

Static frictional resistances of polycrystalline ceramic brackets with conventional slots, glazed slots and metal slot inserts

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Aims: To compare the static frictional resistance of ceramic brackets with a conventional slot (Allure), a glazed slot (Mystique) and a metal slot insert (Clarity).

Method: Twenty five brackets of each type, with slot size 0.022 x 0.028 inch and Roth prescription 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 simulated binding angulations (0, 5 and 10 degrees) were measured for each type of bracket.

Results: At each of the angulations tested, the Clarity brackets produced the lowest static frictional resistance. At 0 degree angulation (below the critical angle for binding) the Allure brackets produced the greatest friction. The difference in friction between the Clarity and Mystique brackets was not statistically significant. As the angulations were increased to 5 degrees the Allure brackets again produced the greatest frictional resistance, although this was not significantly higher than the Mystique brackets. The Mystique brackets produced the greatest frictional resistance at 10 degrees, but again there was no statistical difference from the Allure brackets.

Conclusions: A glazed slot ceramic bracket demonstrates low frictional resistance at non-binding angulations and compares favourably with a metal slot ceramic bracket. Increasing angulations through 5 to 10 degrees of simulated binding results in high levels of static frictional resistance such that the bracket behaves more like a conventional polycrystalline ceramic bracket. (Aust Orthod J 2007; 23: 36–40)

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Introduction

Fixed appliance therapy using the pre-adjusted orthodontic bracket system requires brackets to slide in relation to the archwire. When sliding mechanics are used, frictional resistance occurs at the bracket-wire interface such that some of the applied force is dissipated in overcoming friction and the remainder is transferred to the tooth and its supporting structures to mediate movement.^{1–3}

Frictional resistance is the result of a combination of true friction, bracket binding and archwire notching. Bracket binding occurs as a bracket tips in relation to the archwire such that opposing corners of the bracket come into contact with the wire. The amount that a bracket can tip before binding begins to occur is

termed the critical angle and varies according to bracket slot and archwire dimensions.^{4,5} As tipping begins to exceed the critical angle, the edges of the slot can cause notching of the wire, which further increases resistance to sliding.⁶

Tooth movement is dependent upon not just the force system, but also biological factors, including cellular turnover, vascularity and bone density. This produces cyclical waves of remodelling events rather than linear phenomena.⁷ Intra-orally, bracket binding can be influenced by factors such as masticatory forces which flex the wire and in turn may disrupt the binding effect.⁸ Although laboratory testing is unable to reproduce these biological and masticatory effects, it is considered valuable because of its more controlled environment and ability to limit variables.

Such data can suggest clinical trends, but cannot always be considered a good predictor of clinical efficiency.⁸

Several studies have shown that because of their hard and rough slot bases, ceramic brackets tend to produce greater frictional resistance during sliding than conventional stainless steel brackets.^{9–14} Attempts at reducing the frictional resistance have resulted in the incorporation of metal slot linings, which have been highly successful.^{15–17} Other developments seeking to maximise aesthetics, but with improved frictional behaviour, have included polycrystalline ceramic brackets with either a silica insert¹⁸ or a smooth, glazed ceramic slot base. This study compared the static frictional resistance between a glazed slot ceramic bracket, a metal lined ceramic bracket and a conventional ceramic bracket.

Materials and method

Three different polycrystalline ceramic brackets were tested:

Allure (GAC International, Bohemia, New York, USA): a conventional polycrystalline ceramic bracket.

Mystique (GAC International, Bohemia, New York, USA): a polycrystalline ceramic bracket with a smooth, glazed ceramic slot base.

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

All brackets used were upper left central incisor brackets with Roth prescription and 0.022 x 0.028 inch slots. Incisor brackets were chosen due to their flatter profile base which facilitated mounting in the testing jig. The brackets were from the same batch code for each bracket type. A sample size calculation determined that at a statistical power of 90 per cent, and a significance level of $p \leq 0.05$, 25 brackets of each type would be required.

Straight lengths of 0.019 x 0.025 inch rectangular stainless steel wire Nubryte Gold (GAC International, Bohemia, New York, USA) were used. The wires were from the same batch code to ensure consistency of manufacture.

Saliva Orthana (Nycomed Ltd., Birmingham, UK), an artificial saliva spray which contains pig mucin, xylitol, and mineral salts, was used for lubrication.

