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EFFECT OF ARCH-WIRE COATING ON FRICTION OF CERAMIC BRACKETS LABORATORY STUDY

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Arch-wire,
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ABSTRACT

Introduction: The increasing demand for esthetics has promoted the development of wires coated with polymeric materials such as polymer matrix reinforced with glass-fibers. Thus, the surface and thickness of metallic-coated wires can be modified to affect corrosive properties, mechanical durability and especially friction forces. **Aim:** To evaluate the frictional properties between Teflon coated and non-coated stainless-steel orthodontic arch-wires (0.017 x 0.025-inches and 0.019 x 0.025-inches) with ceramic brackets of 0.018 and 0.022-inch slots. **Material and methods**: Sixteen orthodontic maxillary premolar mono-crystalline ceramic brackets, eight brackets with 0.018-inch and eight brackets with 0.022-inch slot size. Roth prescription were used. Twenty stainless-steel 0.017 x 0.025-inch arch-wires were used (ten Teflon coated and ten non-coated). Twenty stainless-steel 0.019 x 0.025-inch arch-wires were used (ten Teflon coated and ten non-coated). All arch-wires were cut to symmetrical equal halves using a wire cutter at the midline and each half was used separately. The total number of wire segments used in the study was eighty orthodontic maxillary stainless-steel arch-wires. Each ceramic bracket tested five wire segments using new elastomeric modules each time. Each bracket was translated the same distance (5mm) relative to its wire segment by the LR5K Lloyd universal testing machine at the same speed of (5mm per minute). **Results:** The non-coated 17x25 –inch thickness stainless steel arch-wires showed higher friction than coated ones and the non-coated 0.019 x 0.025-inch. The coated 0.019x 0.025-inches stainless steel wire segments showed significant highest friction of 1687.25±97.5 than non-coated 0.019x 0.025-inches and coated/non-coated 0.017x 0.025-inches wire segments. **Conclusion:** The coated stainless-steel arch-wires had higher friction than the non-coated stainless-steel arch-wires on mono-crystalline ceramic brackets.

INTRODUCTION

The Teflon coating on orthodontic arch-wires and brackets increasing the antimicrobial and the mechanical properties, as friction, surface topography, or corrosion resistance. The type and nature of coating materials such as nitride ions, metals, oxides, teflon or resins exhibited stronger impact on determining the potential for corrosion of Nickel-titanium wires compared to values of surface roughness. The result of the study was that coating on the orthodontic wires and brackets used to reduce the friction problem during orthodontic treatment, minimizing the treatment time and the risk of bacteria adhesion[(1)].

Stainless-steel rectangular wires, when exposed to the intra-oral environment for 8 weeks, showed a significant increase in the degree of debris and surface roughness, causing an increase in friction between the wire and bracket during the mechanics of sliding [(2)]. The frictional resistance was evaluated by ceramic brackets (0.018 and 0.022 inch slots) used in combination with stainless-steel, cobalt-chromium, beta-titanium, and nickel-titanium wires. Beta-titanium and nickel-titanium wires were associated with higher frictional forces than stainless-steel or cobalt-chromium wires. Wires in ceramic brackets generated significantly stronger frictional force than did wires in stainless-steel brackets. Furthermore the friction in the ceramic brackets increased as wire size increased and rectangular wires produced greater friction than round wires[(3)]. The friction was considered in buccal segment attachments during over-jet reduction involving sliding mechanics, by comparing the friction in steel and polycrystalline ceramic brackets with 0.022-inch slot size, using polymeric steel and nickel-titanium wires (0.017x0.025-inch and 0.019x0.025-inch), under dry and wet conditions. The results indicated that friction was minimized by using stainless-steel rather than nickel-titanium.

Ceramic brackets had greater frictional resistance than steel brackets only when used with smaller rectangular wires. There was no significant difference in friction between 0.019 x 0.025-inch arch-wires in ceramic and stainless-steel brackets in dry condition, although 0.017 x 0.025-inch arch-wires showed high friction in ceramic brackets than in stainless-steel one [(4)]. The friction was a significant influence on the amount of applied force required to move a tooth during orthodontic treatment. So, arch-wire and bracket selection may be an important consideration when posterior anchorage is critical. Elastic ligature rings, especially when pre-stretched or allowed to relax, were not a significant source of bias toward the frictional forces recorded [(5)].

