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Assessment of Static Friction Generated from Different Aesthetic Archwires (In-Vitro Study)

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Abstract

Background and objectives: The demand for aesthetic orthodontic materials has increased recently. This study designed to compare the static frictional resistance of Fiber-Reinforced Polymer Composite archwire (FRPC) in comparison with other aesthetic coated archwires.

Materials and methods: Four types of 0.018 inch archwires, including three types of aesthetic archwires; FRPC, Teflon coated, Epoxy coated and a conventional Nickel-Titanium archwires, were utilized in this study. Ten pieces from each archwire were obtained by cutting 5cm from the straight portions of the wires. These were subjected to the friction test using Instron Tinius Olsen testing machine. Surface topography of the archwires was examined by stereomicroscope. Statistical analysis was done using one-way ANOVA test and post hoc Tukey HSD test.

Results: The highest frictional force was recorded in FRPC followed by Teflon, Epoxy coated and the least for the uncoated archwire with a statistically high significant difference.

Interpretation and Conclusions: FRPC showed higher friction value when used with ceramic brackets compared to other coated and uncoated archwires.

Keywords: Coated archwires, Friction, FRPC archwire.

INTRODUCTION

Nowadays, the manufacture industries are directed towards esthetic related materials in every field related to dentistry including orthodontics. The first step of aesthetics was the development of plastic brackets followed by ceramic and sapphire ones. Similarly, archwires with different coating materials like Teflon, Epoxy and polymer was introduced. In the mid of 1990s, non-metallic archwires was marketed by Talass (1) and regarded as big innovation in the world of orthodontic archwires.

The other step was the development of Fiber-Reinforced Polymer Composite (FRPC) archwire. FRPC archwires are produced in two steps. In the first step, “Amount, distribution and wetting of fibers by resin is closely controlled” and in the second step “Composite is formed into desired final shape”. Two important processes associated with fabrication of FRPCs, i.e., Pultrusion and Beta staging. Pultrusion: is the process of manufacturing components having continuous lengths and a constant cross sectional shape such as in archwire. In this, bundle of continuous fibers are impregnated with polymeric resin and are then pulled through a Sizing Die that performs composite and establishes resin/fibre ratio. The bundles are then passed through Curing Die which imparts precise shape as it cures the resin. Beta Staging: It is an intervening process in which partially cured resin and its bundles of continuous fibers are deformed into another form (e.g. preformed archwire) after which the curing is completed. Preformed arch wires and rectangular cross-section is possible by this process (2).

It has been found that friction was increased with plastic and ceramic brackets in comparison with metallic brackets (3). Earlier studies evaluated the frictional resistance of metal and aesthetic (ceramic and composite) brackets with metal and aesthetic archwires (4-9). Few researches studied the friction of Fiber-Reinforced Polymer Composite archwire, hence this study aimed to evaluate the frictional resistance of FRPC archwire compared to other coated and uncoated archwires with same gauge in dry condition.

MATERIALS AND METHODS

The sample of the current study was divided into 4 groups. Each group consisted of ten straight portion of 0.018 inch diameter of the following aesthetic initial archwires; epoxy-coated nickel titanium archwires (Orthotechnology Co., Florida, USA), teflon-coated nickel titanium archwires (IOS Co., Houston, USA), fiber-reinforced polymer composite archwires (Dentaurum Co., Ispringen, Germany) and uncoated nickel titanium archwires (Orthotechnology Co., Florida, USA).

Custom-made aluminum blocks with dimensions of 40mm×15mm×9mm were fabricated for this study. Forty 0.022× 0.028 inch polycrystalline ceramic brackets of right 1st premolar (Reflection™, Roth prescription) from Orthotechnology Co., Florida, USA were aligned on these block with the aid of a section of 0.0215 × 0.025 inch straight stainless steel archwire to eliminate the tip and torque as both factors affect the frictional resistance (10). The brackets were secured to the archwire with ligature elastic. This archwire was bent into L-shape bend vertical to the bracket slot; this bend was to allow good grasping during fixation on the aluminum block and to ensure that the bracket slot is parallel to the block surface and perfectly passive (7). The brackets, ligated to this wire, were fixed to the aluminum block by cyanoacrylate adhesive. After fixation, the archwire was removed and the sample was ready for testing (5,7,9).

A total of forty sections (10 from each archwires) were prepared with 50mm length from the straight portion of the archwire. Each tested archwire was seated in the slot of the bracket and ligated with clear ligature elastic (7).

