Original Article

Forces in the Presence of Ceramic Versus Stainless Steel Brackets with Unconventional vs Conventional Ligatures

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ABSTRACT

Objective: To compare the forces resulting from four types of bracket/ligature combinations: ceramic brackets and stainless steel brackets combined with unconventional elastomeric ligatures (UEL) and conventional elastomeric ligatures (CEL) during the leveling and aligning phases of orthodontic therapy.

Materials and Methods: The testing model consisted of five 0.022-inch preadjusted brackets (second premolar, first premolar, canine, lateral incisor, and central incisor) for each of the two bracket types. The canine bracket was welded to a sliding bar that allowed for different amounts of offset in the gingival direction. The forces generated by a 0.014-inch superelastic nickel titanium wire in the presence of either the UEL or CEL bracket/ligature systems at different amounts of upward canine misalignment (1.5 mm, 3 mm, 4.5 mm, and 6 mm) were recorded.

Results: Significant differences were found between UEL and CEL systems for all tested variables ($P < .01$) with the exception of the canine misalignment of 1.5 mm. The average amount of recorded force in the presence of CEL was negligible with 3.0 mm or greater of canine misalignment. On the contrary, during alignment, a force available for tooth movement was recorded in the presence of both ceramic and stainless steel brackets when associated with UEL.

Conclusions: The type of ligature used influenced the actual amount of force released by the orthodontic system significantly more than the type of bracket used (stainless steel vs ceramic).

KEY WORDS: Orthodontic ligatures; Esthetic fixed appliances; Friction

INTRODUCTION

In modern society the esthetic aspect of the orthodontic therapy is important because the number of adults that undergo orthodontic therapy is increasing.[1] The development of appliances that combine both acceptable esthetics and adequate technical performance is an important goal. Ceramic brackets were developed to improve esthetics during orthodontic treatment, with a continuous effort to overcome several problems of these types of brackets: brittleness leading to bracket or tie-wing failure, iatrogenic enamel damage during debonding, enamel wear of opposing teeth, and high frictional resistance to sliding mechanics.[2–6]

Beside esthetics, a second desirable condition in fixed appliance therapy with preadjusted brackets consists in the reduction of "frictional" forces between the bracket and the guiding archwire during both the initial treatment phases of leveling and aligning and the sliding mechanics for space closure. Friction is the resistance to motion that exists when a solid is moved tangentially with respect to the surface of another contacting solid.[7] Friction is, thus, inherent to sliding systems and influences the rate of orthodontic movement.[8] During mechanotherapy involving movement of the bracket along the wire, friction at the bracket-archwire interface may prevent the attainment of optimal force levels in the supporting dental tissue. Therefore, an understanding of the force required to overcome friction is important so that the appropriate

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magnitude of force can be used to produce appropriate biologic tooth movement.[9] To explain the friction between wire and bracket, several variables such as bracket material, wire material, and wire section can be studied.[10–12] For instance, ceramic brackets show a high level of frictional resistance because the ceramic material yields a higher coefficient of friction than stainless steel due to differences in the plastic and elastic properties of the materials.[7]

Previous research[13–15] stated that friction can be determined also by the nature of the ligation. An innovative system of unconventional ligatures is an actual alternative to self-ligating brackets. Recently, unconventional elastomeric ligatures (UEL) have been developed to be combined with both ceramic and stainless steel brackets.[16] Once the unconventional ligature is applied on the bracket, the interaction between the ligature and the slot forms a "tube-like" structure, which allows the archwire to slide freely and to produce its effects more readily on the dentoalveolar component. In vitro studies[17,18] have compared the frictional forces generated by the UEL and the conventional elastomeric ligatures (CEL) with 0.014-inch superelastic nickel titanium wire and 0.019 × 0.025 inch stainless steel wire. The amount of both static and kinetic friction was minimal (<10 g) in the UEL group in the presence of aligned brackets with both types of wires, and it was less than half of that shown by CEL in the presence of a misaligned canine bracket.

The aim of the present in vitro study was to compare the differences in the forces available for tooth movement during the alignment phase of fixed appliance therapy when utilizing either ceramic or stainless steel brackets with either unconventional or conventional elastomeric ligatures.

