Effects of self-ligating bracket and other factors influencing orthodontic treatment outcome: A prospective cohort study

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Objective: The purpose of this prospective cohort study was to evaluate the effects of a self-ligating bracket (SB) and other factors that influence orthodontic treatment outcome. **Methods:** This was a two-armed cohort study using consecutively treated patients in a private practice. The patients were asked to choose between SB and a conventional bracket (CB) and if the patient did not have a preference, that patient was allocated randomly. All the patients were treated using an identical archwire sequence. The treatment duration, number of bracket failures, poor oral hygiene, poor elastic wear, extraction, whether or not to use orthodontic mini-implant (OMI), OMI failure, American Board of Orthodontics (ABO) Discrepancy Index (DI), arch length discrepancy and ABO Cast-Radiograph Evaluation (CRE) score were measured and analyzed. To predict CRE, stepwise regression analysis was conducted to generate the equation. **Results:** The final sample comprised 134 patients with an average age of 22.73 years. The average DI, CRE and treatment duration were 21.81, 14.25 and 28.63 months, respectively. Analysis of covariance showed a significant difference in CRE between CB and SB after adjusting for the effects of confounding variables. Stepwise regression analysis can explain only 25.2% of the variance in CRE score using four variables. **Conclusions:** CB showed a significantly better CRE score compared with SB but its clinical significance seems to be limited. Extraction, bracket type, poor elastic wear and additional appliance use had significant impacts on treatment outcome.

KEY WORDS: Bracket, Cast-Radiograph Evaluation, Orthodontic index, Compliance

INTRODUCTION

The desire to improve treatment results is common among orthodontists. Assessment of the quality of orthodontic treatment generally includes evaluation of post-treatment records such as study casts and panoramic radiographs. The American Board of Orthodontics (ABO) developed Cast-Radiograph Evaluation (CRE) for clinical examination in 1995 for the precise evaluation of orthodontic treatment outcomes, and this evaluation process has been improved and modified through field tests.[1]

ABO CRE has eight criteria: alignment, marginal ridges, buccolingual inclination, occlusal relationships, occlusal contacts, overjet, interproximal contacts, and root angulation. Other indexes such as the Index of Orthodontic Treatment Need (IOTN), Index of Complexity, Outcome, and Need (ICON) and Peer Assessment Rating (PAR) Index are also used for evaluating treatment outcomes, but CRE is the most accurate and stringent method of evaluating treatment results.[2]

Fixed appliances are a basic tool of comprehensive orthodontic treatment and allow three-dimensional control of tooth movement. Various efforts have been made over many years to create more effective and efficient brackets to improve the quality of treatment.

The self-ligating bracket (SB) was introduced with the expectation that elimination of ligature ties produces a friction-free environment and allows better sliding mechanics. But systematic reviews (SRs) showed that the treatment efficiency or effectiveness of SB was not better than the conventional bracket (CB).[3,4]

If an orthodontist spends more time and effort to create a better occlusion, better treatment outcomes may be obtained. Given that SB can reduce the chair time,[4] it is possible that using SB may lead to better treatment results since more time can be used for the evaluation and adjustment of occlusion. On the contrary, some researchers argue that because of the complex structure, the volume of SB is larger and the distance from the tooth surface to the archwire is usually longer, so it is more difficult to control teeth accurately compared to CB (Fig 1);[5] however, no studies have made these comparisons.

Extractions may affect treatment quality. A recent SR showed that a 10% increase in the extraction rate may decrease the CRE score by 0.7 points, which indicates better occlusal outcome.[6] However, since most of the included studies were retrospective, additional studies are needed.

Although many studies have shown that patient cooperation can affect treatment duration,[7,8] there are few studies investigating the association between patient cooperation and treatment outcome.

As orthodontic mini-implants (OMIs) are often used to solve difficult tooth movement such as

intrusion or asymmetry correction, OMI cases may show worse treatment outcomes. But it is difficult to predict its effects because OMI can provide the required anchorage without patient cooperation. Since OMI has become popular recently, there is no study yet on whether OMI related factors affect treatment outcome.

There is controversy about whether the case difficulty affects the treatment outcome. Some studies showed no association,[9,10] while other studies reported a significant correlation.[11-13] In some clinical settings, simple cases are mostly treated by general practitioners and orthodontists treat difficult cases primarily. Under these conditions, the average case complexity is relatively severe, so the extraction rate and OMI frequency will be high.