The free end of the tested archwire was clamped by the load cell of Instron testing machine (Instron H50KT Tinius Olsen, England) with a load cell of 10 N; then the bottom of the aluminum block was fixed by the lower crosshead of the Instron machine (11). For every traction test over a distance of 5 mm at a speed of 5 mm/min, the maximum force needed to move the wire along the bracket (static friction) were recorded from a graph generated by the testing machine built to computer. The maximum frictional resistance force generated was recorded in Newton which then converted to grams using the following equation: Friction in g = [Friction in (N) ÷ 9.8] × 1000 (5,7,8). For each test, a new archwire was used on the bracket block that allocated for the same group and the mean of measurement was recorded (5,7).

Surface topography of the tested archwires was examined using a stereomicroscope (40X) before and after testing.

The data were analyzed using SPSS program version 24. The descriptive statistics included the means and standard deviations, standard errors, maximum and minimum values of the frictional resistance force of each archwire. Inferential statistics included one-way ANOVA and post hoc Tukey's high significant difference (HSD) tests which were used to compare the frictional resistance force among different types of archwires.

The levels of significance were set as followed:

Non-significant P > 0.05
Significant 0.05 ≥ P > 0.01
Highly significant P ≤ 0.01

RESULTS

The results revealed that the mean static friction of FRPC was the highest among the tested groups followed by teflon coated archwire. The epoxy coated type showed the least mean value among the aesthetic archwires as shown in table I and figure 1. One-way ANOVA test revealed statistically high significant difference among the tested archwires.

Comparing the friction between each two types of archwires using post-hoc Tukey's HSD test revealed a non-significant difference between each two types except between FRPC with Epoxy coated and uncoated archwires and between the Teflon-coated and uncoated archwires (Table II).

The surface topography of the aesthetic archwires was shown in figure 2. The stereomicroscope revealed that the epoxy coated archwires showed an integrated surface with a fairly smooth texture compared to FRPC and teflon coated archwires.

Table I: Descriptive statistics of static friction (gm) and archwires' comparison

Archwires	Descriptive statistics					Comparison	
	Mean	S.D.	S.E.	Min.	Max.	F-test	p-value
FRPC	66.540	12.473	3.944	51.02	86.73	5.632	0.003
Teflon	61.427	10.732	3.394	51.20	81.63		
Epoxy	53.316	8.975	2.838	38.27	66.43		
Uncoated	49.287	8.921	2.821	39.80	66.33		

FRPC Fiber-Reinforced Polymer Composite

Table II: Comparison of frictional resistance between the aesthetic archwires using Tukey's HSD test

Archwires		Mean difference	p-value
FRPC	**Teflon**	5.113	0.691
	Epoxy	13.224	0.035
	Uncoated	17.253	0.004
Teflon	**Epoxy**	8.111	0.315
	Uncoated	12.140	0.049
Epoxy	**Uncoated**	4.029	0.821

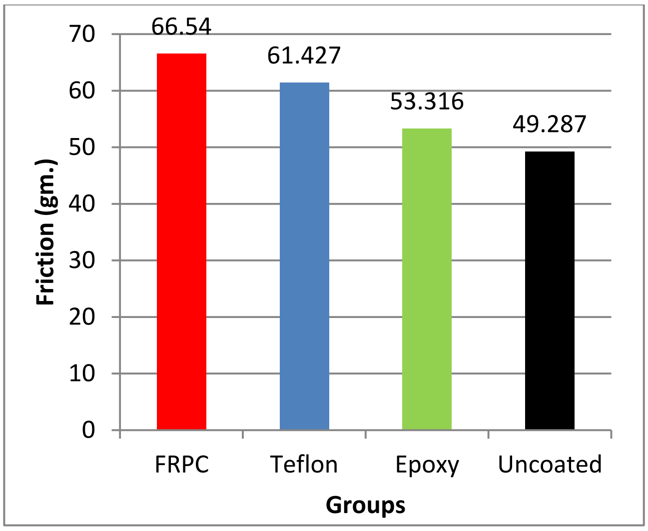

Figure 1: Bar charts representing the mean values of the static friction of different aesthetic archwires

