Efficiency of self-ligating vs conventionally ligated brackets during initial alignment

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Introduction: The aim of this study was to compare the efficiency of self-ligating (SL) and conventionally ligated (CL) brackets during the first 20 weeks of extraction treatment. Methods: Study models of 50 consecutive patients who had premolar extractions in the maxillary and/or mandibular arch, 0.022 × 0.028-in slot brackets, and similar archwire sequences were examined. Forty-four arches received SL Damon 3MX brackets (Ormco, Glendora, Calif), and 40 arches received either CL Victory Series (3M Unitek, Monrovia, Calif) or Mini-Diamond (Ormco) brackets. The models were evaluated for anterior arch alignment, extraction spaces, and arch dimensions at pretreatment (T0), 10 weeks (T1), and 20 weeks (T2). Results: There were no significant differences between the SL and CL groups at 20 weeks in irregularity scores (mandibular arch, P = 0.54; maxillary arch, P = 0.81). There were no significant differences in passive extraction space closures between the SL and CL groups (mandibular arch, T0-T2, P = 0.85; maxillary arch, T0-T2, P = 0.33). Mandibular intercanine widths increased from T0 to T2: 1.96 and 2.86 mm in the SL and CL groups, respectively. This was not significant between the groups (P = 0.31). Logistic regression did not show a difference between the SL and CL bracket groups. Conclusions: SL brackets were no more efficient than CL brackets in anterior alignment or passive extraction space closure during the first 20 weeks of treatment. Ligation technique is only one of many factors that can influence the efficiency of treatment. Similar changes in arch dimensions occurred, irrespective of bracket type, that might be attributed to the archform of the archwires. (Am J Orthod Dentofacial Orthop 2010;138:138.e1-138.e7)
Miles et al\textsuperscript{15} and Miles\textsuperscript{17} postulated that SL brackets might provide a measurable benefit in extraction patients. Additionally, Scott et al\textsuperscript{19} suggested that SL brackets might encourage passive space closure during initial alignment. There is a relative lack of evidence comparing the efficiency of SL and CL brackets in extraction patients because most studies have investigated mixed samples. Only 2 clinical trials have compared SL and CL brackets solely in extraction patients.\textsuperscript{16,19} One study investigated the initial alignment phase and reported no difference between SL and CL brackets.\textsuperscript{19} Neither clinical trial investigated the efficiency of passive space closure during alignment. If there is a measurable advantage of SL brackets, then it should be most apparent during alignment and space closure when the bracket slides along the archwire. In this study, passive space closure was defined as the extraction space closure during alignment without active space-closing mechanics. The amount of passive space closure varies greatly between patients, but this parameter has not been investigated before. If the use of SL brackets could achieve greater passive space closure, there would be less extraction space to close actively. This could reduce the overall treatment time. Furthermore, this might minimize the detrimental effects of active force application such as root resorption.

In this study, we aimed to determine whether there are significant differences in the efficiency of anterior tooth alignment and the amount of passive space closure between SL and CL brackets. Concomitant changes in arch dimensions were also compared between the SL and CL bracket groups.

**MATERIAL AND METHODS**

Ethical approval was obtained from the Dental Sciences and Research Ethics Committee of the University of Queensland School of Dentistry and the Royal Children’s Hospital and Health Services District Ethics Committee. Study models of 50 consecutive patients who received comprehensive fixed appliance treatment with 0.022 $\times$ 0.028-in slot brackets at the School of Dentistry, University of Queensland and the Royal Children’s Hospital were examined.

The dental school patients were treated by postgraduate students under the supervision of an experienced orthodontist. Royal Children’s Hospital patients were treated by an experienced orthodontist (H.M. or C.H.).

Patient records were included if they satisfied the following inclusion criteria: (1) treatment began between 10 and 18 years of age; (2) treatment included bilateral mandibular or maxillary extractions followed by fixed appliance therapy; (3) intraoral photos and study models were available at pretreatment (T0), 10 weeks (T1), and 20 weeks (T2) postbonding; (4) treatment included 0.022 $\times$ 0.028-in slot brackets (SL brackets, Damon 3MX, Ormco, Glendora, Calif; or CL brackets, Victory Series, 3M Unitek, Monrovia, Calif, or Mini-Diamond, Ormco); (5) treatment began with an initial archwire of 0.014-in copper-nickel-titanium (Damon archform, Ormco), followed by 0.014 $\times$ 0.025-in copper-nickel-titanium (Damon archform, Ormco)\textsuperscript{21}; (6) the patients were reviewed every 5 weeks; and (7) the first archwire was left in place until the teeth were passively engaged in all bracket slots before proceeding to the second archwire.