MATERIALS AND METHODS

All materials used in this study were supplied by Leone Orthodontic Products (Sesto Fiorentino, Firenze, Italy). An experimental model[18] was used to assess the forces produced by:

a. Esthetic ceramic brackets (AQUA) with esthetic UEL (Slide) (Figure 1);
b. Esthetic ceramic brackets (AQUA) with CEL (transparent mini modules, with an inside diameter of 1.3 mm and thickness of 0.9 mm);
c. Stainless steel brackets (STEP) with silver UEL (Figure 2);
d. Stainless steel brackets (STEP) with CEL.

The buccal segment model (Figure 3) consisted of either five esthetic ceramic or five stainless steel 0.022-inch preadjusted brackets (Roth prescription for the ceramic brackets and MBT prescription for the stainless steel brackets) for the second premolar, first premolar, canine, lateral incisor, and central incisor. The interbracket distance was set at 8.5 mm. The canine bracket was welded to a sliding bar that allowed for different vertical positions, while the other brackets were mounted in a vice-like device. A section of 0.0215 × 0.028 inch stainless steel wire was used to align all the brackets.

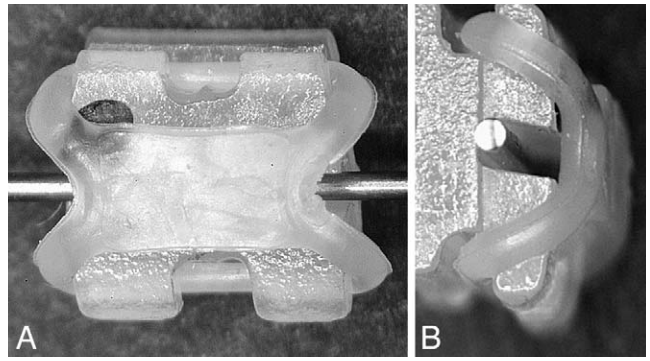

Figure 1. Ceramic bracket (AQUA) with unconventional elastomeric ligature (Slide). (A) Frontal view. (B) Lateral view.

The forces generated by the testing unit consisting of wire, brackets, and either CEL and UEL were measured under dry conditions and at room temperature (20° ± 2° C) by means of an Instron 4301 testing machine (Instron Corp, Canton, Mass) with a load cell of 10 N. The upper end of the sliding bar bearing the canine bracket was connected to the Instron crosshead. A 0 gram frictional force was recorded by the testing machine when pulling the sliding bar with the canine bracket in an upward direction in the absence of any orthodontic wire.

A round 0.014-inch superelastic nickel titanium wire (Memoria, Leone Orthodontic Products, Sesto Fiorentino, Firenze, Italy) was tested. This type of wire is frequently used during the aligning and leveling phase of the straight-wire technique.[9] The wire was secured into the preadjusted brackets using the two types of

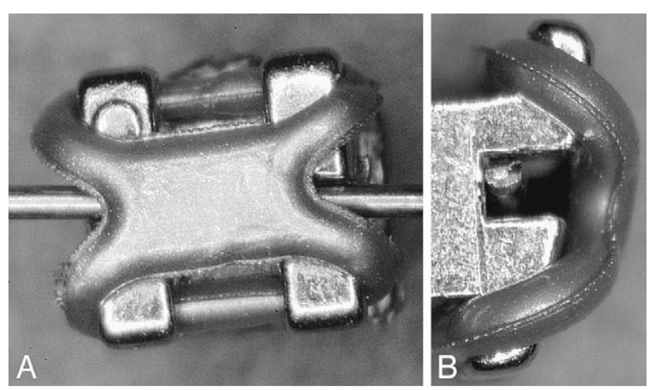

Figure 2. Stainless steel bracket (STEP) with unconventional elastomeric ligature (Slide). (A) Frontal view. (B) Lateral view.