The goals of this study were to compare the treatment outcomes of SB and CB and to identify the factors that affect treatment outcomes in clinical settings with a relatively severe average case complexity.

MATERIALS AND METHODS

The subjects were recruited from a sample of consecutive patients from a single private practice who began orthodontic treatment between March 2008 and August 2009. As more than 60% of the patients chose ceramic brackets in this office, only patients treated with ceramic brackets were included in this study. The inclusion criteria were (1) patients in the permanent dentition, (2) no previous orthodontic treatment, and (3) comprehensive treatment cases. The exclusion criteria were (1) impacted tooth case (except the third molars), (2) jaw surgery case, (3) craniofacial anomalies, and (4) a complex medical or dental history. All the participants were allocated to two groups – SB and CB. .022" Clippy-C (MBT prescription, Tomy, Tokyo, Japan) brackets were bonded in SB; .022" Clarity (MBT prescription, 3M Unitek, Monrovia, CA) brackets were used in CB. The entire treatment procedure, measurements, and analyses were performed by a single investigator.

This study was approved by the Seoul National University Dental Hospital Institutional Review Board (CRI09008). All patients and parents received written and verbal information, and informed consent was obtained in accordance with the Declaration of Helsinki.

Originally, this study was designed to investigate the factors influencing treatment duration and treatment outcome. Using the CRE score in fixed appliance treatment from a previous study[13] and treatment duration data from another study being prepared,[14] sample size was calculated. Fortunately, both methods resulted in the same number of sample size (53 patients per group) to show a 20% difference with 90% power at α=.05. Assuming a 10% drop-out rate, 59 patients in each group were needed. Considering the 20% difference between groups that could occur

during the allocation process (selecting brackets by patients), it was decided that the total sample size needed was 133 or more.

Typodonts (Fig 2) with two types of brackets were presented to the patients. After explaining the differences in the wire-holding mechanism and bracket shape, patients were asked to choose one of the two brackets. If the patient did not have a preference, the type of bracket was chosen randomly using a coin toss.

The brackets were bonded by using conventional adhesive (Transbond XT, 3M Unitek, Monrovia, CA). Leveling was progressed with a predetermined archwire sequence: 014″ nickel-titanium (NiTi), 016″ NiTi, 018″ NiTi, 016x022″ NiTi, 019x025″ NiTi, and 019x025″ stainless steel. Each subject was reviewed at approximately four-week intervals. For patients who required orthodontic mini-implants (OMIs), the OMIs (Mplant U2, Biomaterials Korea Inc, Seoul, Korea) were placed during the leveling stage.

The measured variables are as follows.

- ABO Discrepancy Index (DI) and Cast-Radiograph Evaluation (CRE) score

- Arch length discrepancy (ALD)

- Extractions (or previously extracted tooth space)

- Bracket failure, bracket fracture, poor elastic wear, missed appointments and poor oral hygiene

- OMI use, OMI failure and additional appliance use

To examine the effects of bond failure and OMI failure on treatment outcome, all cases of bond failure and OMI failure including rebonded brackets and repositioned OMI were recorded. One of the concerns for ceramic bracket use is wing fracture.[15] If the bracket wing was fractured and rotational control became difficult, it was recorded, and a new bracket was bonded. Intermaxillary elastics were prescribed for all patients at the finishing stage. Evaluation of oral hygiene was performed at each visit using the Modified Plaque Index. The original Plaque Index evaluates the gingival area on four surfaces (buccal, lingual, mesial, and distal) of six teeth (#12, 16, 24, 32, 36, 44; ISO) using a score from 0-3.[16] The Modified Plaque Index used in this study evaluated the gingival area on the labial surface of 12 anterior teeth using a score from 0-3. If four or more teeth scored more than two points (plaque is visible with or without air drying), oral hygiene was judged to be poor. When additional appliances other than brackets (e.g., headgear, rapid palatal expander, Forsus) were used, they were recorded and used as a confounding variable.

It was not possible for the investigator to be blinded to bracket type during treatment. After debonding, all identifiable information of the patient from the casts and X-rays was removed and

a random identification number was assigned at the administrative office to minimize bias during analysis. All lateral cephalograms were traced and digitized by the same investigator (MH J).

