Original Article

Effect of applied moment on resistance to sliding among esthetic self-ligating brackets

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ABSTRACT

Objective: To determine the effect of mode of ligation and bracket material on resistance to sliding (RS) by comparing various esthetic brackets of conventionally ligated and self-ligating (SL) designs under an increasing applied moment in the second-order dimension.

Materials and Methods: Eight different commercially available esthetic brackets of SL and conventional elastomeric-ligated (CL) designs were mounted on a testing apparatus to simulate canine retraction using sliding mechanics and the application of a moment on 0.019″×0.025″ stainless steel archwire. The samples examined were the CL brackets Clarity™, Inspire Ice™, SpiritMB™, and Mystique™, and the SL brackets ClaritySL™, In-OvationC™, In-OvationR™, and Smartclip™. The RS at calculated moments of 2000 g-mm and 4000 g-mm was determined and compared between the various brackets. Descriptive measures and one-way analysis of variance were used to calculate means and statistical differences among the bracket types.

Results: The CL monocrystalline bracket displayed significantly greater ($P < .05$) RS than all other brackets tested. Among the other brackets, the range of RS values was 145.8–191.7 g and 291.9–389.2 g at moments of 2000 g-mm and 4000 g-mm, respectfully, though these differences were not significant ($P < .05$). All brackets tested displayed greater levels of RS ($P < .05$) at 4000 g-mm than at 2000 g-mm.

Conclusion: With the exception of the CL monocrystalline bracket, all brackets displayed comparable amounts of RS regardless of mode of ligation or bracket slot material. (*Angle Orthod.* 2014;84:134–139.)

KEY WORDS: Self-ligation; Friction; Resistance to sliding

INTRODUCTION

The practice of orthodontics often involves the need to balance the desires of patients with those of the clinician. Thus, the ideal orthodontic appliance would provide maximum esthetics, while being efficient and predictable in performance. Increased resistance to sliding (RS) between the archwire and an esthetic bracket during orthodontic tooth movement is a frequently cited barrier to consolidating these needs.[1,2] Bracket slot material and mode of ligation are two variables that have been given considerable focus in an attempt to produce a bracket with optimal clinical performance in terms of sliding mechanics. Glazed, rounded, or metal-lined bracket slots and self-ligating (SL) designs of esthetic brackets have all been recently produced in search of this goal.[3] Currently, there is a lack of conclusive evidence showing how esthetic bracket material and bracket design affect RS.[4–6] This uncertainty can often be explained by differences in experimental design, as most in vitro studies do not necessarily reflect situations that readily apply to clinical practice. During orthodontic tooth movement, teeth tip until binding occurs between the bracket and archwire,[7,8] and it has been shown that binding within the bracket can make a significantly larger contribution to RS than force of ligation.[9] It follows then that a study where a bracket is gradually

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Table 1. Brackets Tested

Brackets (0.022″ Upper Left Canine)	Ligation Type[a]	Slot Material
SpiritMB (Ormco Corporation, Glendora, Calif)	CL	Metal-slot polycarbonate
Clarity (3M Unitek, Monrovia, Calif)	CL	Metal-slot polycrystalline
Inspire Ice (Ormco Corporation)	CL	Monocrystalline
Mystique (Dentsply GAC International Inc, Bohemia, NY)	CL	Polycrystalline
Smartclip (3M Unitek)	SL	Stainless steel
In-OvationR (Dentsply GAC International Inc)	SL	Stainless steel
ClaritySL (3M Unitek)	SL	Metal-slot polycrystalline
In-OvationC (Dentsply GAC International Inc)	SL	Polycrystalline

[a] CL indicates conventional elastomeric ligated; SL, self ligated.

tipped, allowing the bracket-archwire interface to bind, would be a more appropriate in vitro study of the effects of bracket material and ligation on RS.[10]

For this study various commercially available esthetic brackets of SL and conventional elastomeric-ligated (CL) designs were mounted on a testing apparatus to simulate canine retraction using sliding mechanics and the application of a moment. This experimental design, which dynamically relates the RS to the magnitude of moment applied, will allow for a more clinically relevant comparison of the materials than has been done in the past. The aim of this study was to compare and evaluate the RS between esthetic brackets of different materials and different modes of ligation under an increasing applied moment. Therefore, the following null hypotheses were tested:

—At clinically relevant levels of applied moment, there will be no difference in RS between SL and CL esthetic brackets

—At clinically relevant levels of applied moment, there will be no difference in RS between metal and esthetic SL brackets

MATERIALS AND METHODS

For this study, eight different types of 0.022″ upper left canine brackets of varying mode of ligation and material were tested (Table 1). The test brackets were mounted on a custom-built device to simulate canine retraction mechanics, which has been described previously.[11] The experimental setup allowed the force required to pull the wire through the bracket slot (RS) to be continuously recorded, while simultaneously constantly measuring the force applied to rotate the test bracket. It was therefore possible to dynamically compare RS to the moment applied to the archwire by the bracket (Figure 1).