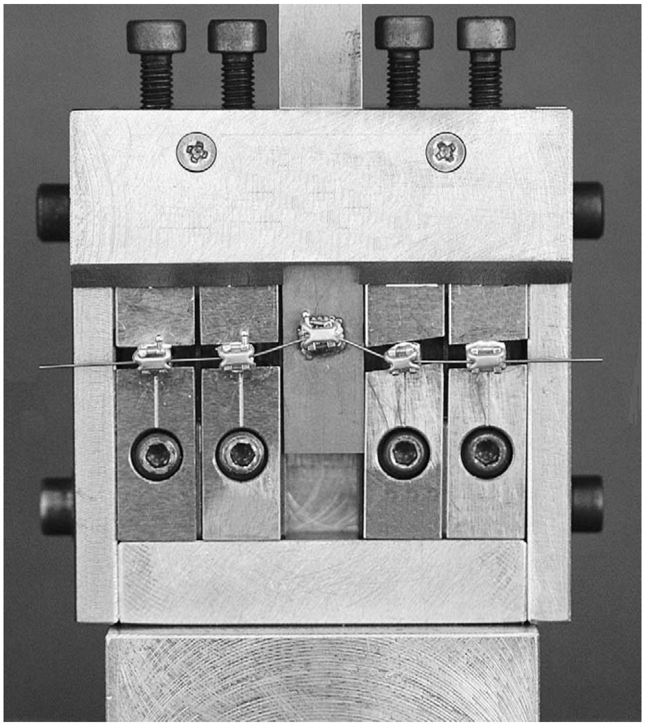

Figure 3. Experimental in vitro model with misaligned canine bracket.

ligatures: UEL (Slide) and CEL (mini modules). The elastomeric ligatures were placed immediately before each test run, to avoid ligature force decay.

The Instron machine recorded the forces released by the archwire-bracket-ligature system following four different amounts of upward displacement of the sliding bar bearing the canine bracket: 1.5 mm, 3.0 mm, 4.5 mm, and 6.0 mm of misalignment. The forces generated by the wire with either ceramic or stainless steel brackets with UEL and CEL were recorded. The forces produced by each wire/ligature combination were tested 20 times with new wires and ligatures on each occasion. A total of 320 tests were carried out (80 tests for esthetic ceramic brackets with UEL, and 80 tests for esthetic ceramic brackets with CEL; 80 tests for stainless steel brackets with UEL, and 80 tests for stainless steel brackets with CEL).

Statistical Analyses

Descriptive statistics were calculated for the forces generated by the wire/ligature combinations at the four different amounts of canine misalignment. The comparisons between the results for the two types of brackets with UEL and CEL were carried out by means of Kruskal-Wallis test with Tukey's post hoc test ($P <$ .05) (SigmaStat 3.1, Systat Software Inc, Point Richmond, Calif).

RESULTS

The descriptive statistics and the analysis of the comparisons on the forces released by the orthodontic wire in the presence of ceramic brackets with UEL and with CEL, and in the presence of stainless steel brackets with UEL and with CEL are shown in Table 1.

At a canine misalignment of 1.5 mm, differences between ceramic brackets with UEL and CEL were not significant for any of the tested variables. At the same amount of canine misalignment, the differences between ceramic and stainless steel brackets with UEL and with CEL were not significant either.

The comparison between the unconventional ligatures and CEL in conjunction with ceramic and stainless steel brackets showed that, in the presence of UEL, a significantly greater amount of force was generated when canine misalignment was of 3.0 mm, 4.5 mm, and 6.0 mm. When the two types of brackets (ceramic vs stainless steel) with UEL were compared, no significant differences were found in the presence of 1.5 mm, 3.0 mm, 4.5 mm, and 6.0 mm of misaligned canine. The same results were found in the comparison between the ceramic and stainless steel brackets with CEL. The average amount of released force for both types of brackets in the presence of CEL with 3.0 mm of canine misalignment or greater was approximately zero.

DISCUSSION

The aim of the present study was to compare the forces released by an orthodontic archwire in the presence of two types of brackets (stainless steel brackets and esthetic ceramic brackets) by combining them with either conventional or unconventional elastomeric ligatures during the leveling and aligning phase of fixed appliance therapy. A testing device similar to the one proposed recently by Franchi and Baccetti[18] was conceived to recreate clinical conditions for the leveling and aligning phase of straight-wire technique, ie, to study the forces released during alignment of a displaced tooth by allowing for different amounts of vertical misalignment of one bracket (canine bracket) with respect to the four remaining aligned brackets.