Statistical analysis

The SPSS software (version 17.0, SPSS, Chicago, IL) was used for statistical analysis. To evaluate the baseline characteristics of the sample and confounding variables, descriptive analysis was performed. After obtaining the square root of the CRE score and logarithm of the treatment duration, normality was confirmed by the Shapiro-Wilk test.

The effects of nominal variables on CRE were analyzed using an independent t-test and the effects of continuous variables were evaluated by correlation analysis. Using significant variables in the t-test and correlation analysis, analysis of covariance (ANCOVA) was performed to compare the CRE scores of the two groups, and stepwise regression analysis was used to predict CRE. The Mann-Whitney U test was also performed to find the differences between all criteria of the CRE in the two bracket systems.

To access intra-examiner reliability, ABO DI, ALD and CRE of 28 randomly selected cases was re-measured at 4-week intervals and the intra-class correlation coefficient (ICC) based on a two-way mixed effect model was calculated. Since all measurements were performed by one investigator, inter-examiner reliability was not evaluated.

RESULTS

During the study period, 321 patients started orthodontic treatment. 148 met the inclusion criteria and a total of 139 patients was allocated (Fig 3). Five patients were excluded from the final data and as a result, 68 patients in CB group and 66 patients in SB group were finally analyzed.

Nineteen patients used additional appliances. In SB, four used Forsus, three used headgear, and two used a palatal expander. In CB, six used Forsus, one used both an expander and headgear, two used headgear, and one used an expander. Ceramic bracket fracture occurred rarely in this study (three in each group) and was not used as a covariate.

The baseline characteristics and clinical features of CB and SB are shown in Tables 1 and 2. The average age was 22.73 years and the average CRE score was 14.25. The reliability tests of ABO DI, ALD and CRE using ICC revealed strong intra-examiner reliability (ABO DI = 0.997, ALD - maxilla = 0.995, ALD - mandible = 0.997, CRE = 0.993). The average treatment duration was 28.63 months, the extraction rate was 71.6% and OMIs were used in 70.1% of the patients.

Among the nominal variables, extraction and additional appliance showed significant differences in the t-test (Table 3). In the correlation analysis, age, poor elastic wear and ALD of mandible showed significant correlations (Table 4). When the effects of the five confounding variables were covaried out, the effect of bracket type on treatment outcome was significant in the ANCOVA (Table 5). Among the eight criteria, buccolingual inclination, occlusal relation and root angulation showed significant differences in the Mann-Whitney U test (Table 6). In the Stepwise regression analysis (Table 7), model 4 could explain only 25.2% of the variance in CRE score. Extraction decreased the score by 2.307, SB use increased the score by 2.500, a 'poor elastic wear' entry increased the score by 1.180 and additional appliance use increased the score by 2.244.

DISCUSSION

Increasing clinical experience does not automatically improve CRE. Even an ABO certified orthodontist may score as high as 32.21[13] while orthodontic residents may show average scores of 22.11,[17] and there was no significant difference between private practice and orthodontic departments at universities.[6] It is obvious that if an orthodontist applies consistent effort (such as prefinish cast and panoramic radiograph evaluation) to achieve better CRE scores, the score improves.[17,18]

The average CRE score in this study was 14.25, which is much lower than the recent SR (27.9).[6] There are several possible reasons.

A recent SR showed that four premolar extraction treatment was associated with an improved CRE score of 4.9 points.[6] The worse CRE score in nonextraction treatment is probably because in some cases, expansion or molar distalization makes the torque or angulation of posterior teeth inappropriate. The extraction rate in this study was 71.6%, which was higher than that of previous studies (24.3-34.4%),[7,8,18] and it would have helped to lower the CRE.

People may behave differently when they know that thery are observed. Therefore, the 'Hawthorne Effect' may be an important factor affecting the generalizability of clinical research to routine practice.[19] This study was conducted in a prospective fashion. The operator knew that the patients' treatment result would be evaluated qualitatively, and CRE score is expected to be affected by the Hawthorne effect. Correlation analysis showed no significant correlation between CRE and treatment duration, but considering significantly longer treatment periods and lower CREs than other studies, it is possible to speculate that more time and efforts were spent to lower the mean CRE value (Fig 4). 18 patients had a treatment period of more than 3 years. Considering that the longer the treatment period, the more likely that decalcification occurs, a long treatment period is usually not desirable.[20]

Although there was a study showed that the treatment outcome worsens when the treatment duration is long,[18] the effect of treatment duration does not seem to be significant according to a SR[6] and there was no significant effect found in the present study. The longer treatment duration (28.63 months) compared to the recent SR result (20.02 months)[21] may have been affected by high extraction rate and the aforementioned Hawthorne effect.