The brackets were tested on straight lengths of 0.019×0.025 stainless steel archwire (Dentsply GAC International Inc, Bohemia, NY), which was pulled through the bracket at a rate of 5 mm/min. To eliminate the influence of wear, a virgin bracket and archwire sample were used in each test run. A single operator tested 10 samples for each bracket/archwire combination in random order, producing a total of 80 test runs. An elastomeric tie (Quik-Stick A1 Alastik, 3M Unitek, Monrovia, Calif) was used to ligate the conventional brackets 24 hours before testing to allow for relaxation and stabilization.

The data recorded for RS were plotted against the calculated moment for each test run. The raw data initially included values collected from 1 second before commencing to increase the moment on the archwire until a maximum moment reading of approximately 1000 g on the lateral load cell. However, to reduce potential influences due to notching of the archwire by the bracket slot, the data were truncated to moments less than approximately 6000 g-mm, to include only the linear portion of the friction vs moment curves. The 6000 g-mm would correspond to a retraction force of 600 g, and so values above this were thought to be not clinical feasible or relevant for canine retraction under sliding mechanics. A line of best fit was then applied to

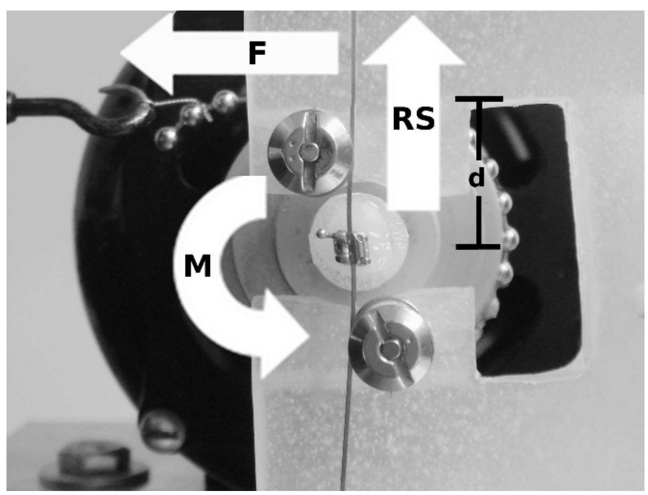

Figure 1. The bracket-archwire interface of the testing assembly as demonstrated with a 0.019″×0.025″ stainless steel archwire/In-OvationR bracket couple at the end of a test run. A lateral force (F) rotates the axle and mounted bracket, while the archwire is pulled vertically through the bracket by the crosshead of the Instron machine. The lateral force rotating the bracket and the force required to pull the archwire (RS) were recorded simultaneously. The moment (M) applied to the bracket was calculated as $M = F \times d$.

