

Static frictional resistances of polycrystalline ceramic brackets with metal slot inserts

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Aims: To compare the static frictional resistances of polycrystalline ceramic brackets with a gold slot insert (Desire), a stainless steel slot insert (Clarity), a conventional polycrystalline ceramic bracket (Transcend 6000) and a stainless steel bracket (Ultratrimm).

Methods: Twenty five brackets of each type were tested by sliding against straight lengths of 0.019 x 0.025 inch rectangular stainless steel wire. During the tests the brackets and wire were lubricated with artificial saliva. Static frictional forces at three different binding angulations (0, 5 and 10 degrees) were measured for all brackets.

Results: Statistically significant increases in static frictional resistance were found as the bracket/wire angulation increased from 0 through 5 to 10 degrees for all bracket types. At angulations below the critical binding angle the Ultratrimm brackets produced the greatest friction and the Transcend 6000 brackets produced the least friction. As the angulation increased the Transcend 6000 brackets produced greater friction than the other brackets. At the highest angulation (10 degrees), the Ultratrimm brackets produced significantly less friction and the Transcend 6000 brackets produced significantly more friction than the other brackets. The Desire and Clarity brackets produced comparable results: there were no statistically significant differences between these two brackets for static friction at any of the angulations.

Conclusions: Polycrystalline ceramic brackets with either stainless steel or gold slot inserts produced similar static frictional resistances to sliding. At binding angulations, the brackets with inserts demonstrated consistently lower static frictional resistances than a conventional ceramic bracket.

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Introduction

The pre-adjusted orthodontic bracket system is the most popular bracket system in use today. Sliding mechanics is one of the most common methods of translating a tooth. One of the major disadvantages of sliding mechanics is the friction produced by the action of the brackets and ligatures sliding against the archwire. The frictional force may retard movement of the archwire through the brackets when anterior teeth are retracted, and if transmitted to the posterior teeth result in loss of anchorage. It has been suggested that at least 50 per cent of applied anchorage may be lost in this way.¹

The appearance of fixed orthodontic appliances has always been a particular concern to many patients.² The number of adult patients undergoing orthodontic treatment has increased substantially, and adult patients are usually more concerned about the appearance of fixed orthodontic appliances than younger patients.³ One of the major disadvantages of

ceramic brackets, compared with conventional stainless steel brackets, is increased frictional resistance during sliding mechanics.^{4,5} Modified ceramic brackets with metal slot inserts have been developed in an attempt to reduce friction to levels comparable with stainless steel brackets.^{6–8} This study aimed to compare the frictional resistances of stainless steel and conventional ceramic brackets with ceramic brackets containing either stainless steel or gold slot inserts.

Materials and methods

Upper left central incisor brackets with the Roth prescription and 0.022 x 0.028 inch slots were used. Incisor brackets were chosen because they had flat bases, which facilitated mounting for the tests. The brackets were from the same batch for each bracket type. The brackets used were:

Desire (Orthocare Ltd, Bradford, UK): a polycrystalline ceramic bracket incorporating a gold slot insert.

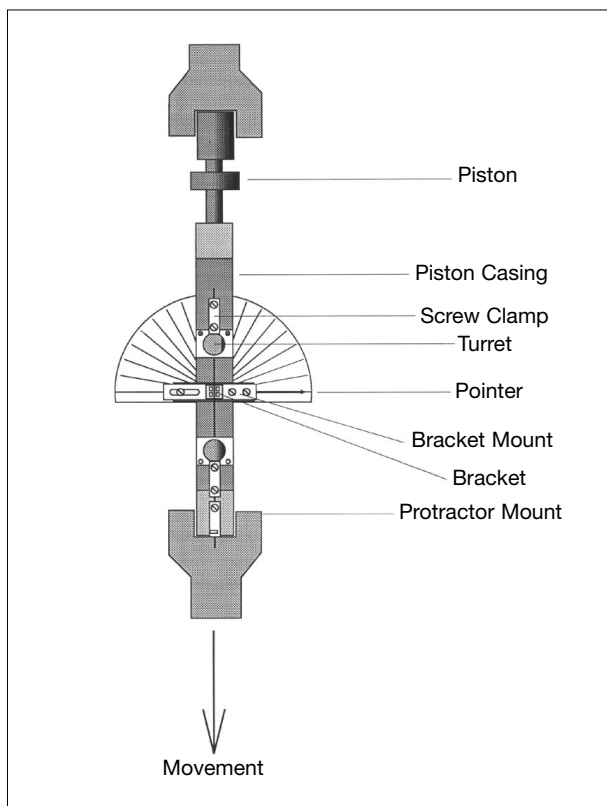


Figure 1a. Superior view of testing apparatus.

