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An In-Vitro Evaluation of Frictional Forces between Conventional, Ceramic and Metal-Insert Ceramic Orthodontic Brackets

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Abstract

Objective of the study was to evaluate and compare frictional forces exerted by stainless steel; Polycrystalline ceramic brackets and metal insert ceramic brackets with stainless steel arch wires under dry conditions.

Study design: Thirty 0.022 x 0.028 slot premolar brackets of each of three groups were tested against .019 x .025 inch stainless steel arch wire using Universal testing machine. The results were subjected to one-way ANOVA and Bonferroni post-hoc test.

Results: Polycrystalline ceramic brackets recorded highest frictional resistance among all three groups (92.32+ 8.52 grams). The stainless steel brackets showed the least friction (66.47 + 7.84 grams) and metal insert ceramic brackets (75.95 + 8.44 grams) fell in between conventional ceramic and stainless steel brackets. One-way ANOVA revealed that the difference between all the groups were statistically significant at $p<0.01$.

Conclusion: The Metal insert ceramic brackets are an effective alternative to stainless steel brackets in patients with high esthetic demands.

Keywords: Friction, Orthodontics; Orthodontic brackets, Metal-insert ceramic brackets.

Introduction

Orthodontic space closure is usually accomplished either with “frictionless” mechanics or by sliding the teeth along the arch wire. Whenever sliding occurs, frictional resistance is encountered[1]. To reduce friction, one needs to understand the impact of friction between brackets and arch wires so as to apply the appropriate force to obtain optimal biologic tissue response and adequate tooth movement during sliding mechanics.

As more and more adult patients are undergoing orthodontic treatment, ceramic brackets were introduced to meet increasing esthetic demands. Ceramic brackets are especially popular among adult patients who have expressed a desire for more esthetic appliance. However, ceramic brackets are associated with several problems, increased frictional resistance in sliding mechanics being the important of them. Several studies conclude that friction is higher with ceramic than stainless steel brackets[2-4]. Therefore, to reduce the undesirable effects of frictional force and to maintain the cosmetic advantages of ceramic brackets, a smoother metal slot has been inserted into ceramic brackets.

However not many studies exists that have evaluated the efficacy of metal insert ceramic bracket in reducing frictional force in sliding mechanics. Therefore a comparative study was undertaken to measure the frictional resistance of stainless steel, polycrystalline ceramic and metal insert ceramic brackets with stainless steel arch wire.

Material and Methods

In this study, the frictional resistance of 30 brackets each of stainless steel (American Orthodontics, Sheboygan, WI, USA), polycrystalline ceramic brackets (American Orthodontics, Sheboygan, WI, USA) and metal insert ceramic brackets (American Orthodontics, Sheboygan, WI, USA). All brackets were maxillary first premolar with 0.022 x 0.028 slot size. Upper premolar brackets were chosen of Roth prescription as they have no built in angulations, thereby eliminating the effect of 2nd order on friction.A prefabricated commercial 4 inch x 2 inch acrylic plate (Figure 1) was used to mount the bracket sample. At one end of the plate a horizontal and vertical line was drawn, the point of intersection of these two lines was taken as a point of bracket placement. The brackets were placed in this point and then stabilized by means of an industrial adhesive.

A .019x.025 inch stainless steel wire (American Orthodontics, Sheboygan, WI, USA) of about 30 mm length was placed in the bracket and ligated with .010 inch stainless steel ligatures twisted until taut and then untwisted a quarter turn[5]. The assembly was tested on universal testing machine (Figure 2) with 500 kg load cell in the tensile mode. One end of the acrylic plate was mounted on to the lower grip of universal testing machine and the free end of the arch wire was fixed to the upper grip connected to the load cell. Before testing each bracket, wire and ligature was cleaned with 95 % alcohol and air dried[6]. Each wire was pulled through the bracket slot by a distance of 7 mm at a speed of 5mm per min[1] under dry conditions. The force levels were measured in Newton's in a digital read out which was later converted into grams. Grams are often substituted for Newton's in clinical orthodontics because the contribution of acceleration (m/s^2) to the magnitude of force is clinically irrelevant. The arch wire and the bracket were tested such that a new bracket and wire is used for every test and then discarded; a fresh ligation is used for each combination. This was done in order to eliminate the influence of dimensional changes.