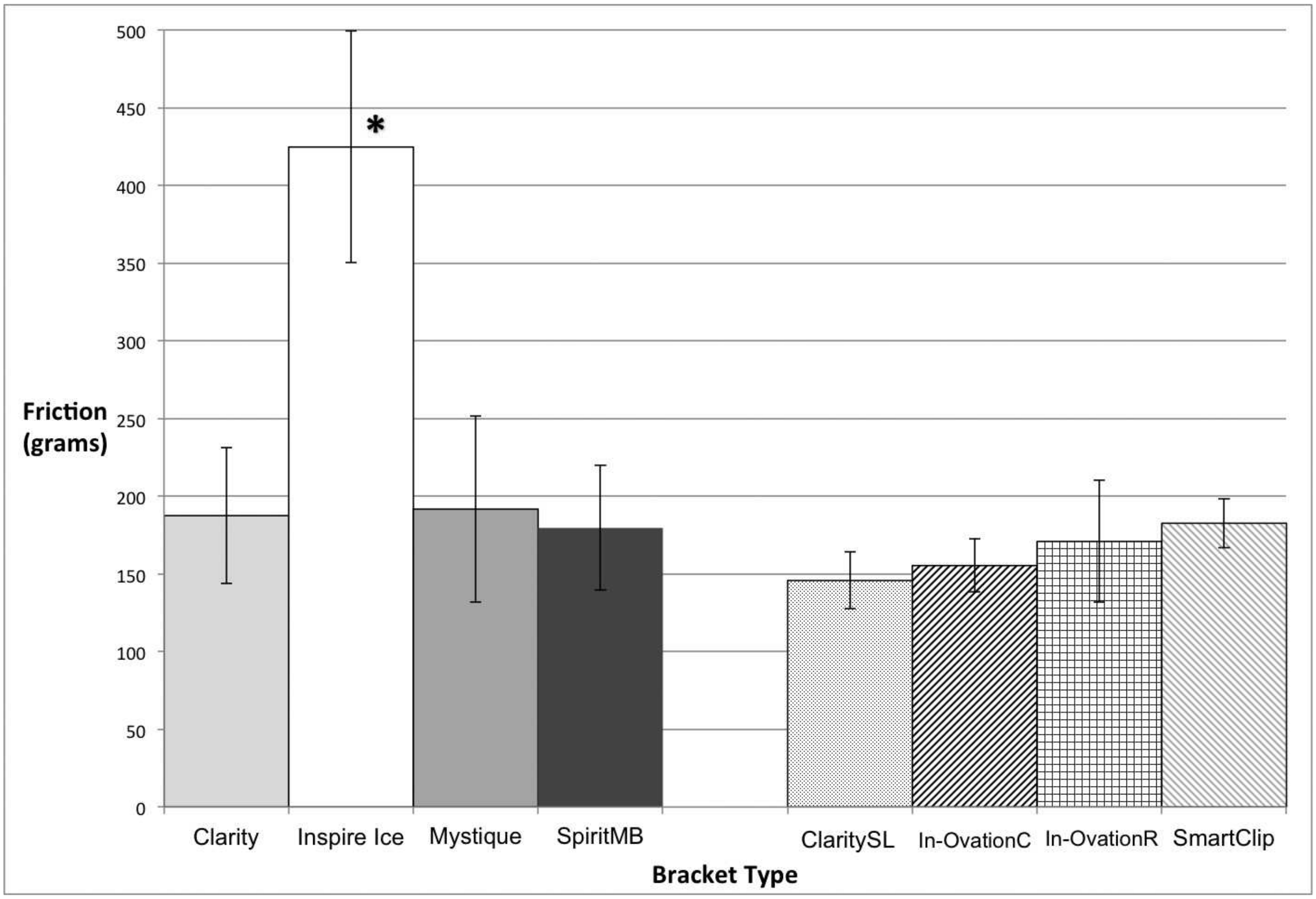

Figure 2. Resistance to sliding with a 2000 g-mm moment. Brackets are grouped by mode of ligation: left = conventional ligation; right = self-ligation. Statistical significance ($P < .05$) is noted by *.

this plotted data, and the linear equation was then used to calculate the RS at moments of 2000 g-mm and 4000 g-mm. Assuming a distance of 10 mm for a bracket to the center of resistance for a maxillary canine, these moments would correspond to clinical retraction forces of 200 g and 400 g, respectively. These moments were selected as being representative of low-end and high-end levels of force used clinically to retract canines with sliding mechanics. The mean values from the 10 sample runs were then calculated for each bracket and archwire combination. Descriptive measures, one-way analysis of variance, and Tukey-Kramer posttest comparisons were used to calculate the means and statistical differences among the different samples.

RESULTS

Results are displayed as the means of 10 sample runs with standard deviations (Figures 2 and 3). At a calculated moment of 2000 g-mm, the RS among the brackets tested had a range of 278.9 g. The monocrystalline (Inspire Ice) bracket displayed statistically greater friction ($P < .05$) than all other brackets tested. No significant differences were found between the remaining CL brackets and the SL designs. The RS of the metal SL brackets tested (Smartclip and In-OvationR) were found to be similar to their esthetic SL counterparts (ClaritySL and In-OvationC, respectively).

At the higher moment level (4000 g-mm), all brackets were found to be equivalent, with the exception of the monocrystalline bracket (Inspire Ice), which again displayed significantly greater ($P < .05$) RS. The range of RS was 499.2 g between the brackets tested. The SL brackets, both metal and esthetic, and the CL esthetic brackets, both with metal or glazed slots, all produced similar levels of frictional resistance. All brackets tested displayed greater levels of RS ($P < .05$) at 4000 g-mm than at 2000 g-mm.

