Annals of R.S.C.B., Vol. 24, Issue 1, 2020, pp. 873- 891
Received 18April2020; accepted 23June2020

Comparison Of Friction In Coated Stainless Steel Archwires Using Ceramic Brackets And Ceramic Self-Ligating Brackets – An Invitro Study

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ABSTRACT

Objectives: This study aims to evaluate and compare friction in coated stainless steel archwires using ceramic brackets and passive ceramic self-ligating brackets with the concept of assessing the feasibility of combining esthetics and efficient mechanotherapy by reducing friction. Methods: Friction testing was done using a canine retraction model on jigs separately representing for ceramic brackets (Gemini Clear, 3M Unitek, Monrovia, California, USA) and ceramic self-ligating brackets (Damon Clear 2 Self -Ligating, Ormco, Orange, Calif). The coated wires tested were: Rhodium coated wires (Tomy Inc., Futaba, Fukushima, Japan), Teflon coated wires (Aditek, Cravinhos, SP, Brazil), and Epoxy resin coated wires (G&H Orthodontics, Franklin, IN, USA). The Universal Testing Machine was utilized to measure frictional losses. Results: Rhodium coated wires showed statistically significant values of higher friction when compared with Epoxy coated wires and Teflon coated wires. Epoxy coated wires in comparison with Rhodium coated wires showed a mean difference of 0.97N when evaluated with self-ligating ceramic brackets which was highly significant. In comparison with Teflon coated wires, there was a mean difference of 0.38N which was statistically significant at 0.05 level. Teflon coated wires exhibited lesser forces but the least frictional loss was associated with Epoxy coated wires. Conclusion: - The results from this study suggest that the least frictional loss was associated with Passive Self-ligating ceramic brackets in combination with Epoxy coated wires and Teflon coated wires.

Key-words: - Coated stainless steel archwires, Friction, Ceramic brackets, Self-ligating brackets

INTRODUCTION

Orthodontics is the field that deals with achieving excellence in esthetics and function of the dentition. This is achieved with the help of attachments and wires, both of which act as conduits for the transfer of force in-order to elicit tooth movement. Hence research in the field of material science is important for providing with better and efficient ways of achieving tooth movement be it in the form of accuracy of the predicted tooth movement, reduced chairside time and overall treatment duration or even patient comfort. To add to the above, a new goal has arisen which is to provide efficient treatment without affecting patient esthetics.

There has been a recent surge in the number of adult patients seeking orthodontic treatment1. Several studies have demonstrated patient prefer for appliances which are not easily visible2–4. Basically, this has given life and generated tremendous interest to the field of Invisible Orthodontics. Ceramic brackets were introduced to orthodontic specialty in 19861. The superior

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esthetics of ceramic brackets compared to conventional stainless-steel brackets is not only well accepted by the patient, particularly adults, but are positively sought for.

Self-Ligating brackets are a system of orthodontic appliances which have been marketed as having low friction and better efficiency than conventional brackets. Since elastomeric modules are not used in these brackets, friction is reduced and tooth movement not impeded. To cater to the esthetically conscious patients, ceramic versions of the self-ligating system have also been developed.

Friction within the orthodontic appliance is an undesirable factor at play at different phases of orthodontic treatment. This is evident during the alignment phase where the severity of crowding can contribute proportionally to friction and sometimes result in loss of anchor. Additionally, friction-based retraction mechanics involve the use of a stiff archwire along which force is applied for teeth to slide. Hence the force provided for retraction must first surpass the frictional forces in order for tooth movement to occur5. The drawback of such a system is that heavy forces have to be given which can potentially lead to loss of anchorage6,7. Nanda has coined the term ‘Appliance Ankylosis’ in reference to friction impeding tooth movement and as a consequence, treatment duration8. Assuming that alignment is achieved, some level of friction still exists which arises majorly from characteristics associated with the materials in play.

Various types of coated wires have come up with the aim of entirely eliminating the metallic appearance of the appliance. Important properties of such coated wires are biocompatibility, integral stability of coating, stability of colour and ability to camouflage and reduced intersurface friction.

PTFE or Teflon is a polymer with a completely fluoridated chain and as a bio-material has numerous applications in the field of medicine including cardiology where its anti-adherent property is relied upon. Farranato et al studied friction and found that Teflon coated wires had the least frictional losses amongst all the experimental groups9. Although different components were tested, De Franco et al found that Teflon coated ligatures could reduce bracket-archwire friction10. Considering that Teflon could impart a tooth coloured shade to the archwire and reduce friction as evidenced by Husmann et al, Teflon coated wires are viable for use in orthodontics11.