Teflon-coated (which is an anti-adherent and aesthetic material) arch-wires resulted in lower friction than the uncoated arch-wires ($P<0.01$). Teflon coating had the potential to reduce the resistance of sliding (RS) of orthodontic arch-wires[(6)]. Low-friction ligatures showed lower friction when compared with conventional ligatures coupled with 0.019 x 0.025-inch nickel-titanium arch-wires, but no difference when coupled with 0.019 x 0.025-inch stainless-steel[(7)]. The aim of this study was to evaluate the frictional properties between Teflon coated and non-coated stainless-steel orthodontic arch-wires (0.017 x 0.025-inches and 0.019 x 0.025-inches) with ceramic brackets of 0.018 and 0.022-inch slots.

MATERIALS AND METHODS

1. Materials:

This research was waived from Ethical Committee review of the Suez Canal University Faculty of Dentistry. The sample size for this study was calculated according to One-Way Analysis of Variance (ANOVA) with Post-Hoc Tukey's correction where the effect size 0.70, using alpha (α) level of 0.05 and Beta (β) level of 0.05, power = 95%. The estimated minimum sample size (n) was a total of 40 wires, it was found that sample size should be at least 5 wires for each group (four groups).

Sixteen orthodontic maxillary premolar monocrystalline ceramic brackets, each group contains four brackets, eight brackets with 0.018-inch in two groups and eight brackets with 0.022-inch slot size in the other two groups (Clear Viz ceramic brackets, Dynaflex, California, USA.) Roth prescription were used. Twenty stainless-steel 0.017x0.025-inch arch-wires were used (ten Teflon coated and ten non-coated) (Clear Viz ceramic brackets, Dynaflex, California, USA.). Twenty stainless-steel 0.019 x 0.025-inch arch-wires were used (ten Teflon coated and ten non-coated) (Clear Viz ceramic brackets, Dynaflex, California, USA.). Elastomeric modules (Clear Viz ceramic brackets, Dynaflex, California, USA). Sixteen rectangular metal blocks, with acceptance of ethical committee.

2. Methods:

2.1. Construction of metal blocks:

Sixteen metal rectangular blocks of 1.5 cm width and 5 cm length were made for bracket bonding.

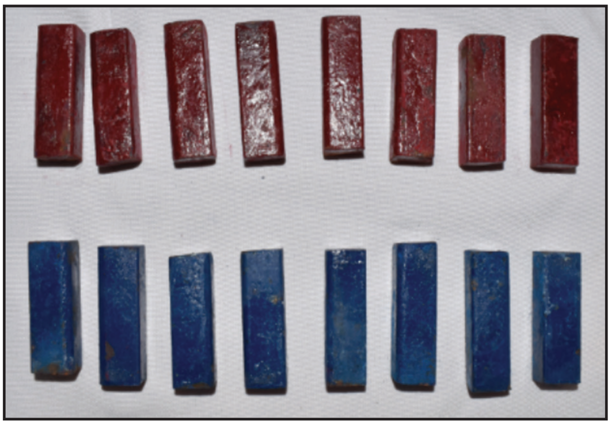

Fig. (1) Eight metal blocks with dark red color and eight metal blocks with blue color.

2.2. Bonding of the brackets:

A ruler is used to locate the middle of the metal block when the bracket was bonded. Each bracket was bonded using Alpha Cyanoacrylate adhesive (Amir Alpha Cyanoacrylate adhesive, Co, Zamalek, Cairo, Egypt.)

2.3. Preparing the arch-wires:

Each wire segment was bent at 90 degrees at the distal end part which is 5mm in length using the Angle bird peak plier.

2.3. Placing arch-wires in brackets:

Coated and non-coated 0.017 x 0.025-inches arch-wires were ligated to 0.018 ceramic bracket slot size and coated and non-coated 0.019 x 0.025-inches arch-wires were ligated to 0.022 ceramic bracket slot size.

Each ceramic bracket tested five wire segments using new elastomeric modules each time.

Testing the samples:

Each bracket was translated the same distance (5mm) relative to its wire segment by the testing machine at the same speed of (5mm per minute).

The LR5K Lloyd universal testing machine consists of upper clamp with load cell and lower clamp, each clamp has two arms that can be moved outside and inside (close and open) for proper holding for the metal blocks horizontally (Tests were done in the dental material department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt).