DISCUSSION

Recently, ceramic SL brackets have been introduced in an attempt to reduce the friction of tooth movement along an archwire and to respond to the esthetic demands of patients. The present study

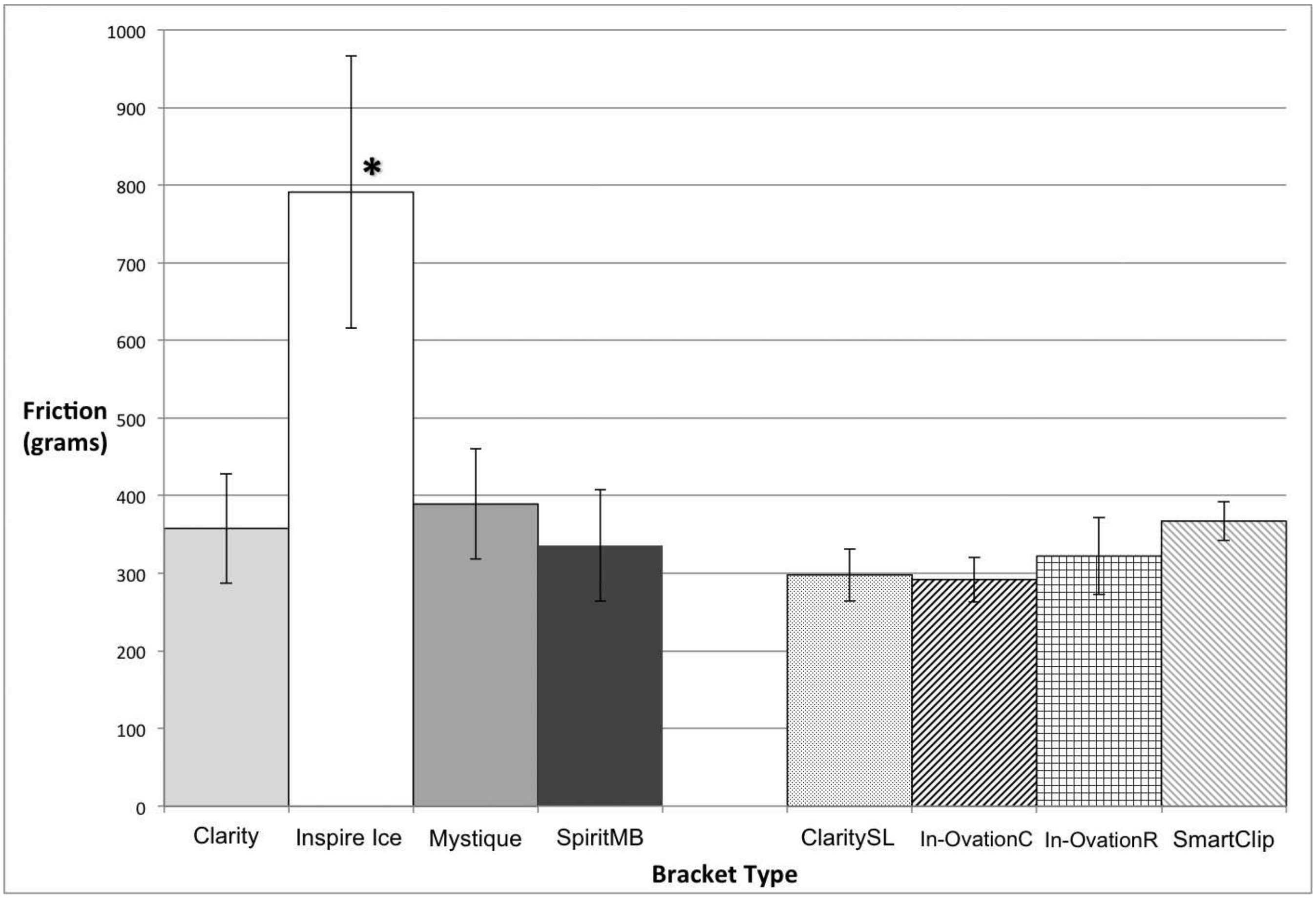

Figure 3. Resistance to sliding with a 4000 g-mm moment. Brackets are grouped by mode of ligation: left = conventional ligation; right = self-ligation. Statistical significance ($P < .05$) is noted by *.

compared the effect on RS of esthetic bracket material and mode of ligation under calculated moments of 2000 g-mm and 4000 g-mm.