Rhodium is a precious silver-white metal of the platinum group of elements. It is used to plate orthodontic wires because it imparts a pearlescent and esthetic hue, is chemically stable and has excellent wear resistance12. Owing to its hyporeflective surface, it seldom shows the obvious metallic sheen associated with orthodontic wires on smiling.

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Epoxy resin is a thermoset synthetic resin made by combining epoxide with another compound13. Primarily recognized for its excellent adhesion, epoxy resins display a broad range of physical properties, such as chemical resistance, electrical insulation, and dimensional stability. It has a very wide range of applications in various fields and industries including electronics, construction materials etc. They are also used in the dental field as part of some composite resins, moulds, and polyurethane aligners.

This study aims to assess the frictional forces between coated stainless steel archwires and to compare them using ceramic brackets and passive self-ligating ceramic brackets and thus assess the feasibility of balancing the use of esthetically pleasing materials and functionality of the orthodontic appliance.

MATERIALS AND METHFODS

In this study, ceramic brackets (Gemini Clear, 3M Unitek, Monrovia, California, USA) and passive ceramic self-ligating brackets (Damon Clear 2 Self -Ligating, Ormco, Orange, Calif) were taken against which the different coated archwires were compared against each other (Table I); Rhodium coated wires (Tomy Inc., Futaba, Fukushima, Japan), Teflon coated wires (Aditek, Cravinhos, SP, Brazil), and Epoxy resin coated wires (G&H Orthodontics, Franklin, IN, USA). Wire Samples were cut from the buccal segment section of the ‘as -received’ archwires for the three groups.

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Figure 1 – ARMAMENTARIUM

Figure 2 – CERAMIC BRACKETS (GEMINI CLEAR BRACKETS, 3M UNITEK)

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Figure 3 - PASSIVE CERAMIC SELF-LIGATING BRACKETS (DAMON CLEAR 2 BRACKETS, ORMCO)

Figure 4 - GROUP I SAMPLES– RHODIUM PLATED WIRES (TOMY INC.)

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Figure 5 - GROUP II SAMPLES– EPOXY RESIN COATED WIRES (G&H ORTHODONTICS)

Figure 6 - GROUP III SAMPLES– TEFLON COATED WIRES (ADITEK)

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This study included the use of maxillary central and lateral incisor, canine and 2nd premolar ceramic and ceramic passive self-ligating brackets. The bracket slot dimension was uniformly 0.022 × 0.028 in and the wire dimensions were all 0.019 × 0.025 in.

Table I: Coated wires evaluated for frictional resistance:

Coated Wire	**Bracket Type**	**Dimension in Inches**	**Manufacturer**
Group I Rhodium (n=30)	**Ceramic brackets**	0 .019 ” × 0 .025 ”	**Tomy Inc.**
	Ceramic Self-ligating brackets	0 .019 ” × 0 .025 ”	**Tomy Inc.**
Group II Epoxy Resin (n=30)	**Ceramic brackets**	0 .019 ” × 0 .025 ”	**G & H Orthodontics**
	Ceramic Self-ligating brackets	0 .019 ” × 0 .025 ”	**G & H Orthodontics**
Group III Teflon (n=30)	**Ceramic brackets**	0 .019 ” × 0 .025 ”	**Aditek**
	Ceramic Self-ligating brackets	0 .019 ” × 0 .025 ”	**Aditek**

Sample size calculation was done by a pilot study comprising 5 samples of coated wires per group: an estimated thirty samples per group was deemed as sufficient for this study.

Friction testing was done using a canine retraction model on jigs separately representing for ceramic brackets and ceramic self-ligating brackets. The test was conducted according to the protocol and design given by Tidy14. A rigid rectangular acrylic plastic jig (14 cm × 4 cm × 0.5 cm), with a cutout (1.5 cm × 1.2 cm) at a span of 2 cm from one of the extremities was used for the friction test simulating a half-arch fixed appliance.

Three maxillary ceramic brackets (central, lateral incisor and 2nd premolar) with conventional stainless-steel buccal tubes and ceramic self -ligating brackets with Snaplink™ Buccal Tubes (central, lateral incisor and 2nd premolar) were bonded onto two separate jigs with an industrial adhesive. The brackets and buccal tube were bonded with an interbracket distance of 8 mm, with a 16 mm space present between the lateral incisor bracket and the second premolar bracket for the purpose of retracting the movable canine bracket. A stainless-steel wire (0.021’’ x 0.025” G&H Orthodontics, Franklin, IN, USA) was used to level the brackets before polymerization and removed after resin setting.