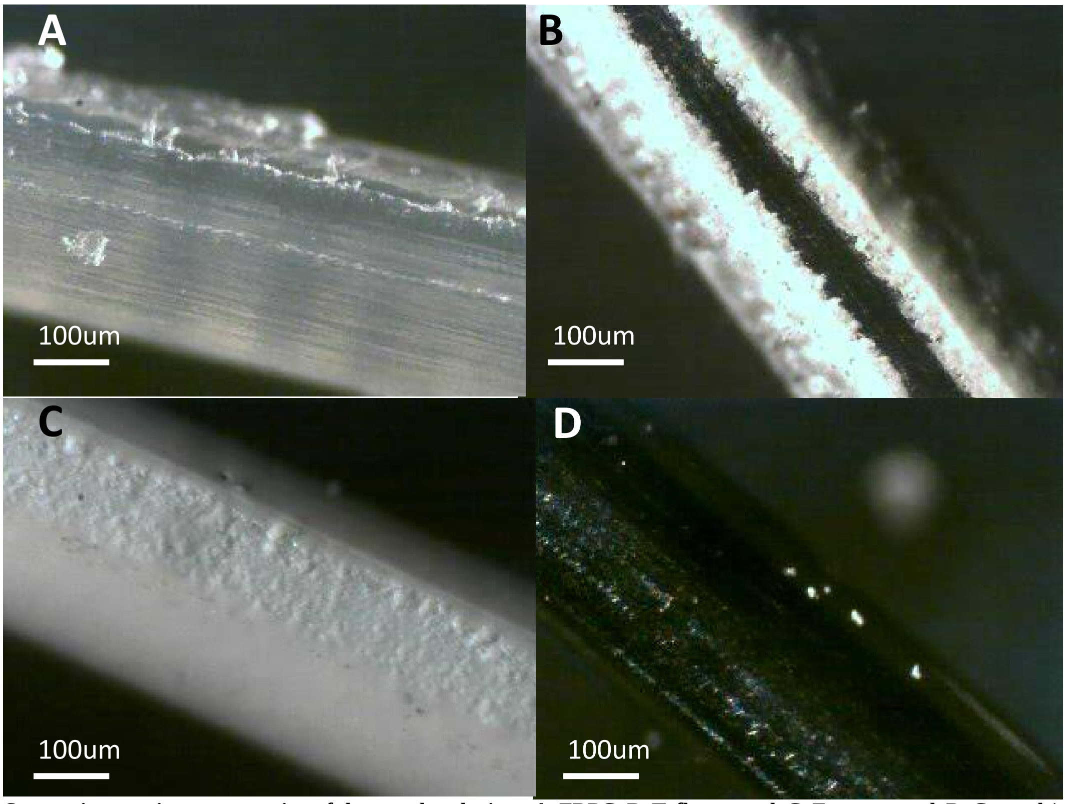

Figure 2: Stereomicroscopic representation of the tested archwires; A, FRPC, B. Teflon coated, C. Epoxy coated, D. Control (uncoated).

DISCUSSION

In the present study, ceramic brackets were used to simulate the clinical situation and the archwires were ligated using ligature elastics as steel ligatures generated higher friction than elastic ligatures [12,13].

The results of the current study showed that FRPC archwires exhibited the highest friction resistance compared to other coated archwires. This finding disagreed with that reported by Inami *et al.* [14] who claimed that the as-received FRPC showed a comparable friction to that of metallic archwires apart from the Beta Titanium ones. This may probably due to the difference in the surface texture of the bracket/archwire combination. It was suggested that there was a correlation between the surface roughness of the archwires and their frictional behavior and the rougher the surface, the greater the frictional resistance [13,15-18]. Furthermore, Suwa *et al.* [19] reported similar frictional properties of FRPC archwires compared to metal archwires, also FRPC archwires showed a higher friction resistance when tested on polycrystalline ceramic brackets compared to other brackets. This is probably due to the higher coefficient of friction of ceramic brackets compared to stainless steel one due to their rougher texture and more porous surface. They have shown to generate significantly greater frictional resistance forces than stainless steel brackets with any of the archwires combination.

Additionally, the results showed that there was no significant difference between teflon and epoxy coated archwires; this came in accordance with Rongo *et al.* [20]. Epoxy resin has excellent adhesion and a broad range of physical properties, such as chemical resistance and dimensional stability that might contribute for having the least roughness and this comes in agreement with Kravitz [21].

As a conclusion; FRPC archwire has the highest frictional resistance with polycrystalline ceramic brackets compared to other coated and conventional NiTi archwires.

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