Effect of Bracket Material

At both the higher and lower amounts of applied moment, the CL monocrystalline bracket (Inspire Ice) showed significant greater RS than all other brackets examined. Previously, much focus has been on the slot surface material of esthetic brackets and its effect on frictional resistance. In this study both polycarbonate (SpiritMB) and polycrystalline brackets (Clarity) with metal slots, stainless steel brackets (Smartclip and In-OvationR), and polycrystalline brackets with a glazed slot (Mystique and In-OvationC) displayed similar amounts of RS. In terms of bracket material only the property of monocrystalline ceramic had any significant influence on RS when tested under an increasing applied moment in the second-order dimension.

In comparison to previous studies that investigated RS under conditions in which binding occurs at the archwire-bracket interface, the present results are in line with those of Bazakidou et al.,[1] who also found RS to be greatest for a monocrystalline bracket when testing various ceramic, stainless steel, and polycarbonate brackets on 0.019″×0.025″ stainless steel archwire. Similarly, Guerrero et al.,[12] with an in vitro study testing in the presence of artificial saliva, observed the highest frictional values with monocrystalline brackets. They observed that although monocrystalline brackets tend to have a smoother surface, the sharp hard edges of the bracket slot tend to induce greater amounts of friction during sliding mechanics when these edges are binding with the archwire. The similar RS values between polycarbonate and polycrystalline ceramic brackets with and without metal slot inserts has also been reported by Thorstenson and Kusy.[13]

Effect of Mode of Ligation

Using a testing apparatus that allows the bracket to bind with the archwire during simulated sliding mechanics, the present study compared the RS between several different designs of CL and SL brackets. With the exception of the monocrystalline bracket tested, all brackets, regardless of mode of ligation, produced similar amounts of RS. The study conditions were such that equivalent moments were produced at the bracket-archwire interface, effectively simulating clinical conditions of a tipping tooth, albeit limited to the second-order dimension. The present results demonstrate that during sliding mechanics, especially when moderate levels of force are used, the friction induced by ligation has little influence on the overall RS.

These results are in contrast to those of Voudouris and colleagues,[14] who reported significantly lower levels of RS with esthetic SL brackets than with CL designs. This, however, can be easily explained by their experimental design, in which the bracket and archwire were perfectly aligned so that no binding would occur due to excessive angulation of the bracket relative to the archwire. As has been previously discussed,[15] binding between an archwire and bracket is an unavoidable phenomenon in orthodontics; therefore, a more practical examination of friction mechanics should include binding in the determination of RS. In one such study, Reicheneder et al.[16] examined the RS of both CL and SL esthetic brackets under conditions where binding was induced between the archwire and bracket slot by a suspended 250 g weight. They found that the passive SL esthetic brackets made of a glass-filled polycrystalline material produced significantly less RS than CL brackets made of monocrystalline or polycrystalline materials. Possible reasons for this finding may be that, unlike the present investigation, which was performed under dry conditions with elastic ligatures applied 24 hours before testing, Reicheneder et al.[16] first incubated their bracket-archwire specimens in a heated artificial saliva solution for 28 days. This process is known to have a variable effect on RS, and some studies[17] have reported a decreased amount of force delivered by elastic ligatures. Others[18,19] have reported increased amounts of RS depending on the exact storage environment or elastic material used. In a similar fashion to the elastic ligatures, the brackets themselves may become degraded[20] at different rates and stick to the archwire more than in the untreated state.

The strengths of the present study stem from the testing apparatus, which allowed for a comparison of RS among different brackets at similar moments rather than degree of tip between the archwire and bracket slot. This design reduces the influences of manufacturing and mounting variables between samples and can be more applicable clinically as it is easier to assess amount of applied force to a bracket as opposed to the angulation between bracket slot and archwire. Limitations of the study include an in vitro investigation limited to the second-order dimension, as among other variables, the mesiobuccal rotation of canine retraction would also be present clinically. Additionally, though assumed to be the same for each bracket tested, the rotating axle and guide rollers of the experimental setup would also contribute to the total amount of RS reported. For this reason, the presented values should only be used for comparison purposes, as any in vitro investigation will not adequately represent the complex oral environment. However, though not all in vivo conditions can be practically simulated on a lab bench top, the results of this study may lead the way to improved study design of clinical trials required to validate the current findings.

CONCLUSIONS

- With the exception of the monocrystalline bracket, CL esthetic brackets displayed comparable amounts of RS to SL esthetic brackets.
- Stainless steel SL brackets displayed similar amounts of RS compared with esthetic SL brackets.

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