The following exclusion criteria were applied: treatment with nonsymmetrical extractions, no impacted or unerupted permanent teeth anterior to the first molars in the arch that received extractions, treatment with removable appliances or rapid maxillary expansion appliances, and incomplete records at a time point.

Fifty patients (20 male, 30 female) fulfilled the inclusion criteria.

Pretreatment characteristics were recorded including the patient’s age bonding, sex, mandibular and maxillary crowding, irregularity index, extraction space, intercanine width, intermolar width, and arch depth.

All study models were evaluated by using Little’s irregularity index\textsuperscript{22} to quantify the alignment of the 6 anterior teeth. Crowding was calculated as the difference between the sum of tooth widths and arch circumference taken from the line of best fit, through the contact points mesial to the first molars, on a photocopy of the patient’s occlusal archform.

Extraction space was measured from the closest points on the adjacent teeth before extraction. The mesiodistal widths of the teeth to be extracted were not used because they were often displaced from the archform; this decreased the extraction space to be closed. Similarly, extraction spaces at T1 and T2 were measured from the closest points on the crowns of the teeth on either side of the extraction space. The contact points were not used because many teeth were rotated.

Intercanine widths were measured from the cusp tips of the canines. Measurements were not taken from the gingival margin because the quality of the gingival impression was inconsistent. Intermolar widths were measured from the central and mesial occlusal pits of the mandibular and maxillary first molars because this area of the impression was clearer than the cusps. Arch depth was measured as the perpendicular distance from a line drawn through the mesial contact points of the first molars to the labial surfaces of the central incisors.
Wax was applied to cover the brackets on each model before measurement. An identification number was assigned to each model. Therefore, the researcher (E.O.) was blinded to patient name, time point, and bracket type during data collection to minimize systematic error. The study models were measured with electronic calipers with sharpened tips that were accurate to 0.01 mm (Mitutoyo, Tokyo, Japan). All model measurements were made by the principal researcher (E.O.).

Statistical analysis

The difference in irregularity scores was used to determine the sample size. Based on a previous study, a clinically significant difference of 0.98 mm in irregularity score, at a power of 80% and a level of significance of 0.05, would require a minimum of 17 patients per treatment group. In the final sample of 50 patients, 44 arches were treated with SL brackets and 40 arches with CL brackets.

Statistical analysis was performed using Minitab software (version 9.2, Minitab, State College, Pa) and SAS software (version 9.2, SAS Institute, Cary, NC). The mandibular and maxillary arches were analyzed separately. Descriptive statistics were calculated, and the data were checked for normality. Two-sample t tests were performed at T0, T1, and T2 to compare the bracket groups for irregularity scores, residual extraction spaces, intercanine widths, intermolar widths, and arch depths. The amounts of passive extraction space closure from T0 to T1, T1 to T2, and T0 to T2 for each bracket group were also calculated and compared by using 2-sample t tests. A chi-square goodness-of-fit test was used to determine whether the male-to-female ratio was significantly different between the bracket groups. Logistic regression was also used to determine whether there was a difference between the SL and CL bracket groups. Regression coefficients and confidence intervals were calculated for each variable (age, sex, irregularity index, intercanine width, intermolar width, and arch depth) for both arches. Multiple imputation was used to account for missing data.

Intraexaminer reliability was assessed by remeasuring 20 subjects at least 4 weeks after the original measurements. A t test was performed to compare the first and second measurements.

RESULTS

Intraexaminer reliability was high. There were no statistically significant differences between the first and second measurements for irregularity index ($P = 0.51$) and extraction space closure ($P = 0.38$).

The average differences between the measurements were $0.07 \pm 0.52$ mm for the irregularity index and $0.06 \pm 0.33$ mm for extraction space.

Fifty patients (20 male, 30 female) fulfilled the inclusion criteria. This gave a total of 84 arches; 44 arches were treated with SL brackets and 40 arches with CL brackets. In the CL sample, 18 arches received Mini-Diamond brackets. The numbers of arches included in the statistical analysis for each bracket group at T0, T1, and T2 are summarized in Table I. No SL arches were excluded. Six CL maxillary arches were excluded from analysis at T2 because 5 models were missing, and 1 patient received a different archwire sequence. Four mandibular arches were also excluded at T2 because of missing models.

The mean irregularity index scores decreased in both bracket groups over time (Table II). Both groups had greater decreases in irregularity during the first 10 weeks of treatment compared with the subsequent 10 weeks.

Over 20 weeks, the mean irregularity scores in the SL group decreased from 10.88 to 2.84 mm in the mandibular arch, and from 11.98 to 4.37 mm in the maxillary arch. Scores in the CL group decreased from 12.52 to 2.45 mm in the mandibular arch, and from 12.53 to 4.16 mm in the maxillary arch.

