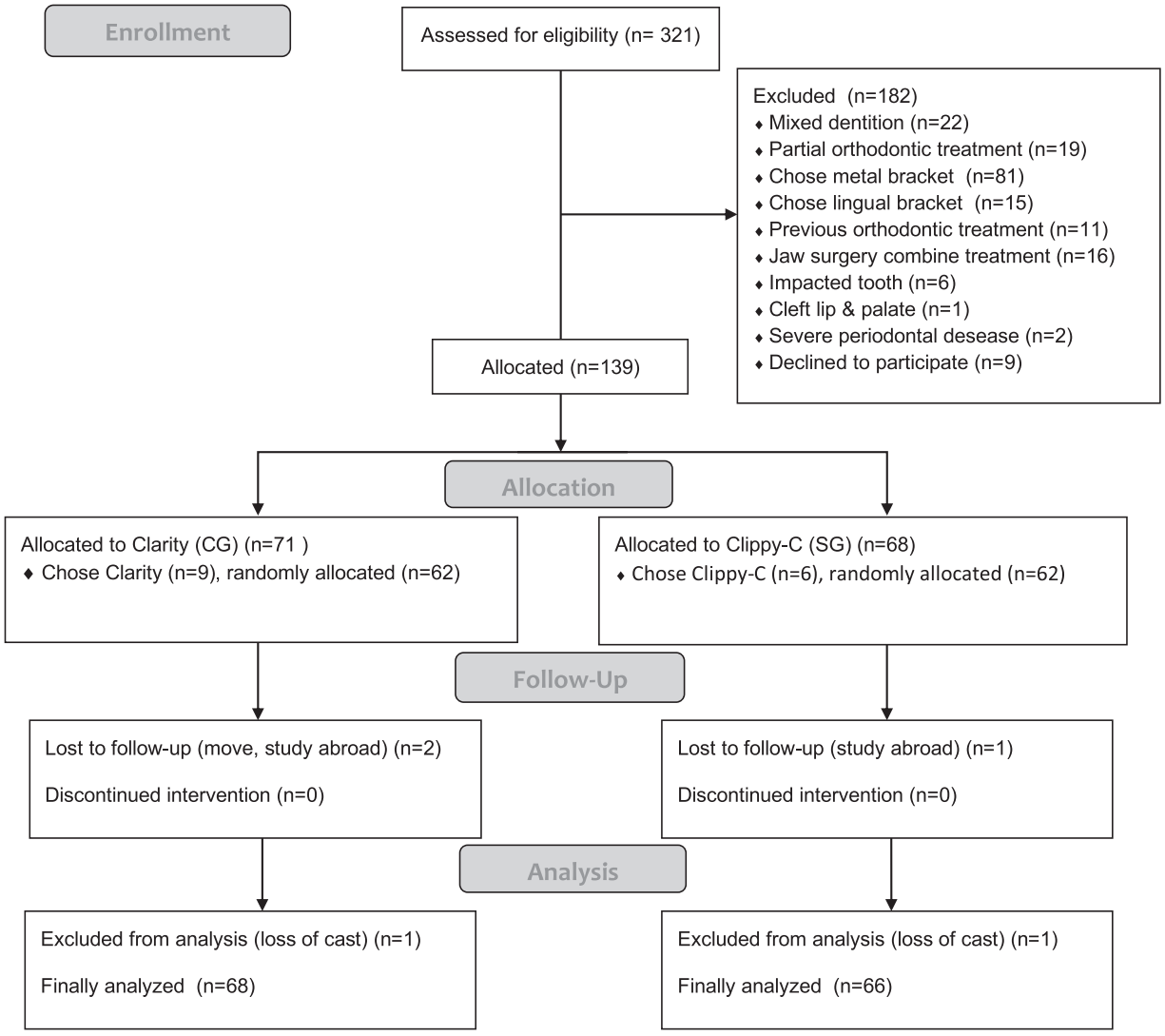

Figure 2. Flow diagram of the study.

effect of bracket system on treatment duration was not significant in the ANCOVA (Table 7).