There is controversy on whether case complexity affects the quality of treatment. Some studies have shown results that imply case difficulty is not significantly correlated with treatment outcomes,[9,10] while other studies have shown them to be significantly correlated (however their correlation coefficient was only 0.17 and 0.20).[11,12] ABO DI was developed to evaluate pretreatment case complexity.[22] The DI value of this study (21.81) was much higher than previous studies evaluated DI (15.49-16.8)[12,17,23] and did not show significant correlation with the CRE score.

SRs showed that the treatment outcomes of SB and CB did not show a significant difference,[3,4] but in the ANCOVA, there was a statistically significant difference found in the present study. As the difference was only 2.74, whether this is clinically meaningful is questionable. Among the CRE measurements, buccolingual inclination, occlusal relation and root angulation showed significant differences, and further research is needed to determine if these differences are due to the distance between the archwire and tooth surface.[5] The fact that all the patients were mixed and treated together may have masked the strengths or weaknesses of SB.

The result of this study showed age was associated with treatment outcome. It can be speculated that the older the patient is, the better the cooperation,[24] but considering that the correlation coefficient was only -0.213, the influence seems to be limited.

Previous studies showed that the factors related to patient cooperation increased treatment duration,[7,8,25] but only poor elastic wear showed statistically significant correlation with CRE. When considering the effects of these factors on treatment outcome, it is assumed that poor elastic wear is more directly related to treatment outcome than missed appointment, bracket failure or poor oral hygiene.

In this research, all patients with post-treatment data, including those with premature termination, were used for analysis. The number of patients with premature termination was only three, and even if treatment continued, these cases were expected to have ended within 3-4 months, so their impact on the study results would have been negligible.

Although their influence was not analyzed in this study, the diversity of tooth morphology[26] and the size ratio of upper and lower teeth[27] can affect the treatment outcome. While tooth reshaping, archwire bending or interproximal stripping may reduce their impact, the effects of anatomical diversity cannot be completely eliminated in many cases. Therefore, deduction of a few points in

CRE seems to be inevitable. Since various variables can affect, the predictability through stepwise regression anaysis was low.

The OMI related factors do not appear to affect treatment outcome significantly. The main reason is that most OMI cases were simple anchorage reinforcement cases. As it becomes increasingly difficult to obtain cooperation in adolescents and the SRs showed the long-term orthopedic effects of headgear are not significant,[28,29] headgear was recommended only if the patient or parents refused to use OMIs.

Additional appliances may have affected the torque or angulation of the posterior teeth. Because a small number of patients used an additional appliance and several appliances were used, it was difficult to analyze the effects of each additional appliance on the treatment outcome in this study results.

A recent study showed custom indirect bonding using CAD/CAM could reduce treatment duration while providing excellent treatment outcome.[30] It seems that precise bracket positioning can affect the effectiveness and efficiency of treatment. More study is needed on this topic.

Limitations

Since this study used samples treated by one orthodontist in one private practice and all the patients had the same racial and cultural backgrounds, generalization of these results requires caution.

CONCLUSION

In this prospective cohort study, CB exhibited better treatment outcome than SB. However, the difference was small, so its clinical significance seems to be limited. Extraction, poor elastic wear and additional appliance use also had a significant impact on treatment outcome. Stepwise regression analysis result could account for only 25.2% of the variance in CRE using 4 variables.

FIGURE LEGENDS

Fig 1. A, Because of the 'play,' the tooth cannot be perfectly controlled even if the point of force application is located on the tooth surface. Red circle, point of force application; purple line, archwire. B, If the size of the bracket is large and the tooth surface is further away from the slot

base, the inaccuracy of tooth control becomes even greater. Light blue rectangle, bracket.

Fig 2. Typodonts with two types of brackets. A, Clarity (conventional bracket). B, Clippy-C (self-ligating bracket)

Fig 3. Diagram of patient flow

Fig 4. The horizontal axis is CRE score, and the vertical axis is the number of patients. Suppose that the usual treatment showed a wide range of CRE scores (A). If the orthodontist is aware that the treatment outcome will be evaluated, the overall CRE scores might have been improved by the Hawthorne effect, and the change in the distribution of the CRE score to a narrower range may have occur.