There were no statistically significant differences between the treatment groups at T1 or T2 in the mandible (T1, $P = 0.81$; T2, $P = 0.54$) or the maxilla (T1, $P = 0.87$; T2, $P = 0.81$).

For passive extraction space closure, the residual extraction spaces were measured, and the left and right sides were averaged for each patient. The mean residual extraction spaces for each bracket group at T1 and T2 were then calculated (Table II). There were no significant differences in residual extraction spaces between the groups at T1 or T2 in the mandible (T1, $P = 0.35$; T2, $P = 0.99$) or the maxilla (T1, $P = 0.37$; T2, $P = 0.44$).

Overall space closure from T0 to T2 was similar in both arches. The differences were less than 1 mm and not statistically significant.

The mean changes in arch dimensions from T0 to T2 were calculated for each arch (Table III). There were no statistically significant differences between the groups.
for any changes in arch dimensions in either arch. In both groups, mandibular intercanine widths increased ($P = 0.31$), intermolar widths decreased ($P = 0.88$), and arch depths decreased ($P = 0.61$). In the maxillary arch, intercanine widths increased ($P = 0.63$), intermolar widths increased ($P = 0.87$), and arch depths decreased ($P = 0.33$).

The changes were greatest in mandibular and maxillary intercanine widths. Mandibular intercanine widths increased from T0 to T2: 1.96 and 2.86 mm in the SL and CL groups, respectively. Maxillary intercanine widths increased from T0 to T2: 2.83 and 3.4 mm in the SL and CL groups, respectively.

Logistic regression was used to determine whether there was a difference between the SL and CL bracket groups. Multiple imputation was used to account for the small amount of missing data at T2. The following variables were tested at 0, 10, and 20 weeks: age, sex, irregularity index, intercanine width, intermolar width, and arch depth.

Regression coefficients and confidence intervals were calculated for each variable in both arches (Tables IV and V). The confidence intervals also included the variance because of missing data. All regression coefficients were close to zero, except sex and intermolar width at T2, which also had large confidence intervals. No variable was significantly associated with the probability of reduction in irregularity in either arch. Arch depth at T2 had borderline significance for the maxillary arch but was not considered highly significant (particularly because of the multiple comparisons in this study).

**DISCUSSION**

Studies have demonstrated that SL brackets generate significantly lower levels of in-vitro friction than do CL brackets. This has led to the promotion of SL brackets on the assumption that decreased friction leads to enhanced clinical efficiency. However, our study concurs with the growing body of evidence that there is no statistically significant difference in treatment efficiency between SL and CL brackets during initial alignment. Our study demonstrated that Damon 3MX SL brackets were no more efficient than Victory Series and Mini-Diamond CL brackets in anterior alignment or passive extraction space closure during the first 20 weeks of orthodontic treatment.

Early clinical studies by Eberting et al and Harradine reported decreased total treatment times and fewer appointments for patients treated with Damon SL brackets. However, these retrospective studies were both potentially subject to bias. The effect of confounding factors might have been considerable because the selection criteria were not well detailed, the pretreatment characteristics of the sample were not tested for equivalence, and clinical variables such as archwire sequences were different in each bracket group.

Subsequent well-designed retrospective and prospective clinical studies reported no significant differences in treatment efficiency between SL and CL brackets during initial alignment and active space closure. Most of these studies evaluated the alignment efficiency of the mandibular anterior arch because rotations, irregularity, and small interbracket distances are typically encountered in this region.
We investigated the anterior alignment of both arches with the irregularity index.

Various authors have drawn the same conclusions irrespective of the particular brand of SL bracket. Miles et al.\(^{15}\) and Miles\(^{17}\) did not find any significant differences when they prospectively compared Damon SL and SmartClip (3M Unitek) SL with Victory Series CL brackets during initial alignment. Pandis et al.\(^{18}\) also found no difference when comparing the time to alignment in the mandibular arch between Damon 2 (Ormco) SL and Microarch (GAC International, Bohemia, NY) CL brackets. A recent large retrospective study concluded that InOvation (GAC) SL brackets had no measurable advantages over Victory Series CL brackets in initial alignment time, total treatment time, or number of appointments.\(^{20}\)

Despite these findings, it has been suggested that SL brackets might provide benefits for extraction patients during initial alignment or space closure.\(^{15,17}\) Correspondingly, spontaneous tooth movement into extraction spaces because of reduced friction during alignment could be a time-saving benefit.\(^{19}\) Therefore, we exclusively investigated extraction subjects during initial orthodontic treatment to assess the efficiency of alignment and passive extraction space closure.