The three different types of brackets were tested against the 0.019 x 0.025 inch archwire at 0, 5 and

10 degree bracket to archwire angulations to simulate increasing levels of bracket binding. A specially constructed jig was used to hold the bracket and archwire in place, with a predetermined archwire tension of 1 kg, bracket angulations of 0, 5 or 10 degrees and a simulated ligation force of 200 grams.¹² Full details of the jig have been published in a previous study.¹⁷

Each group of 25 brackets was placed in a solution of acetone for 10 minutes for degreasing and allowed to air dry for an equivalent length of time. The brackets were then transferred to a container containing 5 ml of artificial saliva and left standing for 24 hours to permit surface adsorption. The archwire was cut to lengths of 10 cm and cleaned with an alcohol wipe immediately before each test. The archwire and bracket were mounted in the jig and liberally coated with artificial saliva immediately before testing.

A universal load testing machine (Instron, High Wycombe, UK) was used to hold the jig in place and produce a 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. All results were recorded on a microprocessor connected to the Instron machine. Units of measurement from the Instron were kN (kiloNewtons) and data were of the order of 10^{-3} to 10^{-4} kN. For data storage in the computer this was recorded as E-03 or E-04 kN and the tabulated data are in this format.

Initial examination of the data revealed that it followed a normal distribution, and an analysis of variance (ANOVA) was carried out to determine statistically significant differences between groups. The static frictional resistance of the three different brackets at 0, 5 and 10 degrees angulations were compared. Where the ANOVA identified significant differences between the three brackets, a Bonferroni post hoc correction was used to localise the differences.

Results

Table I presents the mean static frictional resistances of each of the three ceramic brackets under test, at 0, 5 and 10 degrees of angulation, together with the 95 per cent confidence interval (95 per cent CI) and standard error (SE) to report the precision of the means. Figure 1 illustrates the data graphically.

Table II presents the results of the inter-bracket Bonferroni post hoc corrections for static friction. This is intended to identify statistically significant

Table I. Static frictional resistances of the brackets.

Bracket	Angle	Mean (kN)	95% CI	SE
Mystique	0	5.45E-04	4.73E-04 6.16E-04	3.47E-05
Mystique	5	1.91E-03	1.77E-03 2.09E-03	1.02E-04
Mystique	10	6.47E-03	5.88E-03 7.05E-03	2.85E-04
Allure	0	8.03E-04	6.85E-04 9.22E-04	5.74E-05
Allure	5	2.05E-03	1.88E-03 2.23E-03	8.67E-05
Allure	10	5.97E-03	5.11E-03 6.83E-03	4.18E-04
Clarity	0	5.27E-04	4.46E-04 6.083E-04	3.91E-05
Clarity	5	1.59E-03	1.37E-03 1.79E-03	1.03E-04
Clarity	10	5.01E-03	4.59E-03 5.42E-03	2.03E-04

differences in static frictional resistance between the three different brackets by comparing them at each of the three fixed simulated binding angulations.

Discussion

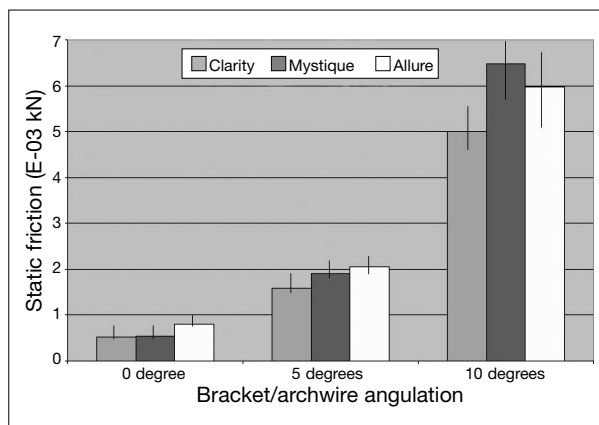
This comparative laboratory study investigated the static frictional resistance of three different types of ceramic brackets under increasing levels of bracket binding. Although the findings from this laboratory study cannot be extrapolated directly to the clinical state because of the lack of biological resistance effects and occlusal forces on the system, the study has standardised the majority of variables to enable the effects of bracket design and bracket/archwire angulation to be compared. From this, trends may be applied to the clinical state with caution and may form the basis for future clinical studies.⁸

At 0 degree angulation the Allure bracket produced frictional forces that were significantly higher than the other two brackets. (Allure mean: 8.03E-04 kN; Mystique mean: 5.45E-04 kN; Clarity mean: 5.27E-04 kN; $p < 0.001$). The Clarity bracket produced the lowest resistance to sliding. These results agree with a