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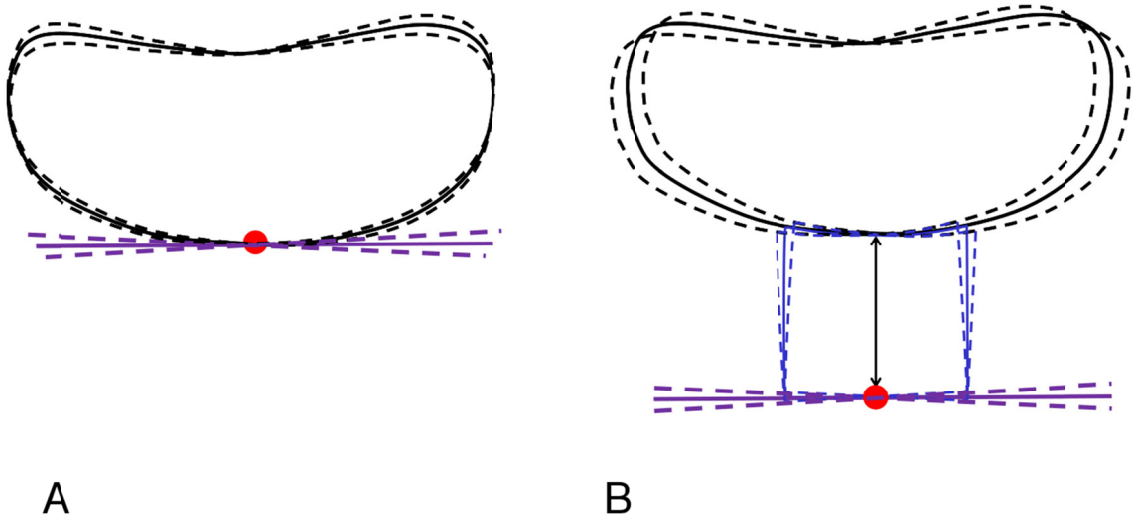

Figure 1.

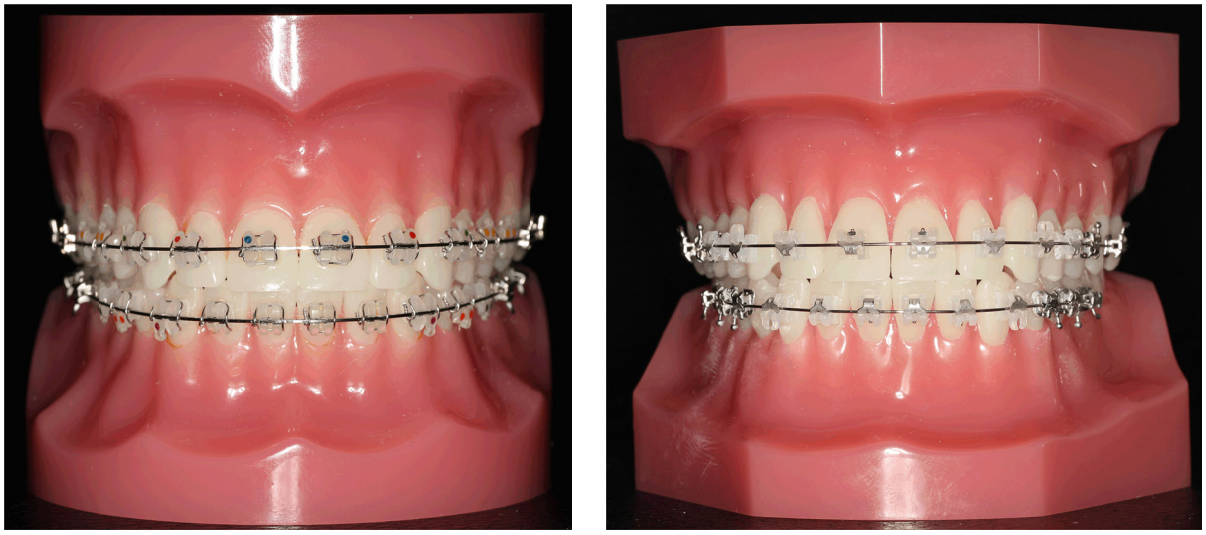

Figure 2.