Fig. (2) The LR5K Lloyd universal testing machine.

Each metal block was placed on the lower clamp and hold by the arms for stabilization of the metal block.

The upper arms hold metal blocks with three bonded brackets, used to test the friction during movement of the upper arms.

The upper load cell pulled each stainless-steel arch-wire from the ninety degree's bend for a distance of 5mm and with speed of 5mm/min.

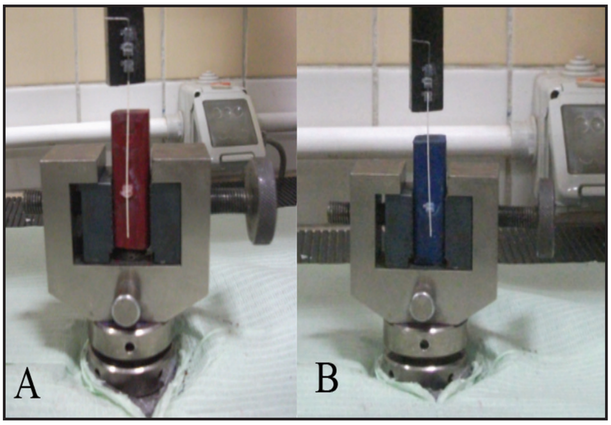

Fig. (3) A: Testing the friction of 0.017 x 0.025" arch-wires in 0.018" bracket slot size. B: Testing the friction of 0.019 x 0.025" arch-wires in 0.022" bracket slot size.

2.4. Statistical analysis

The collected data was organized in tables and figures by using Microsoft Excel 2016 and data were statistically analyzed using statistical package for social sciences (SPSS Version 23.0, Inc. Chicago, USA) for Mac OS.

The statistical significance was carried out using Mann-Whitney, Smirnov-Kolmogorov, and independent sample 't' test after confirming the underlying normality assumption by Using Shapiro-Wilk at 0.05 level. One-Way Analysis of Variance (ANOVA) with Post-Hoc Tukey's correction for multiple group comparisons is used to test the intergroup comparisons of the wire segments (0.017x 0.025 or 0.019x 0.025) and coatings friction (coated/non-coated) were studied.

The value of four tests were to confirm the results of each group. The p-values less than 0.05 were considered to be statistically significant [S: Significant, NS: Non significant]. All hypotheses were formulated using two tailed alternatives against each null hypothesis.

RESULTS

Group 1: (coated and non-coated 0.017 x 0.025" wires)

Effect of coating on friction of 0.017 x 0.025" stainless-steel wire segments in 0.018" bracket slot size. The results revealed that, the non-coated 0.017 x 0.025" stainless steel wire segment in 0.018" bracket slot size showed higher significant friction than coated ones.

Table (1) *Descriptive statistic representing the effect of coating on friction of 0.017 x 0.025" stainless steel wire segment in 0.018" ceramic bracket slot size.*

(0.017 x 0.025" wires in 0.018" bracket slot size)		
Descriptive measure	Coated	Non-coated
Mean	212.2	289.2
Standard error	2.0	6.4
Standard. Deviation	89.0	284.3
Mann-Whitney	0.041*	
Kolmogorov-Smirnov Test	<0.0001***	
t-test	<0.0001***	

** Significantly different at $p<0.05$*
*** Highly significantly different at $p<0.01$*
**** V. high significantly different at $p<0.001$*
NS non-significantly different at $p>0.05$

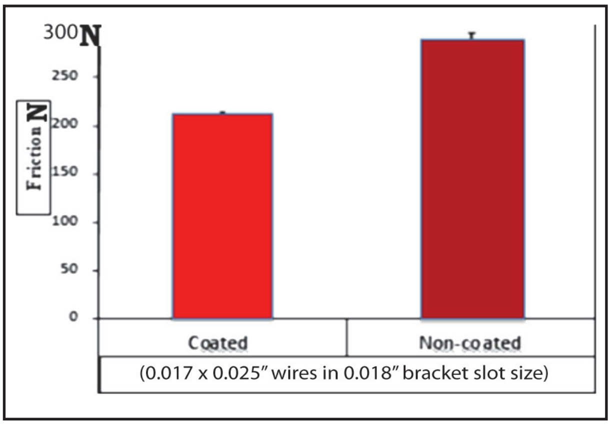

Fig. (4) Effect of coating on friction of 0.017 x 0.025" stainless steel wire in 0.018" ceramic bracket slot size