Statistical Analysis

The test results for each bracket arch wire combination were tabulated and the data was subjected to descriptive statistics including the mean, standard deviation (SD), median and range were calculated. One way ANOVA with Bonferroni Post Hoc test was used to evaluate the difference between the 3 groups. The ά level was set at 0.05 and all the statistical analysis was done using SPSS software {version-13; SPSS Inc.233, Wacker Drive, Chicago, IL, USA}

Results

The results showed that stainless steel brackets showed the least frictional resistance (66.47+7.84gm) while polycrystalline ceramic bracket showed the highest friction (92.32+8.52). The mean of Metal insert ceramic bracket (75.95+8.44) fell in between conventional ceramic and stainless steel bracket (Table 1, Graph 1). One-way ANOVA intergroup comparisons (Table 2) showed that the mean difference between stainless steel and metal insert ceramic bracket was significant at P <.01 while the others were significant at P <.001.

Table 1. Descriptive statistics for friction in the three bracket groups.

Bracket	N	Mean	SD	SEM	95% CI	
					Upper limit	Lower limit
Steel	30	66.47	7.84	2.03	70.87	62.11
Metal-Insert Ceramic	30	75.95	8.44	2.17	80.62	71.27
Ceramic	30	92.32	8.52	2.20	97.03	87.60

Table 2. Comparison of friction for the three bracket groups

Group†	Mean Difference	SEM	P value *	95% Confidence level	
				Lower limit	Upper limit
SS v/s MIC	-9.480	3.023	.009	-17.091	-1.941
SS v/s PC	-25.847	3.023	.000	-33.386	-18.307
MIC v/s PC	-16.367	3.023	.000	-23.906	-8.827

† - SS – Stainless steel bracket, MIC – Metal insert ceramic bracket, PC – Polycrystalline ceramic bracket; * One way ANOVA and Bonferroni Post Hoc test

Discussion

Friction is defined as the resistance to motion when one object moves tangentially against another[7]. Friction is an important factor in orthodontic anchorage control, particularly with space closure using sliding mechanics in fixed appliances. Controlling the position of anchor teeth is accomplished best by minimizing the reaction force that reaches them. Unfortunately, anchor teeth usually feel the reaction to both frictional resistance and tooth movement forces, so controlling and minimizing friction is an important aspect of anchorage control[8].

The introduction of newer materials which have higher esthetic values in orthodontics has been triggered by the rise in demands from the patient, community and the practitioners. Ceramic brackets were first made available commercially in the late 1980s, largely to overcome the esthetic limitations of plastic brackets as they are quite durable and resist staining. However inability to form chemical bonds with resin adhesives, low fracture toughness and increased frictional resistance between metal arch wire and ceramic bracket remained as disadvantage with ceramic brackets. The polycrystalline ceramic bracket have considerably rougher surface than steel brackets. The rough but hard ceramic material is likely to penetrate the surface of even a steel wire during sliding, creating considerable resistance. Therefore to reduce the undesirable effects of frictional force, some authors suggested the development of ceramic brackets with smoother slot surfaces to decrease any possible effects of static fatigue[9].Several variables exist that directly or indirectly contribute to the friction between the bracket and wire including 1) Arch wire: active torque, thickness or vertical dimension, cross sectional shape and size, composition. 2) Ligation of arch wire to bracket: ligature type, force. 3) Brackets: material, width. 4) Orthodontic appliances: inter-bracket distance, level of bracket slots between adjacent teeth, forces applied for retraction, bracket wire angulations, and point of force application[10].In the present study .019 x .025 stainless steel wires was used with .022 slot because this size of wire gives good overbite control while allowing free sliding through buccal segments. Thinner wires tend to give less overbite and torque control while thicker wire sometimes restricts free sliding in the molars and premolars. The .022 slot allows more freedom of movement for larger wires and hence helps to keep the force light[8]. .019 X.025 inch arch wire has been found to perform well as it is less flexible and hence shows less deflection and binding during space closure as compared to wire of .017 X .025 inch or lesser[11].