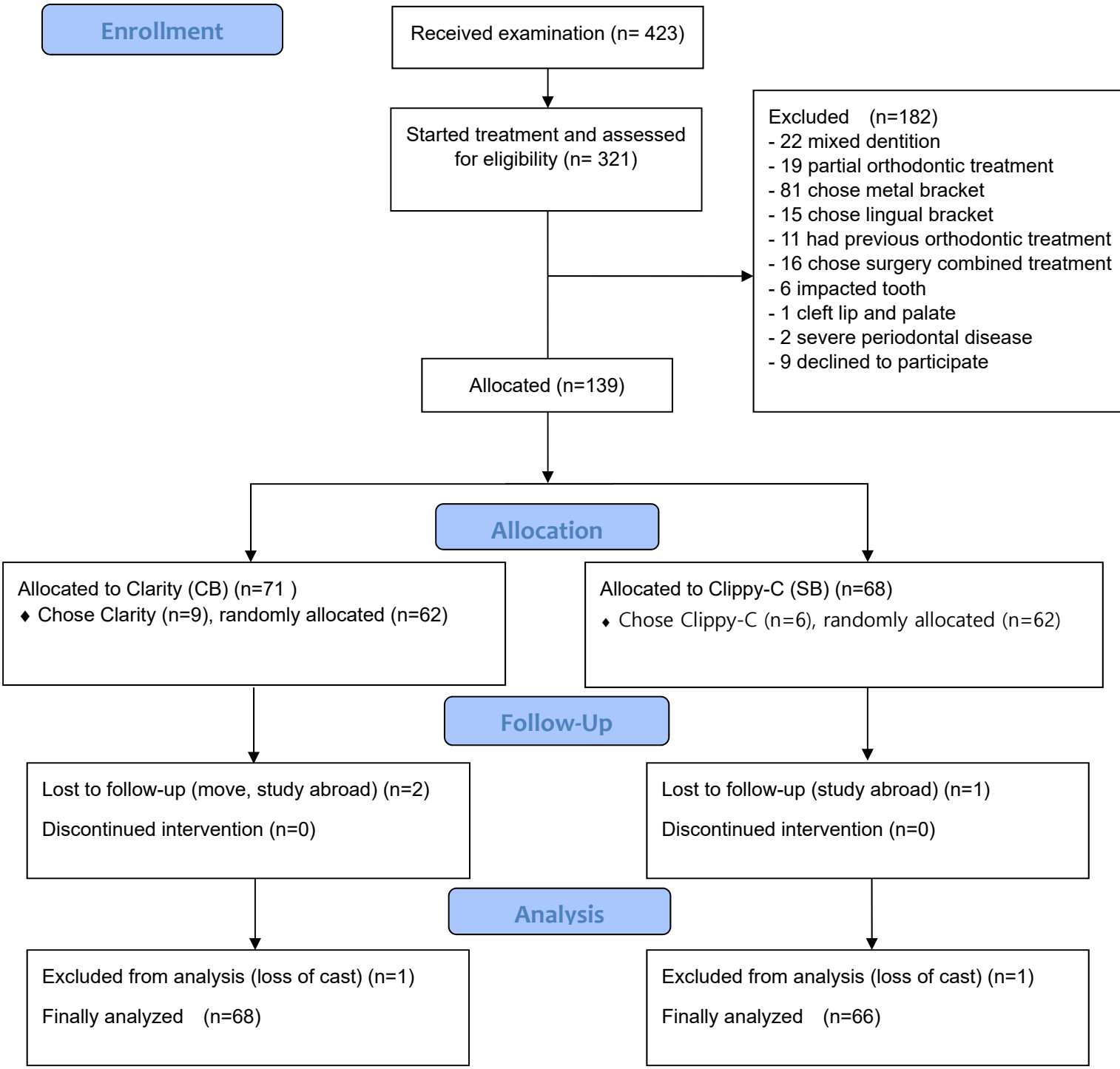

Fig 3. Diagram of patient flow

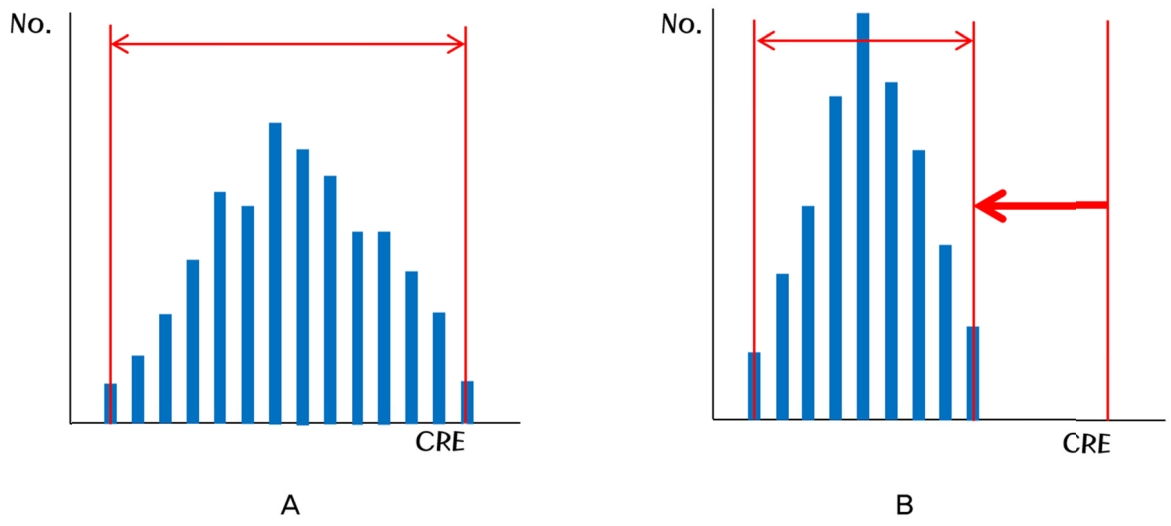

Figure 4.

Table 1. Baseline characteristics of the sample

Variable	CB	SB	Overall
Age (y)	22.99 (9.09)*	22.45 (7.78)*	22.73 (8.44)*
Sex			
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			
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	21.40 (10.17)*	22.23 (12.37)*	21.81 (11.27)*
DI <10	6 (8.8%)	6 (9.1%)	12 (9.0%)
10≤DI<20	28 (41.2%)	27 (40.9%)	55 (41.0%)
20≤DI	34 (50.0%)	33 (50.0%)	67 (50.0%)
Irregularity index			
Maxilla	5.25 (4.34)	5.96 (5.11)	5.60 (4.73)
Mandible	3.92 (2.88)	4.89 (3.49)	4.40 (3.23)
Arch length discrepancy			
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)*

*Mean (SD); †Frequency (%); ABO DI, American Board of Orthodontics Discrepancy Index