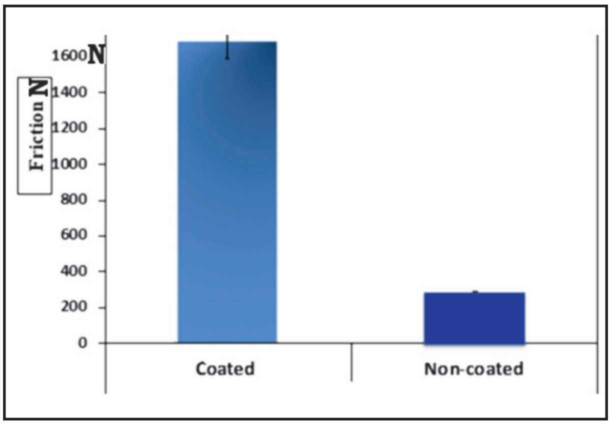

Fig. (5) Bar chart showing the effect of coating on friction of 0.019 x 0.025" stainless-steel wire in 0.022" bracket slot size.

Group2: (coated and non-coated 0.019 x 0.025" wires)

Effect of coating on friction of 0.019 x 0.025" stainless steel wire segment in 0.022" bracket slot size. The result showed that the coated 19x25" stainless steel wire segment in 0.022" bracket slot size showed higher significant friction than non-coated ones.

Table(2) *Descriptive statistic representing, Effect of coating on friction of 0.019 x 0.025" stainless steel wire segments in 0.022" bracket slot size.*

(0.019x 0.025" wires in 0.022" bracket slot size)		
Descriptive measure	Coated	Non-coated
Mean	1687.2	281.4
Standard error	97.5	5.3
Standard Deviation	4337.1	237.2
Mann-Whitney	<0.0001***	
Kolmogorov Smirnov Test	-0.0001***	
t-test	<0.0001***	

Group 3: (coated 0.017 x 0.025" and coated 0.019 x 0.025" wires)

Effect of coating on friction of coated 0.017 x 0.025" arch-wires in 0.018" bracket slot size and coated 0.019 x 0.025" wire in 0.022" bracket slot size. The result revealed that the coated 0.019 x 0.025" stainless steel wire segment showed higher significant friction than 0.017 x 0.025" coated wire segment.

Table (3) *Descriptive statistic representing, the effect of coating on friction of coated 0.017 x 0.025" wire in 0.018" bracket slot size and coated 0.019 x 0.025" wire in 0.022" bracket slot size.*

(Coated 0.017x0.025" in 0.018" bracket, coated 0.019x0.025" in 0.022" bracket)		
Descriptive measure	17x25	19x25
Mean	212.2	1687.2
Standard error	2.0	97.5
Standard Deviation	89.0	4337.1
Mann-Whitney	<0.001***	
Kolmogorov-Smirnov Test	<0.001***	
t-test	<0.001***	

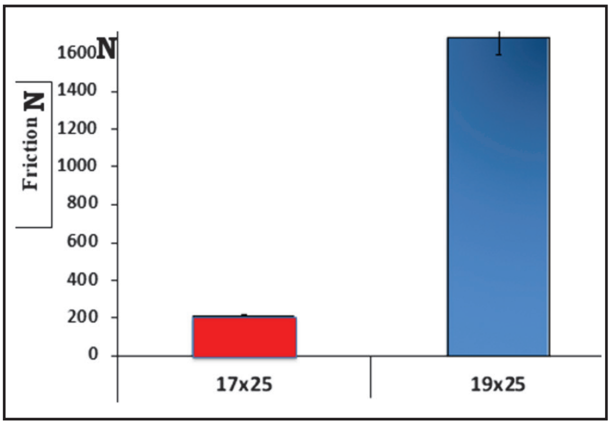

Fig. (6) Effect of coating on friction of coated 0.017 x 0.025" wire in 0.018" bracket slot size and coated 0.019 x 0.025" wire in 0.022" bracket slot size.