In the presence of a 1.5-mm misaligned canine the forces produced by the two types of brackets with UEL and with CEL were not statistically different, and they ranged from 95 to 120 g. Similar results were found in a previous work on stainless steel brackets.[18] Starting from a 3.0-mm misalignment of the canine bracket, the difference in behavior between UEL and CEL became statistically significant. The use of CEL produced a negligible amount of released force for alignment when the tooth misalignment was greater than or equal to 3 mm, whereas the use of low-friction liga-

Table 1. Descriptive Statistics and Statistical Comparisons of the Forces (grams) Released by the Ceramic Brackets (B) With Low-Friction Ligatures (Slide) and With CEL vs Stainless Steel (SS) Brackets With Low-Friction Ligatures (Slide) and With CEL at Different Amounts of Canine Misalignment (CM)[a]

	Ceramic B. + Slide		Ceramic B. + CEL		Kruskal-Wallis Test
	Mean	SD	Mean	SD	Significance
0.014″ SE–1.5 mm CM	115.9	3.3	110.6	8.1	NS
0.014″ SE–3.0 mm CM	124.3	5.7	0.3	0.2	*
0.014″ SE–4.5 mm CM	115.4	5.7	0.4	0.5	*
0.014″ SE–6.0 mm CM	111.0	6.5	0.2	0.2	*
	SS B. + Slide		SS B. + CEL		
	Mean	SD	Mean	SD	Significance
0.014″ SE–1.5 mm CM	97.6	7.6	91.9	2.7	NS
0.014″ SE–3.0 mm CM	112.4	6.7	0.1	0.1	*
0.014″ SE–4.5 mm CM	99.7	8.0	0.1	0.1	*
0.014″ SE–6.0 mm CM	116.6	12.9	0.1	0.1	*
	Ceramic B. + Slide		SS B. + Slide		
	Mean	SD	Mean	SD	Significance
0.014″ SE–1.5 mm CM	115.9	3.3	97.6	7.6	NS
0.014″ SE–3.0 mm CM	124.3	5.7	112.4	6.7	NS
0.014″ SE–4.5 mm CM	115.4	5.7	99.7	8.0	NS
0.014″ SE–6.0 mm CM	111.0	6.5	116.6	12.9	NS
	Ceramic B. + CEL		SS B. + CEL		
	Mean	SD	Mean	SD	Significance
0.014″ SE–1.5 mm CM	110.6	8.1	91.9	2.7	NS
0.014″ SE–3.0 mm CM	0.3	0.2	0.1	0.1	NS
0.014″ SE–4.5 mm CM	0.4	0.5	0.1	0.1	NS
0.014″ SE–6.0 mm CM	0.2	0.2	0.1	0.1	NS

* $P < .05$. NS indicates not significant.
[a] UEL indicates unconventional elastomeric ligatures; CEL, conventional elastomeric ligatures.

tures allowed for the release of an average amount of force of 110 g and 130 g (for ceramic and stainless steel brackets, respectively). The statistical comparison between the two bracket types in the presence of UEL and CEL did not show a significant difference at any of the amounts of canine misalignment. Therefore, the type of ligature influenced the actual amount of force released by the orthodontic system significantly more than the type of bracket (stainless steel vs ceramic).

The outcomes of the current study indicate that when a slight amount of tooth alignment is needed (1.5 mm) the differences in the performance of conventional vs unconventional ligatures are minimal (with both types of brackets), while these differences become significant when correction of a misalignment greater than 3.0 mm is attempted. A negligible amount of force for alignment is actually available in the presence of conventional ligatures and of a misalignment equal to or greater than 3.0 mm (with both types of brackets).

On the other hand, the presence of UEL enables ceramic brackets to release a significant amount of orthodontic force during the aligning and leveling phases of treatment, very similarly to stainless steel brackets. Therefore, the use of recently developed unconventional ligatures allows the orthodontist to join the advantages of low-friction biomechanics to those in the use of esthetic ceramic brackets. The clinical interpretation of these data, however, requires further consideration. Each individual test with the Instron machine was performed with new elastomeric ligatures. No attempt was made in the present study to evaluate the effect of time and oral environment on the amount of force released in the presence of different types of elastomeric ligatures.[19,20]

CONCLUSIONS

- The forces released by orthodontic wire in the presence of esthetic ceramic brackets were similar to those released by stainless steel brackets with both low-friction and conventional elastomeric ligatures.
- For tooth misalignments of 3.0 mm or greater, the force available for tooth movement was recorded in the presence of either type of bracket only in the presence of unconventional ligatures, while in the

presence of conventional ligatures the amount of force generated was negligible.

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