Table 2. Comparison of the measured clinical variables between 2 groups

Variable	CB	SB	Overall
Treatment duration (m)	29.25 (7.53)*	27.98 (7.10)*	28.63 (7.32)*
Extraction	49 (72.1%)†	47 (71.2%)†	96 (71.6%)†
4 premolar extraction	36 (52.9%)†	34 (51.5%)†	70 (52.2%)†
OMI use	46 (67.6%)†	48 (72.7%)†	94 (70.1%)†
Ave OMI	3.70	4.02	3.86
OMI failure	0.63 (0.85)*	0.87 (1.30)*	0.75 (1.10)*
Additional appliance	10 (14.7%)†	9 (13.6%)†	19 (14.2%)†
Bracket failure	1.81 (1.93)*	1.12 (1.09)*	1.47 (1.61)*
Poor elastic wear	2.12 (2.47)*	1.77 (1.94)*	1.96 (2.23)*
Poor oral hygiene	3.10 (4.51)*	3.15 (3.08)*	3.13 (3.86)*
Missed appointment	1.87 (3.58)*	1.73 (3.69)*	1.80 (3.62)*
Total CRE score	12.90 (4.62)*	15.64 (4.81)*	14.25 (4.90)*
CRE<10	13 (19.1%)	6 (9.1%)	19 (14.2%)
10≤CRE<20	48 (70.6%)	46 (69.7%)	94 (70.1%)
20≤CRE<30	7 (10.3%)	14 (21.2%)	21 (15.7%)