Since there was no significant difference between CB and SB, stepwise regression analysis was performed for the entire sample (Table 8). Model 5 could explain 64.6% of the variance in treatment duration. Each "poor elastic wear" entry increased the treatment duration by 1.04 months, a "missed appointment" entry by 1.03 months, extraction by 1.23 months, a "poor hygiene" entry by 1.01 months, and a one-point higher ABO-DI score by 1.00 month.

DISCUSSION

To minimize bias during allocation, each patient was allowed to choose the bracket type, and if the patient had no preference, random assignment was made. The expected problem was a significant difference in the number of patients between the two groups, but most of the patients (89.2%) chose random allocation rather than a specific bracket type. Some of the patients (six in CB, three in SB) wanted to use the same bracket used by their friends or family members.

Since mixed-dentition patients were excluded, the average age of the sample was high. Age was not associated with an increase in treatment duration, which was consistent with a previous SR.[9] As bone metabolism tends to slow down with age,[17] comparisons with patients in their 40s or older may produce different results. In this study, only three patients in each group were older than 40 years.

The orthodontic practice where this study was conducted was located in the Seo-Cho Gu district, the inhabitants of which have a high socioeconomic status and a high interest in esthetics. For this reason, 65.7% of the patients chose ceramic brackets. A

Table 3. Baseline Characteristics of the Sample[a]

Variable	CB	SB	Overall
Age, mean (SD) y	22.99 (9.09)	22.45 (7.78)	22.73 (8.44)
Sex, n (%)			
Male	22 (32.4%)	15 (22.7%)	37 (27.6%)
Female	46 (67.6%)	51 (77.3)	97 (72.4%)
Total	68	66	134
Angle classification, n (%)			
I	35 (51.5%)	33 (50.0%)	68 (50.7%)
II	28 (41.2%)	28 (42.4%)	56 (41.8%)
III	5 (7.4%)	5 (7.6%)	10 (7.5%)
ABO-DI, mean (SD)	21.40 (10.17)	22.23 (12.37)	21.81 (11.27)
Arch length discrepancy, mean (SD)			
Maxilla	3.67 (3.73)	4.38 (4.23)	4.02 (3.99)
Mandible	3.45 (3.16)	3.48 (4.38)	3.47 (3.80)

[a] ABO-DI indicates American Board of Orthodontics Discrepancy Index.

comparison of treatment efficiency between ceramic and metal brackets is rare. One reason why few studies have been performed on this topic is that most offices do not have a sufficient number of patients requesting ceramic brackets. In previous studies, the mean percentage of ceramic bracket patients was only 7.9% to 25.6%.[10,14,18]

The designs of SB can be classified into two main categories: active and passive types. The active type possesses a spring clip that presses against the archwire for better control. In contrast, the passive type has a slide that closes without encroaching on the slot lumen. In this research, the active type was used, and a recent SR comparing active and passive types concluded there were no significant differences.[19]

Although more efficient tooth movement has been claimed as one of the advantages of SB, published randomized controlled trials have failed to show such results. There are even SRs in which CB was determined to be more effective for alignment[19] or exhibited slightly shorter total treatment duration than SB.[4] It seems that the reason why SB failed to show better results was not because of friction but because binding was the main resistance to tooth movement.[20]

Until now, there has been no cohort study comparing the clinical efficacy of ceramic CB and SB. Based on the studies of metal vs ceramic and CB vs SB, it is likely that there will be no significant difference in treatment efficiency. The result of this study was as expected.

The use of OMI did not significantly affect treatment duration. In simple anchorage reinforcement cases that required 1–2 mm more tooth movement, the treatment duration did not seem to be significantly different. However, in very complex (and rare) cases, such as whole arch intrusion,[21] treatment duration may be longer.