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The respective coated wires were placed and their two extremities were bent to prevent the wire from sliding out of the bracket assembly during the friction test.

Brass wire of diameter 19 gauge was bonded to the mesh bases of the canine brackets using adhesive. This was done in order to support a 100gm weight, simulating the weight of a tooth.

The study was carried out under dry conditions using a universal testing machine (Autograph AG - IS 50kN, Shimadzu, Kyoto, Japan). The acrylic plastic jigs with the bonded brackets was clamped to the stable crosshead of the testing machine on one side.

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Figure 7 - SHIMADZU UNIVERSAL TESTING MACHINE MODEL AUTOGRAPH AG- IS 50kN

Stainless-steel ligature wire of 0.010” (G&H Orthodontics, Franklin, IN, USA) was used to tie the ceramic brackets and also to form a loop around the canine bracket; one of the extremities

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was engaged on the bracket while another end was engaged to the movable load cell of the machine.

The crosshead speed was maintained at 5mm per minute and a trial run was done before each test with no load on the power arm to rule out binding between the straight wire and the bracket. A100gm weight representing the resistance offered by a tooth was suspended from the power arm, and the load required to move the bracket was recorded. The load-cell reading represented the clinical force of retraction that would be applied to the tooth, part of which would be the friction, and the rest would be the translation force acting on the tooth.

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Figure 8 - FRICTION TESTING USING UNIVERSAL TESTING MACHINE

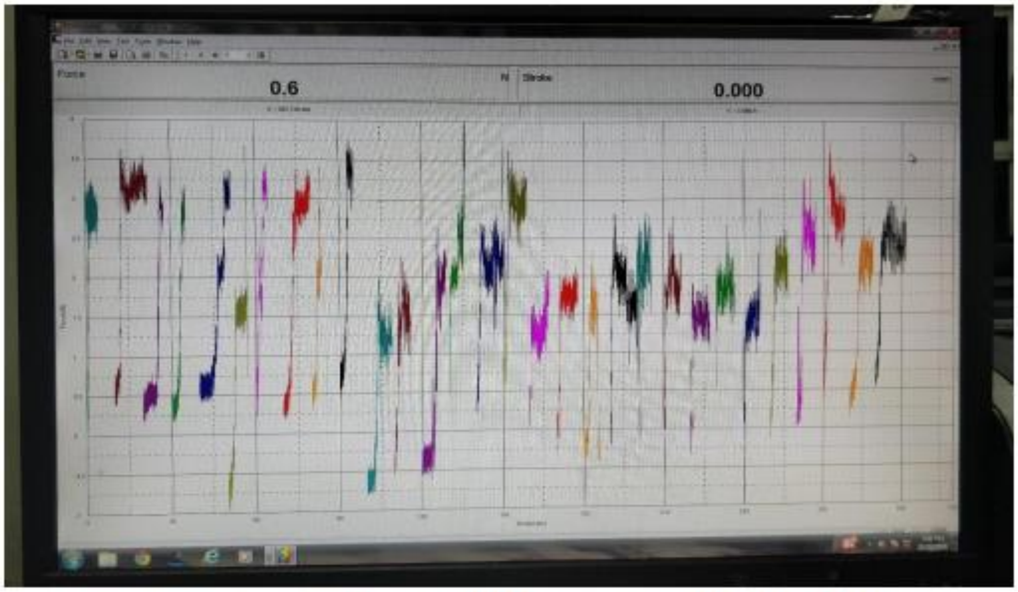

Figure 9 - GRAPH READING ON TRAPEZIUM X TESTING SOFTWARE

Statistical Analysis

Descriptive statistics like mean and standard deviation (SD) were calculated for each bracket-archwire combination. Paired t-test was carried out for group comparison between ceramic brackets and ceramic self-ligating brackets. One-way analysis of variance (ANOVA) was used to compare the three groups with multiple range test by Tukey-Honestly significant difference to establish the significance of the values following ANOVA. In the present study, $P < 0.05$ was considered as the level of statistical significance. The statistical analysis was carried out using the SPSS Software version 16 statistical package (IBM Corporation, Chicago, IL, USA).

Results

The mean values from ceramic brackets and ceramic self-ligating brackets when compared (Table II) showed that it was statistically highly significant for rhodium coated wires and statistically significant for epoxy coated and Teflon coated wires.