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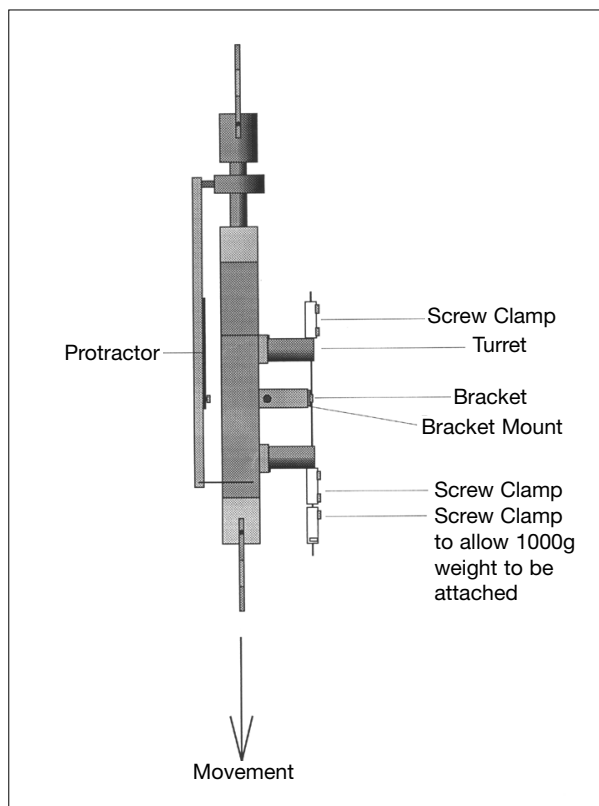


Figure 1b. Lateral view of testing apparatus.

Clarity (3M-Unitek, Monrovia, USA): a polycrystalline ceramic bracket incorporating a stainless steel slot insert.

Transcend 6000 (3M-Unitek, Monrovia, USA): a traditional polycrystalline ceramic bracket with no slot insert.

Ultratrimm (Dentaurum, Ispringen, Germany): a conventional stainless steel bracket. Stainless steel brackets are considered the 'gold standard' against which other brackets are compared.

Straight lengths of 0.019 x 0.025 inch stainless steel rectangular wire (Ormco, USA) were used. Wires from the same batch number were used to ensure consistency of manufacture. Saliva Orthana (Nycomed, UK), an artificial saliva containing mucin, xylitol and mineral salts, was used for lubrication.

A sample size calculation was carried out using estimates for the data from a previous study.⁹ At a statistical power of 90 per cent with a significance level of 0.05, a sample size nomogram suggested a

sample size of 25 brackets per group would be required.¹⁰

All brackets were tested against a 0.019 x 0.025 inch stainless steel archwire at 0, 5 and 10 degrees bracket to archwire angulations. A universal load testing machine with a 1kN load cell (Instron, High Wycombe, UK) was used to produce steady movement of the archwire through the bracket slot. The speed of movement was set at 0.5 mm/min and the test was run over 2.5 mm with force level readings taken 25 times per second. A jig was used to hold the bracket and archwire in place (Figure 1). The archwire was placed under a fixed tension of 1 kg and the bracket placed in the jig at a pre-set angulation, with a fixed simulated ligation force of 200 g as suggested by previous workers.¹¹ All results were recorded on a microprocessor connected to the Instron machine.

Each group of 25 brackets was degreased in a solution of acetone for 10 minutes, and then allowed to air dry for an equivalent amount of time. The brackets were then transferred to a container with approximately

Table I. Static frictional resistances of the brackets.

Bracket	Angle	Mean (kN)	95% CI	SE
Ultratrimm	0	8.32E-04	7.96E-04 8.68E-04	1.73E-05
Ultratrimm	5	3.44E-03	3.16E-03 3.71E-03	1.34E-04
Ultratrimm	10	6.05E-03	5.46E-03 6.64E-03	2.86E-04
Transcend	0	5.07E-04	4.60E-04 5.55E-04	2.29E-05
Transcend	5	4.29E-03	3.70E-03 4.89E-03	2.89E-04
Transcend	10	1.57E-02	1.34E-02 1.80E-02	1.09E-03
Clarity	0	6.68E-04	5.83E-04 4.10E-05	7.53E-04
Clarity	5	2.73E-03	2.27E-03 3.19E-03	2.23E-04
Clarity	10	1.20E-02	1.06E-02 1.33E-02	6.62E-04
Desire	0	6.82E-04	6.00E-04 7.65E-04	4.02E-05
Desire	5	3.49E-03	2.72E-03 4.26E-03	3.73E-04
Desire	10	1.20E-02	1.05E-02 1.36E-02	7.39E-04

5 ml of artificial saliva and left standing for 24 hours. The archwire was cut into 15 cm lengths, cleaned with alcohol immediately before each test, and with a bracket mounted in the jig. To ensure that the system was well lubricated, artificial saliva was applied to the bracket and archwire immediately prior to each test. All brackets and lengths of wire were used once.