Our results clearly indicate that the brackets providing the least frictional resistance are the stainless steel brackets (Mean 66.47±7.84 gms). Stainless steel brackets are made from 316 L austenitic stainless steel, 'L' referring to the low carbon content. Good strength, resistance to fracture and deformation, low cost and more importantly low frictional values are the major advantages. But their drawback is that; offer little in terms of esthetics. The stainless steel bracket has the lowest and statistically most significant frictional force value, because of the characteristics of the metal which allows better polishing and smoother surface.The ceramic bracket with metal reinforced slot showed the intermediate values of frictional force (Mean 75.95±8.44) probably because its slot is reinforced with metal which prevents direct contact between ceramic and wire. Even with metal insert ceramic bracket some clinical complications such as ceramic stiffness and enamel abrasion are still a challenge. Cacciafesta et al compared the frictional resistance between ceramic bracket with metal insert slot and stainless steel brackets with three different wires: stainless steel, nickel-titanium and beta-titanium. They found that metal insert ceramic brackets generated significantly lower frictional forces than did conventional ceramic brackets but higher than stainless steel brackets[7].The larger frictional force values produced by polycrystalline ceramic brackets (Mean 92.32±8.52) could be attributed to the ceramic bracket characteristics such as hardness and stiffness as ceramic bracket is made of multiple crystals. Manufacturing procedure, finishing and polishing are difficult to do; this might explain the granular and pitted surface of ceramic bracket. The rough but hard ceramic material is likely to penetrate the surface of even a steel wire during sliding creating considerable resistance. Omana et al compared the frictional forces of ceramic brackets with stainless steel bracket and found that ceramic brackets again demonstrated significantly higher frictional forces compared to the stainless steel brackets[3]. Karamouzos et al reviewed the properties of ceramic brackets and found that the stainless steel brackets in general produce lesser friction than ceramic brackets and this was attributed to the lower surface roughness of stainless steel. They also reported that injection molded ceramic brackets created less friction than other ceramic brackets. They suggested the development of ceramic brackets with smoother slot surfaces and metal inserts to overcome friction[4].

Two main limitations of our study are that 1) the result of our study indicates the in-vitro friction generated in a dry state and hence may not directly correspond to the wet oral environment. 2) The force system recorded in-vitro is substantially different from the applied forces in clinical orthodontic movement and therefore might not be accurately reproductive of the frictional force during clinical tooth movement. The values recorded should be used to compare the effects of different factors, rather than to quantify in-vivo friction. Additional studies are necessary to improve the metal slot adjustment in ceramic bracket, as well as its clinical performance, which influences the frictional resistance values.

Conclusions

Frictional resistance of thirty 0.22” slot brackets each of stainless steel, polycrystalline ceramic and metal insert ceramic brackets were tested against .019 X.025 inch arch wire using universal testing machine.

The following are the salient conclusions from the study:- The stainless steel brackets showed the least friction among all the three types of brackets evaluated (66.47±7.84 gms).Polycrystalline ceramic brackets (Mean 92.32±8.52) showed the maximum amount of friction. The metal insert brackets (Mean 75.95±8.44) showed frictional resistance more the stainless steel but less than the ceramic counterparts.

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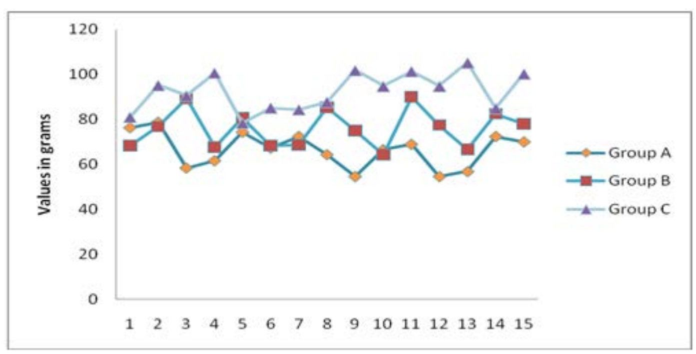
Legends Graph and Figure