*Mean (SD); †Frequency (%); OMI use, number of patients who used OMI; Ave OMI, total number of OMI used/OMI use; OMI failure, total number of OMI failure/OMI use; CRE, Cast-Radiograph Evaluation score

Table 3. Comparison of Cast-Radiograph Evaluation (CRE) score (after square root transformation) by nominal variables in independent t-test

Variable	Group	n	CRE	CRE-SR	t value	p value
Sex	Male	37	14.108	3.756 (0.798)*	0.362	0.719
	Female	97	13.720	3.704 (0.587)*		
Extraction	Nonextraction	38	16.144	4.018 (0.556)*	3.500	0.001
	Extraction	96	12.960	3.600 (0.648)*		
OMI use	Yes	94	13.366	3.656 (0.611)*	-1.730	0.086
	No	40	14.946	3.866 (0.718)*		
Additional	Yes	19	17.281	4.157 (0.653)*	-3.292	0.001
appliance	No	115	13.293	3.646 (0.622)*		

*Mean (SD); CRE, Cast-Radiograph Evaluation score; CRE-SR, CRE after square root transformation

Table 4. Correlation between continuous variables and Cast-Radiograph Evaluation score (after square root transformation) (Pearson correlation analysis)

Variable	Correlation coefficient	p value
Age	-0.213	0.014
Treatment duration (log)	0.000	0.998
OMI failure	-0.121	0.163
Bracket failure	0.077	0.376
Poor elastic wear	0.244	0.005
Poor oral hygiene	0.131	0.132
Missed appointment	0.112	0.198
ABO DI	0.088	0.310
ALD–maxilla	-0.010	0.908
ALD-mandible	-0.171	0.048

OMI failure, total number of OMI failure/number of patients who used OMI; ABO DI, American Board of Orthodontics Discrepancy Index; ALD, Arch Length Discrepancy; ALD-maxilla, Arch length discrepancy of maxilla; ALD-mandible, Arch length discrepancy of mandible

Table 5. Result of Analysis of Covariance tested influence of bracket type after removing effects of covariates on the Cast-Radiograph Evaluation score (after square root transformation)

Variable	F	P value
Bracket Type	17.579	<.001
Covariates		
Extraction	7.646	0.007
Age	0.245	0.621
Poor elastic wear	10.445	0.002
ALD-mandible	2.039	0.156
Additional appliance	2.906	0.091

ALD-mandible, Arch length discrepancy of mandible

Table 6. Comparison of all criteria of Cast-Radiograph Evaluation score between 2 groups in Mann-Whitney U test

Variable	CB	SB	p value	overall
Alignment & rotation	0.84 (0-4)*	1.18 (0-4)*	0.059	1.01 (1.13)†
Marginal ridges	0.99 (0-4)*	0.97 (0-3)*	0.867	0.98 (1.00)†
Buccolingual inclination	2.75 (0-6)*	4.26 (0-9)*	<.001	3.49 (2.10)†
Overjet	1.01 (0-4)*	0.77 (0-5)*	0.144	0.90 (1.16)†
Occlusal contacts	4.97 (0-12)*	5.35 (0-11)*	0.229	5.16 (2.58)†
Occlusal relationships	1.85 (0-14)*	2.29 (0-11)*	0.038	2.07 (2.67)†
Interproximal contacts	0.00 (0-0)*	0.03 (0-2)*	0.310	0.01 (0.17)†
Root angulation	0.53 (0-4)*	0.83 (0-3)*	0.010	0.68 (0.79)†

CB, conventional bracket; SB, self-ligating bracket; *Mean (minimum-maximum); †Mean (SD)

Table 7. Result of stepwise regression analysis to predict Cast-Radiograph Evaluation score (after square root transformation)

Model	R	R^2 / adjusted R^2	F	P value
1	0.291	0.085 / 0.078	12.250	0.001
2	0.408	0.166 / 0.153	13.049	<.001
3	0.491	0.241 / 0.223	13.743	<.001
4	0.524	0.274 / 0.252	12.176	<.001

Model 1 = -0.418 x extraction + 4.018; Model 2 = -0.414 x extraction + 0.369 x bracket type + 3.834; Model 3 = -0.423 x extraction + 0.396 x bracket type + 0.080 x poor elastic wear + 3.671; Model 4 = -0.363 x extraction + 0.398 x bracket type + 0.072 x poor elastic wear + 0.351 x additional appliance + 3.593;