Initial examination of the data revealed that it followed a normal distribution, and an analysis of variance (ANOVA) was carried out to investigate for statistical differences within the groups. Wherever the ANOVA demonstrated significant differences within groups multiple comparisons were carried out using the Bonferroni *post hoc* correction to identify the individual differences. Inter-bracket examination was carried out to compare the differences in static frictional resistances between the four different brackets

Table II. Inter-bracket multiple comparisons for static friction.

Angle	(I) Bracket	(J) Bracket	Mean diff. (I-J) (kN)	SE	p
0	Ultratrimm	Transcend	3.25E-04	4.55E-05	< 0.001
		Clarity	1.64E-04	4.55E-05	0.003
		Desire	1.50E-04	4.55E-05	0.008
0	Transcend	Clarity	-1.61E-04	4.55E-05	0.004
		Desire	-1.75E-04	4.55E-05	0.001
0	Clarity	Desire	-1.38E-05	4.55E-05	> 0.99
5	Ultratrimm	Transcend	-8.56E-04	3.81E-04	0.161
		Clarity	7.10E-04	3.81E-04	0.392
		Desire	-4.81E-05	3.81E-04	> 0.99
5	Transcend	Clarity	1.56E-03	3.81E-04	< 0.001
		Desire	8.08E-04	3.81E-04	0.219
5	Clarity	Desire	-7.58E-04	3.81E-04	0.296
10	Ultratrimm	Transcend	-9.66E-03	9.79E-04	< 0.001
		Clarity	-5.95E-03	8.96E-04	< 0.001
		Desire	-5.95E-03	1.04E-03	< 0.001
10	Transcend	Clarity	3.67E-03	9.79E-04	0.002
		Desire	3.67E-03	1.11E-03	0.008
10	Clarity	Desire	0.00	1.04E-03	> 0.99

Significant values are in bold

at fixed 0, 5 and 10 degree angulations. Intra-bracket examination was then carried out to compare the static frictional resistance of each bracket type at increasing binding angles of 0, 5 and 10 degrees.

Results

Table I presents the mean static frictional resistances of the four brackets under test at 0, 5 and 10 degrees of angulation, together with the 95 per cent confidence intervals. Figure 2 illustrates the data graphically.

Table II presents the results of the inter-bracket Bonferroni *post hoc* corrections for static friction. This identifies statistically significant differences in static frictional resistance between the four different brackets by comparing them at each of the three fixed simulated binding angulations.

Table III shows the results of the intra-bracket Bonferroni *post hoc* corrections for static friction. The table shows comparisons of the effect on mean static friction produced by increasing bracket/archwire angulations for each of the four different brackets.

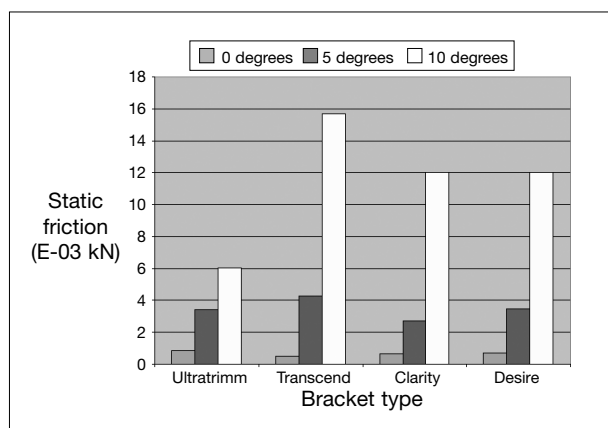


Figure 2. Graph of static frictional resistance (E-03kN) against bracket type at 0, 5 and 10 degrees bracket/archwire angulations.

Discussion

The method we used to test the frictional characteristics of the different brackets reflects a popular method that has been used by a number of investigators over many years and has been shown to produce reliable results.^{5,6,8,9,11–14} In order to eliminate certain variables that may contribute to frictional resistance bracket width, archwire material, archwire dimensions and ligation technique were kept constant throughout the study.

When all brackets were compared at a non-binding angulation (0 degrees), the Ultratrimm bracket produced frictional forces that were significantly higher than the other three brackets (Ultratrimm mean: $8.32\text{E-}04$ kN; Desire mean: $6.82\text{E-}04$ kN; Clarity mean: $6.68\text{E-}04$ kN; Transcend 6000 mean: $5.07\text{E-}04$ kN). This concurs with previous workers who reported that stainless steel brackets produced greater friction than ceramic brackets when sliding against stainless steel archwires, although this was not statistically significant.¹⁵ Transcend 6000 brackets produced significantly less friction at 0 degrees than the other three brackets. This suggests that the increase in frictional resistance, often seen clinically with conventional ceramic brackets (when compared with stainless steel or ceramic brackets with metal slot inserts) may not be due to classic friction, but is more influenced by the binding and archwire notching which are seen at higher angulations. There was no statistically significant difference between the frictional resistances of the Desire and Clarity brackets at 0 degrees angulation.