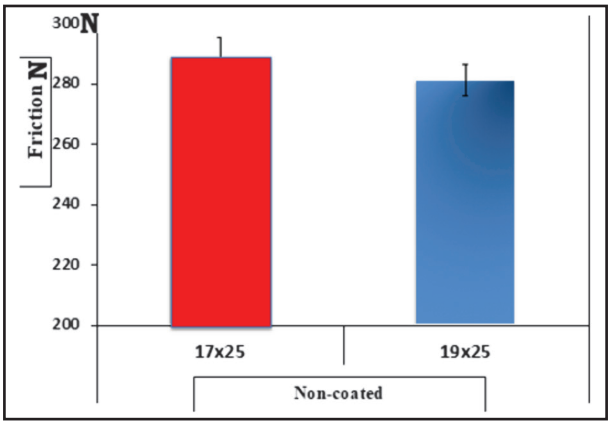

Fig. (7) Effect of friction of 0.017 x 0.025" wire in 0.018" bracket slot size and 0.019 x 0.025" wire in 0.022" bracket slot size.

Group 4: (non-coated 0.017 x 0.025" and non-coated 0.019 x 0.025" wires)

Effect of friction on non-coated 0.017 x 0.025" in 0.018" bracket slot size and non-coated 0.019 x 0.025" in 0.022" bracket slot size. So, the non-coated 0.017 x0.025" stainless steel wire segments showed higher significant friction than non-coated 0.019 x 0.025" wire segments.

Table (4) *Descriptive statistic representing, the effect of coating of friction on non-coated 0.017 x 0.025" wire segments in 0.018" bracket slot size and non-coated 0.019 x 0.025" wire segments in 0.022" bracket slot size.*

(Non-coated 17x25 wires in 0.018 bracket and 19x25 wires in 0.022 bracket)		
Descriptive measure	17x25	19x25
Mean	289.2	281.4
Standard error	6.4	5.3 237.2
Standard Deviation	284.3	
Mann-Whitney	0.011*	
Kolmogorov-Smirnov Test	<0.0001***	
t-test	>0.05 NS	

DISCUSSION

Ceramic brackets were developed to improve the esthetics during orthodontic treatment. This study was designed to compare the frictional forces between the coated and non-coated stainless-steel arch-wires in mono-crystalline ceramic brackets.

The aim of the study was to evaluate the frictional properties between Teflon coated and non-coated stainless-steel orthodontic arch-wires (0.017 x 0.025-inches and 0.019 x 0.025-inches) with ceramic brackets of 0.018 and 0.022-inch slots.

The mono-crystalline alumina brackets were used in this study because they created lower frictional forces with 0.019 x 0.025-inch rectangular and 0.018-inch round arch-wires compared to the polycrystalline alumina brackets [(8)].

The ceramic brackets had high friction with the stainless-steel arch-wires while the metal brackets had low friction with the stainless-steel arch-wires[(9)].

Another study reported that the pure ceramic brackets had higher friction than the ceramic brackets with metal slots in association with 0.017 x0.025-inch rectangular stainless-steel [(10)]. This was in agreement with Rongo *et al*, that mono-crystalline ceramic brackets had high friction than metal brackets [11].

Teflon coated 0.017x 0.025-inch, 0.019x0.025-inch arch-wires were highly esthetic than the non-coated ones [12].

In this study, the result showed that the non-coated 0.017 x 0.025" wires had higher friction than the coated wires because coated metallic arch-wires as nickel-titanium and stainless-steel arch-wires treated with poly-tetra-fluoro-ethylene, palladium, epoxy-resin or propylene-polymer, enhance the esthetics and decrease the friction[13]. This was in agreement with Bacela *et al*[1] revealed that the materials used in the coating as Teflon, zinc oxide, titanium oxide and silver nanoparticles reduced corrosivity, friction during teeth movement, minimize treatment time and risk of bacterial adhesion.

The result of this study revealed that all the Teflon coated 0.019x 0.025-inch stainless-steel wire segments showed the highest friction of 1687.25±97.5 than non-coated, coated/non-coated 0.017x 0.025-inch wire segments on mono-crystalline ceramic brackets, this was in agreement with Ehsani *et al*[14].

CONCLUSION

The 0.019 x 0.025-inch thickness rectangular stainless-steel arch-wires had higher friction than 0.017 x 0.025-inch on mono-crystalline ceramic brackets. The coated stainless-steel arch-wires had higher friction than the non-coated arch-wires.

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