Two previous studies compared SL and CL brackets solely in extraction patients. Miles\(^{16}\) prospectively compared 0.018-in Victory series CL brackets and SmartClip SL brackets during active space closure. He found no differences in the rate of tooth movement between the bracket types: 1.1 mm per month with SL brackets and 1.2 mm per month with CL brackets. These rates are not comparable with our results because of different biomechanics and types of tooth movement during these stages.

Scott et al.\(^{19}\) conducted a randomized controlled trial of patients having mandibular first premolar extractions. He concluded that Damon 3MX brackets were no more efficient during mandibular alignment than Synthesis (Ormco) CL brackets. Those authors did not investigate

<table>
<thead>
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<th>Table IV. Logistic regression for the mandibular arch</th>
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<th>95% CI</th>
<th>P value</th>
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the maxillary arch or passive extraction space closure. Our study is the first to quantify the amount of tooth movement during passive extraction space closure. We found no difference in the amount of passive space closure during initial alignment, in either arch, between the bracket types.

We used the same initial archwire sequence as that of Scott et al,\textsuperscript{19} which included 0.014-in and 0.014 $\times$ 0.025-in copper-nickel-titanium archwires in the Damon archform. The SL group of Pandis et al\textsuperscript{18} also used the same sequence. Similar changes in arch dimensions were observed in all patients with these archwires regardless of the bracket type used. Therefore, the dimensional changes can be attributed to the Damon archform. Mean mandibular intercanine widths increased, mandibular intermolar widths decreased, and arch depths decreased. Mandibular intercanine widths increased by averages of 1.96 and 2.86 mm in the SL and CL groups, respectively. Scott et al\textsuperscript{19} reported similar increases of 2.55 and 2.66 mm in SL and CL groups, respectively.

Mean maxillary intercanine widths increased by 2.83 and 3.4 mm in the SL and CL groups, respectively. The increases in maxillary intermolar widths in both bracket groups were negligible. Interestingly, maxillary and mandibular intercanine widths increased despite the extractions. This might be due to the distal movement of the canines into the extraction spaces.\textsuperscript{19} These findings discredit previous suggestions that premolar extractions inevitably cause “shrinking” of the dental arch, increased buccal corridors, and damage to smile esthetics.\textsuperscript{24} Furthermore, studies have shown that buccal corridors do not influence smile esthetics.\textsuperscript{25,26}

The results from this study concur with previous studies that found no difference in the alignment of mandibular teeth in extraction patients with severe irregularity.\textsuperscript{18,19} The mean irregularity scores in the study of Scott et al\textsuperscript{19} were 12.44 mm in the CL group and 11.23 mm in the SL group. Similarly, the patients we investigated had severe irregularity scores. Pandis et al\textsuperscript{18} investigated moderate and severe irregularity. They reported no significant difference in subjects with severe irregularity scores greater than five. Interestingly, they found that patients with moderate irregularity, with irregularity scores between 2 and 5, were 2.7 times more likely to align faster in the SL bracket treatment group. Different archwire sequences were used in each bracket group in the study of Pandis et al\textsuperscript{18}; this might have been a confounding factor contributing to the hazard ratio.

A strength of this study was the inclusion and exclusion criteria that enabled control over certain clinical variables such as bracket composition and dimension, archwire type and sequence, and interappointment interval. Consecutive eligible patients were included to minimize confounding factors. Therefore, the critical difference between the treatment groups was the method of ligation.

This study had several limitations. There was no control group available to measure the natural drift of the teeth into the extraction spaces without orthodontic appliances. It could also be argued that extraction therapy is not routinely performed with the SL bracket philosophy and is not intended for this sample of patients. Despite the strict inclusion and exclusion criteria, the possibility of sampling bias because of the retrospective nature of the study cannot be dismissed. Several patients were excluded because of missing models at the various time points, or they received an alternate archwire sequence that reduced the power of the study at T2. The patients were also treated by several clinicians with various levels of experience. The 3 bracket types used in this study had different prescription values.

It might be postulated that, as irregularity increases, other factors negate any benefit of the reduced friction of SL brackets. For example, the narrower bracket design of the Damon 3MX might have increased the contact angle and contributed to elastic binding and notching. Future research could explore these hypotheses in extraction patients, with larger sample sizes in a prospective clinical trial.

It is not surprising that bracket type does not appear to have a significant influence on treatment efficiency. Treatment efficiency is the product of many mechanical and biologic factors. It is unlikely that any 1 factor is responsible for the rate of tooth movement. The biology of tooth movement is a complex and highly coordinated process at the cellular, molecular, and genetic levels. Individual variation undoubtedly has a fundamental underlying role in tooth movement and treatment efficiency.

CONCLUSIONS

1. SL brackets were no more efficient than CL brackets in anterior alignment and passive extraction space closure during the first 20 weeks of orthodontic treatment.
2. Changes in arch dimensions were similar in the SL and CL groups.

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REFERENCES