Table II: Comparison of friction in Ceramic SL brackets and Ceramic brackets among groups

Groups	Variable	Mean $\pm$ SD	P ValueA
Rhodium	Ceramic Self-ligating brackets	2.46 $\pm$0.18	0.002*

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	Ceramic brackets	2.92 ± 0.32	
Epoxy	Ceramic Self-ligating brackets	1.48 ±0.29	0.04*
	Ceramic brackets	1.63 ± 0.23	
Teflon	Ceramic Self-ligating brackets	1.87 ± 0.46	0.05*
	Ceramic brackets	1.99 ± 0.52	

A Paired T Test was used to calculate the P-value
*P value <0.01 is Statistically highly significant
*P value <0.05 is Statistically significant

One-way ANOVA was used to check for variance in coated wires with ceramic bracket (Table III) and ceramic self-ligating brackets (Table IV) which gave a p-value of 0.001 which indicates that the values were very highly significant. Tukey's Post HOC test however indicated that friction in Epoxy coated wires and Teflon coated wires using Ceramic brackets was not statistically significant since p-value was 0.1.

Table III: Comparison between Groups using One-way Analysis of Variance in Ceramic Brackets

Groups	N	Friction Mean ± SD	P value A	Group compared with	Mean Difference	P valueT
Rhodium	30	2.92 ± 0.32	0.001 *	Epoxy	1.29100	.001*
				Teflon	.92700	.001*
Epoxy	30	1.63 ± 0.23		Rhodium	-1.29100	.001*
				Teflon	-.36400	.100
Teflon	30	1.99 ±0.52		Epoxy	-.92700	.001*
				Rhodium	.36400	.100

AOne-way ANOVA was used to calculate the p-value between the three groups
*P value <0.001 is statistically very highly significant
TTukey's HSD Post Hoc test

Table IV: Comparison between Groups using One-way Analysis of Variance in Ceramic Self-ligating Brackets

Groups	N	Friction Mean ± SD	P valueA	Group compared	Mean Difference	P valueT

				with		
Rhodium	30	2.46 ± 0.18	0.001 *	Epoxy	.97600	.000*
				Teflon	.59200	.002**
Epoxy	30	1.48 ± 0.29		Rhodium	-.97600	.000*
				Teflon	-.38400	.043**
Teflon	30	1.87 ± 0.46		Epoxy	-.59200	.002**
				Rhodium	.38400	.043**

AOne-way ANOVA was used to calculate the p-value between the three groups
*P value <0.001 is statistically very highly significant
**P value <0.05 is statistically significant
TTukey's HSD Post Hoc test

Discussion

Friction mechanics is popular among orthodontists owing to its simplicity. However, the efficiency of this modality of space closure may be compromised due to friction between the archwire and bracket slot. Friction is defined as the resisting force tangential to the common boundaries between two bodies when, under the action of an external force, one body moves or tends to move relative to the surface of the other15. According to Kusy and Whitley, it is one among three components that contribute to resistance to sliding; the other factors being binding of the wire and notching at the edges of bracket slot16,17. This can be explained by the fact that no material is inherently smooth on a microscopic level and has peaks called 'asperities' which contribute to surface roughness and hence friction18,19. They also found that 12−60% of the orthodontic force is reduced by the frictional force during orthodontic treatment20.

Frictional force is related to a number of factors such as: archwire material, surface area, size, stiffness and surface roughness, bracket material, slot width and depth, shape, interbracket distance, material and method of choice for ligation, biological and physiological factors like saliva, plaque, bite force and frequency.Drescher et al assessed multiple variables such as wire size, bracket width, and interbracket span and its influence on the frictional resistance during orthodontic treatment. It was found that material of the wire was the decisive factor in affecting frictional resistance18.

According to Kapila and Sachdeva, space closure in continuous archwire technique involves a relative motion of bracket over wire. Excessive amount of bracket – wire friction may result in loss of anchorage or binding of wire with bracket slot leading to little or no tooth movement. The

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preferred wire material for effective tooth movement would be the one that produces least amount of friction at the bracket wire interface21,22.

The use of ceramic brackets offereda couple of advantages over the traditional esthetic brackets1. Ceramic brackets provided higher strength, more resistance to wear and deformation, better colour stability and superior esthetics. All currently available ceramic brackets are composed of aluminium oxide in either of two forms: monocrystalline or polycrystalline. Monocrystalline brackets are milled from single crystals of sapphire using diamond tools. These were closely followed by the introduction of polycrystalline sapphire (alumina) brackets, which were manufactured and sintered using special binders to thermally fuse the individual particles.

Epoxy coated wires are produced by manufacturers as they provide a white esthetic coating to the wires. The process of coating involves the use of depository process plates which provides for thickness of epoxy resin coating of 0.002 inches23. According to Kaphoor and Sundareswaran, the thickness of epoxy coating on NiTi wires from G&H was found to be 0.00055”24.