Graph 1: Friction Resistance of Stainless Steel, Metal Insert Ceramic and Polycrystalline Ceramic Comparison of Group A, GroupB, Group C



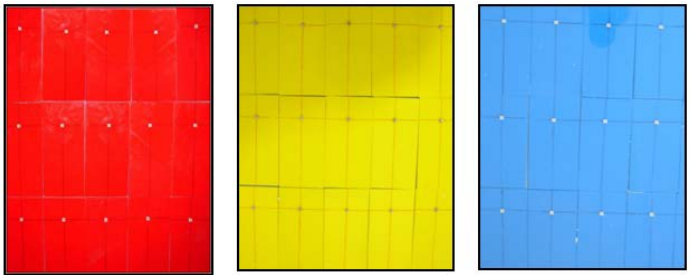


Figure 1: Brackets mounted on acrylic sheets

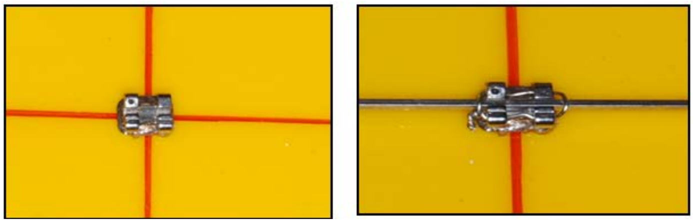


Figure 2: Close up view of stainless steel bracket

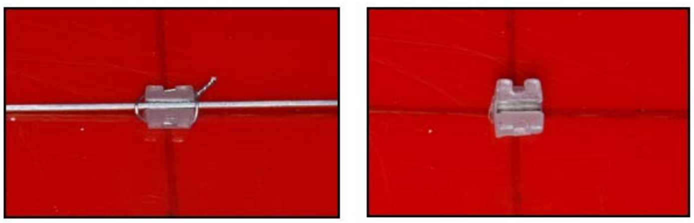


Figure 3: Close up view of metal insert ceramic bracket

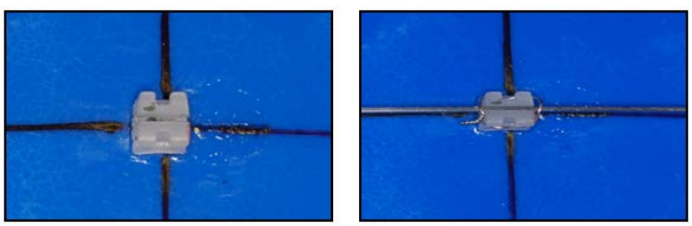


Figure 4: Close up view of polycrysatalline ceramic bracke

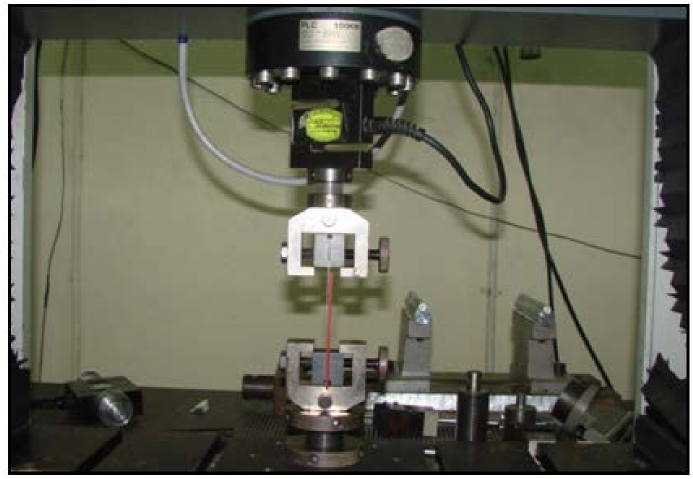


Figure 5 : Instron Universal testing Machine