In a recent SR, the average failure rate of OMIs was 13.5%.[22] Most of the previous studies did not evaluate the stability of replaced OMI, which is likely to have a higher failure rate because the related patient factors such as bone quality and eating habits are unlikely to change. In this study, every OMI failure, including replaced OMI, was recorded, and the failure rate was 19.3%. Ten patients underwent OMI replacement more than four times. When OMI replacement is necessary, treatment duration may increase. Unexpectedly, this study showed that OMI failure had little effect on treatment duration. Because OMIs were placed during leveling, if the OMI failed soon after placement, replacement may not affect the treatment duration.

One of the well-known problems of ceramic brackets is bracket fracture due to the low fracture toughness of aluminum oxide.[23] If a bracket fracture occurs, it may require new bracket bonding and potentially affect treatment duration. Because only six bracket fractures were observed (three in each group), their effect on treatment duration seemed to be negligible and was not used as a covariate.

According to previous studies, the metal bracket's failure rate ranges from 2.95% to 23.0%,[24–27] and the ceramic bracket's failure rate is 1.9% to 20.0%.[14,28]

Table 4. Comparison of the Clinical Features Between the Two Groups[a]

Variable	CB	SB	Overall
Treatment duration, mean (SD), mo	29.25 (7.53)	27.98 (7.10)	28.63 (7.32)
Extraction, n (%)	49 (72.1)	47 (71.2)	96 (71.6)
Four premolar extractions	36 (52.9)	34 (51.5)	70 (52.2)
OMI use, n (%)	46 (67.6)	48 (72.7)	94 (70.1)
Average OMI, mean (SD)	3.70	4.02	3.86
OMI failure, mean (SD)	0.63 (0.85)	0.87 (1.30)	0.75 (1.10)
Additional appliance, mean (SD)	10 (14.7%)	9 (13.6%)	19 (14.2%)
Bracket failure, mean (SD)	1.81 (1.93)	1.12 (1.09)	1.47 (1.61)
Poor elastic wear, mean (SD)	2.12 (2.47)	1.77 (1.94)	1.96 (2.23)
Poor oral hygiene, mean (SD)	3.10 (4.51)	3.15 (3.08)	3.13 (3.86)
Missed appointment, mean (SD)	1.87 (3.58)	1.73 (3.69)	1.80 (3.62)

[a] Average OMI indicates total number of OMI used/OMI use; OMI failure, total number of OMI failure/OMI use; OMI use, number of patients who used OMI.

Table 5. Comparison of Treatment Duration (After Log Transformation) by Nominal Variables in Independent *t*-Test

Variable	Group	n	Duration, mo	Duration (Log)	*t* Value	*P* Value
Sex	Male	37	27.80	1.444	0.95	.342
	Female	97	27.73	1.443		
Extraction	Nonextraction	38	23.92	1.379	−4.04	.000
	Extraction	96	28.75	1.459		
OMI use	Yes	94	27.50	1.439	−0.62	.534
	No	40	28.33	1.452		
Additional appliance	Yes	19	28.33	1.452	−0.38	.705
	No	115	27.67	1.442		

Table 6. Result of Pearson Correlation Analysis of Continuous Variables and Treatment Duration (After Log Transformation)[a]

Variable	Correlation Coefficient	*P* Value
Age	−.027	.761
OMI failure	.148	.088
Bracket failure	.184	.034
Poor elastic wear	.570	.000
Poor oral hygiene	.356	.000
Missed appointment	.515	.000
ABO-DI	.313	.000
ALD-maxilla	.169	.051
ALD-mandible	.204	.018

[a] ABO-DI indicates American Board of Orthodontics Discrepancy Index; ALD, Arch Length Discrepancy; ALD-maxilla, arch length discrepancy of maxilla; ALD-mandible, arch length discrepancy of mandible; OMI failure, total number of OMI failures/number of patients who used OMI.