Teflon coated wires are prepared by atomization using clean and compressed air. Initially there exists a thickness of 20-25um which is then heat treated to give a homogenous surface11.

In this study, the least friction was seen when using Epoxy resin coated wires which is statistically highly significant for both bracket types and is in correlation with the study done by Clocheret et al25. They evaluated friction in various combinations of 15 archwire types with 16 types of brackets using small oscillating displacements with the objective to better mimic forces experienced in the oral cavity. They found that epoxy coated wires had the least coefficient of friction at 0.16 while the highest values were seen with respect to True chrome wires at 1.38.

Husmann et al studied the frictional behaviour of eight coated wires of different dimensions using a canine retraction set up; the coatings compared include teflon coated wires, ion implanted wires, polished wires, uncoated wires. It was found that all the types of surface treatments and coatings improved the frictional characteristics of wires compared with uncoated ones. Teflon, however, was found to exhibit the most reduction in friction11.

Farranato et al investigated the effect of Teflon coating on the resistance to sliding of orthodontic archwires. Twelve types of commercially available round and rectangular, Nickel Titanium and Stainless Steel archwires with and without Teflon coating were used in the study. Resistance to sliding was tested using two passive and one active self-ligating brackets in a Universal Testing Machine. For all bracket–archwire combinations, Teflon-coated archwires resulted in lower friction than the corresponding uncoated archwires9.

Choi et al conducted a study with similar surface coatings as used in our study and assessed the surface roughness. The results were similar wherein both Epoxy resin and Teflon coatings showed the least frictional losses and surface roughness; of the two wires, Teflon was marginally superior3.

Ryu et al investigated the ultrastructural and mechanical properties of three white-coated superelastic nickel-titanium (NiTi) archwires. The coatings evaluated were silver platinum and polymer, epoxy resin and Teflon. The surface roughness of the silver platinum and polymer group was found to be the highest, followed by the epoxy resin group and the Teflon group in the coated areas indicating that Teflon and epoxy resin coated wires show less values for friction with Teflon being the least4.

Likewise, most studies have proven Teflon coated wires to reduce frictional losses. In our study, however, Teflon coated wires showed slightly higher frictional values than epoxy resin when using ceramic self-ligating brackets. A Possible reason for this could be variability in terms of thickness of the surface coating, homogeneity and finish between manufacturers. Our findings are in agreement with previous studies and hence it may be summarized that both Epoxy coated wires and Teflon coated wires are potentially effective in reducing friction between the archwire and the bracket. In ceramic brackets however, the difference was not statistically significant.

Rhodium coated wires have a high degree of surface roughness which increases friction. While thickness of the coating material varied from 0.00055” 24 to 0.002” 23 for epoxy coated wires, rhodium plated wires have a surface plating of only around 10µm in thickness12. There is a difference in core alloy dimension which may potentially contribute to the difference in mechanical properties and consequently friction.

Ravi et al had done a similar study with the same methodology as given by Tidy comparing friction in various combinations of stainless steel and TMA wires with active, passive and interactive types of self-ligating ceramic brackets26. Stainless steel wires of 0.019” × 0.025” dimension showed a mean frictional value of 2.26N whereas Epoxy coated, and Teflon coated wires were found to reduce friction. In our study, Rhodium coated wires showed 2.65N for frictional resistance when compared to stainless steel. Rhodium coated wires showed increased friction which is in accordance with the study done by Kim et al12.

Multiple comparisons using Tukey post hoc test indicates that the inter-group variability remains significant at less than the 0.05 level for all coated archwires in self-ligating ceramic brackets while only for rhodium in ceramic brackets. The results of the current study indicated that rhodium wires used in both ceramic brackets and ceramic self-ligating brackets showed the highest friction compared to Teflon coated and Epoxy coated. The difference between Teflon and Epoxy coating was statistically significant only for the ceramic self-ligating brackets.

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The means for Teflon coated wires and Epoxy coated wires was statistically significant and different only for ceramic self-ligating brackets at p=0.001. Clinically, however, the difference correlates to only 39gms which may not be clinically significant as there are a multitude of physical and biological factors which will easily overshadow this difference27.

For all combinations of brackets and wires utilized in this study, ceramic self-ligating brackets showed lower frictional values over ceramic brackets which was statistically significant. When esthetics is the main concern for selection of orthodontic appliance, Passive Self-ligating ceramic brackets in combination with Epoxy coated wires and Teflon coated wires were found to be viable options for reducing friction thus offering a balance of efficient tooth movement and good esthetics.

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Annals of R.S.C.B., Vol. 24, Issue 1, 2020, pp. 873- 891
Received 18April2020; accepted 23June2020