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

Angle (Degrees)	Bracket (I)	Bracket (J)	Mean difference (I minus J) (kN)	SE	p
0	Allure	Mystique	2.58E-04	6.34E-05	< 0.001
		Clarity	2.76E-04	6.34E-05	< 0.001
0	Mystique	Clarity	1.80E-05	6.34E-05	> 0.99
5	Allure	Mystique	1.40E-04	1.26E-04	> 0.99
		Clarity	4.60E-04	1.26E-04	0.001
5	Mystique	Clarity	3.20E-04	1.26E-04	0.02
10	Allure	Mystique	-5.00E-04	4.45E-04	0.815
		Clarity	9.60E-04	4.45E-04	0.101
10	Mystique	Clarity	1.46E-03	4.45E-04	0.005

Significant values are in bold

**Figure 1.** Graph of static frictional resistance against bracket type at 0, 5 and 10 degrees bracket/archwire angulations.

number of previous studies which showed that ceramic brackets with metal slots exhibit lower frictional resistance than conventional ceramic brackets when sliding against stainless steel wires,^{6,10,14,15,19} but is in contrast with a more recent study which found that at 0 degree angulation a conventional ceramic bracket demonstrated lower friction than brackets with metal inserts.¹⁷ However, the conventional ceramic bracket tested was from a different manufacturer than the Allure bracket used in the present study and so this may reflect differences in surface finish.

Although the Clarity bracket produced lower frictional values than the Mystique bracket, this was not statistically significant ($p > 0.99$). This contrasts with a previous study which investigated a polycrystalline ceramic bracket with a silica insert and found lower friction than with a bracket with a steel slot insert.¹⁸ The statistically significant differences between the Allure bracket and both the Mystique and Clarity brackets may be considered clinically significant when translated to orthodontic forces. The differences equated to friction levels of approximately 26–28 g force.

At 5 degrees angulations, the Allure bracket again produced the highest levels of friction (Mean: 2.05E-03 kN), followed by Mystique (Mean: 1.91E-03 kN). The Clarity bracket produced the least friction (Mean: 1.59E-03 kN). The differences between the Allure and Clarity brackets and the Mystique and Clarity brackets were statistically significant ($p = 0.001$; $p = 0.02$). The Allure bracket produced higher frictional values than the Mystique bracket, but this was not statistically significant ($p > 0.99$). Previous work has suggested that as angulation increases, the resistance to sliding produced is a combination of classic friction, binding and notching.^{4–6,20} The results of this study suggest that more binding and notching may have occurred with the Allure bracket at 5 degrees. The statistically significant differences between the Clarity brackets and both the Mystique and Allure brackets can be considered clinically significant, and translates to frictional differences of approximately 32 g force and 46 g force respectively.

At 10 degrees angulations, the Mystique bracket produced the highest friction (Mean: 6.47E-03 kN), followed by the Allure brackets (Mean: 5.97E-03 kN) and the Clarity bracket (Mean: 5.01E-03 kN). The difference in friction between the Mystique and Clarity brackets was statistically significant ($p = 0.005$). The differences in friction between the Mystique and Allure brackets, and the Allure and Clarity brackets at 10 degrees were not statistically significant ($p = 0.815$; $p = 0.101$). The greater frictional resistance in the Mystique bracket at 10 degrees implies that binding and notching in the Mystique bracket was worse, and this may reflect a smooth glazed slot base, but rough slot ends. The difference between the Mystique bracket and Clarity bracket may be considered highly clinically significant, with the difference equating to approximately 146 g force.

Conclusions

1. At 0 degree angulation there was no statistically significant difference in static friction between the Mystique and the Clarity brackets. The Allure bracket produced statistically significantly higher values for static friction than the other two brackets. This indicates that at non-binding angulations the glazed surface of the Mystique may be effective in reducing the roughness which is often associated with ceramic brackets.

2. At 5 degrees angulations the Clarity brackets produced the lowest static frictional resistance and this was statistically significant when compared to the other two brackets. There was no significant difference in frictional resistance between the Mystique and Allure brackets. This suggests that once the critical angle for binding is exceeded, when the notching and binding components of friction are brought into play, the harder and rougher edges of the Mystique and Allure bracket slots may have resulted in higher frictional values.

3. At 10 degrees angulations, the Clarity brackets once again produced the least friction. The Mystique bracket produced the highest friction. The only statistically significant difference in friction was between the Mystique and Clarity brackets.

4. These findings appear to partially confirm the manufacturer's claim that the frictional resistance of Mystique brackets is comparable to sliding on metal surfaces, but this seems only to be true when the bracket to archwire angulation is below the critical angle for binding. Once this critical angle is exceeded the Mystique bracket begins to behave more like a conventional ceramic bracket. Hence it is recommended when using the Mystique or Allure brackets in particular, the slots are properly aligned before commencing sliding mechanics.

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