Table 7. Result of ANCOVA to Test Influence of Bracket Type (Removing Effects of Covariates on the Treatment Duration, After Log Transformation)[a]

Variable	*F*	*P* Value
Bracket type	0.711	.401
Covariates		
Extraction	49.245	.000
Bracket failure	0.203	.653
Poor elastic wear	31.950	.000
Poor oral hygiene	10.602	.001
Missed appointment	42.362	.000
ABO-DI	6.463	.012

[a] ABO-DI indicates American Board of Orthodontics Discrepancy Index.

Table 8. Result of Stepwise Regression Analysis to Predict Treatment Duration (After Log Transformation)[a]

Model	*R*	R^2	*F*	*P* Value
1	.570	.325	63.561	.000
2	.689	.474	59.100	.000
3	.776	.602	65.560	.000
4	.792	.628	54.454	.000
5	.803	.646	46.618	.000

[a] Model 1 = 0.028 × poor elastic wear + 1.389; model 2 = 0.023 × poor elastic wear + 0.012 × missed appointment + 1.376; model 3 = 0.023 × poor elastic wear + 0.012 × missed appointment + 0.086 × extraction + 1.229; model 4 = 0.020 × poor elastic wear + 0.011 × missed appointment + 0.093 × extraction + 0.005 × poor oral hygiene + 1.210; model 5 = 0.017 × poor elastic wear + 0.011 × missed appointment + 0.091 × extraction + 0.006 × poor oral hygiene + 0.001 × ABO-DI + 1.186.

Although most of the bonding failure studies did not include rebonded brackets, all cases of failure including rebonded brackets and molar tubes were recorded in this study, but the failure rate (5.81%) was not high as compared with previous studies. As in other studies,[8,10] bracket failure affected treatment duration but was less relevant than other variables related to patient cooperation.

Poor hygiene, poor elastic wear, and missed appointments are all related to patient cooperation and have been shown to affect treatment duration.[6,8–10] The same results were obtained in this study. Poor oral hygiene does not have a direct effect on treatment duration but can be a good indicator of overall cooperation.[6,8]

Although this study showed a significantly longer duration of treatment in the extraction group, controversy over the topic remains. Typically, extraction treatment is performed in more complex cases and seems to require a longer treatment duration, but there may be various situations. If a large amount of molar distalization is planned to avoid extraction, it can lead to longer treatment duration because of the large amount of movement required. In the cases with first molar extraction, there can be a significant difference between the prosthetic treatment combined plan and orthodontic space closure. In this study, among the seven patients (four in CB, three in SB) with a first molar extraction space, only one in the CB group chose prosthetic treatment, whereas the others chose orthodontic space closure.

The ABO-DI was developed to evaluate case complexity[29] and is expected to affect treatment duration.[30] The DI value of this study (21.81) was much higher than in previous studies in consecutive patients (15.49–15.7).[30,31] A recent SR showed chair time can be reduced by SB.[5] Because complex cases usually require more frequent assessment and adjustment, one possible hypothesis is that SB can make treatment more efficient by reducing chair time if there are many complex cases. But the result of this study did not show a significant difference. The fact that the two groups of patients were mixed and treated together may have masked the benefits of SB.

The need for an additional appliance may indicate that treatment was complex and therefore affect treatment duration, but there was no significant difference. Since a small number of patients used additional appliances and several appliances were used, it is difficult to determine the effects of additional appliances with this result. Because it becomes increasingly difficult to obtain cooperation in adolescent patients and SRs showed that the long-term orthopedic effect of headgear is not significant,[32,33] headgear was recommended only if the patient refused to use OMI.

This study used samples from one private practice involving one orthodontist, and all patients had the same racial and cultural backgrounds. Generalization of the study results requires caution.

CONCLUSIONS

- In this prospective cohort study, SB exhibited no advantage over CB in terms of treatment duration.
- Patient cooperation, extraction, and malocclusion severity had a significant impact on treatment duration.

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