Table III. Intra-bracket multiple comparisons for static friction.

Bracket	(I) Angle	(J) Angle	Mean diff. (I-J) (kN)	SE	<i>p</i>
Ultratrimm	0	5	-2.61E-03	2.585E-04	< 0.001
		10	-5.22E-03	2.585E-04	< 0.001
Ultratrimm	5	10	-2.61E-03	2.585E-04	< 0.001
Transcend	0	5	-3.78E-03	7.16E-04	< 0.001
		10	-1.52E-02	7.82E-04	< 0.001
Transcend	5	10	-1.14E-02	7.82E-04	< 0.001
Clarity	0	5	-2.06E-03	5.71E-04	0.002
		10	-1.13E-02	5.71E-04	< 0.001
Clarity	5	10	-9.23E-03	5.71E-04	< 0.001
Desire	0	5	-2.81E-03	5.07E-04	< 0.001
		10	-1.13E-02	5.85E-04	< 0.001
Desire	5	10	-8.51E-03	5.85E-04	< 0.001

Significant values are in bold

When the brackets were compared at 5 degrees angulation, the Transcend 6000 brackets produced the greatest friction (Mean: $4.29\text{E-}03$ kN), followed by Desire (Mean: $3.49\text{E-}03$ kN), Ultratrimm (Mean: $3.44\text{E-}03$ kN) and with the Clarity brackets producing the least friction (Mean: $2.73\text{E-}03$ kN). However, the only statistically significant difference in friction was found to be between the Transcend 6000 brackets and the Clarity brackets.

At 10 degrees angulation, Transcend 6000 produced the highest friction (Mean: $1.57\text{E-}02$ kN) followed by the Desire and Clarity brackets (Means: $1.20\text{E-}02$ kN). The Ultratrimm brackets produced the least friction (Mean: $6.05\text{E-}03$ kN), which agrees with previous workers.⁶ The difference between Transcend 6000 and the other brackets was statistically significant as were the differences between Ultratrimm and the other brackets. There was no statistically significant difference between the Clarity and Desire brackets.

Our finding that there were no statistically significant differences between the Clarity and Desire brackets at any of the three angulations, indicates that lining ceramic bracket slots with stainless steel or gold results in similar static frictional resistances in the wet state. Previous workers found that although a ceramic bracket with a gold insert produced less

friction than stainless steel brackets in the dry state, the frictional forces were similar in the wet state.⁸ This agrees with the findings of the present study, and suggests that the non-oxidising layer of gold may not be as effective at reducing friction in the wet state as it is in the dry state.

Intra-bracket results for each of the four brackets showed that as the bracket/archwire angulation increased from 0 through 5 to 10 degrees, the static frictional resistance increased concomitantly, and multiple comparisons showed that for each bracket the increase in friction was highly significant. This increased frictional resistance has been attributed by previous workers to increased notching and binding at the higher angulations, with the critical angle for binding being between 0 and 5 degrees.^{13,16,17} The critical angle depends on the specific wire-bracket geometry. Since the brackets and the archwire tested in this study had the same dimensions, it can be assumed that the critical angle for binding is the same for the combinations tested. The increase in friction for each bracket, which occurred between 0 and 5 degrees, implies that the critical angle for binding for all four brackets lies between these two angulations.

The large increases in frictional resistance exhibited by the Transcend 6000 brackets from 0 to 5 degrees and between 5 and 10 degrees may be due to an increase in notching of the archwire. Ceramic brackets are extremely hard with rough slot edges, and this may explain the increase in archwire notching as angulation between the archwire and the bracket increased. This is in agreement with a previous study which reported that the activity and severity of notching were nearly three times greater from ceramic brackets than from stainless steel brackets.¹⁶

Conclusions

It can be concluded that:

1. Ceramic brackets with either a gold slot insert (Desire) or stainless steel slot insert (Clarity) produced similar static frictional resistances when sliding along a 0.019 x 0.025 inch stainless steel archwire at 0, 5 and 10 degree angulations.
2. A stainless steel bracket produced the highest friction when compared with conventional ceramic or ceramic brackets with metal slot inserts at a non-binding bracket/archwire angulation of 0 degrees.

3. Conventional ceramic brackets produced greater friction than stainless steel or ceramic brackets with metal slot inserts at binding angulations of 5 degrees or more.

4. The stainless steel bracket produced lower friction than a conventional ceramic bracket or ceramic brackets with metal slot inserts at a binding angulation of 10 degrees.

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