Evaluation of Load Deflection, Surface Roughness and Frictional Forces of Aesthetic Niti Arch Wires

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Abstract

Objective: The purpose of this in vitro study is that NiTi esthetic arch wires are preferred to match esthetic braces; but the presence of coating layer is greatly affect friction during sliding mechanics.

The aims of this study were to evaluate the load deflection and the influence of surface roughness with the coating material types on the frictional force of coated nickel titanium wires.

Method: The sample of this study consisted of 90 segments of uncoated and coated Nickle titanium arch wires for three tests (friction test, roughness test and loading force test) 45 segment for each test involving two wire dimensions (0.016 × 0.022 and 0.019 × 0.025 inches). The static frictional force was measured through pulling the wires through a set of ceramic brackets by the universal testing machine while, the surface topography of wires were assessed by using Atomic force microscope (AFM) and load deflection test also measured. The data were analyzed using one-way analysis of variance (ANOVA) and Tukey's post hoc significance difference tests. Differences were considered significant at $P<0.05$.

Results: The frictional forces of gold wires is lesser than both control(uncoated) niti wire and epoxy coated wire for both wire dimention (0.016×0.022 and 0.019×0.025) inch. Surface roughness of coated arch wires is higher than control wires for both wire dimentions. Load deflection force of control wire is a higher than coated wires for (0.016×0.022) inches wire dimension.

Conclusion: The gold plated wires had lower frictional force than both (control and epoxy coated wires). Surface roughness of coated arch wires was higher than control(uncoated)arch wire. Load deflection force of coated wires was lesser than control wires.

Keywords: *Coated arch wires, Load deflection force, Friction, Surface roughness.*

Introduction

The demand for the aesthetic modalities is growing among patients seeking orthodontic treatment, the development of the orthodontic arch wires with optimum aesthetic appearance and clinical performance has become an essential and important factor of the treatment nowadays[1].

The presence of coating layer was usually influence the mechanical and frictional properties of arch wires[2,3]. Therefore; the manufacturers always try to coat the wires with a material that offer a perfect aesthetic and frictional properties[4]. Friction is defined as the resistance to movements of two or more contacting objects, or the force of resistance to movements[5,6]. The frictional forces in clinical orthodontics were considered as a primary concern, since it resists normal tooth movements[7]. During sliding movements of the teeth, the wire edges contact the bracket slot angles and a frictional force will develop, this will compete with

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normal tooth movements and decrease the magnitude of applied orthodontic forces[8]. Some researchers have investigated that frictional forces of aesthetic orthodontic wires focused on the link with the surface roughness of coating layer of coated arch wires[9].

Friction is a multifactorial subject that is affected by several physical and biological factors such as arch wire dimension, form, and materials type. A small arch wire size produces less friction than larger arch wire because of the larger elasticity and the increased free space that is present between arch wire and bracket slot, and that friction is increased with rectangular wire than with round wires[11,12].

Materials and Method

Samples: Ninty segments of uncoated and coated nickel titanium wires.

The uncoated wires form IOS|USA company. And coated nickel titanium

Wires include both gold plated wires from orthotechnology/Florida/USA and epoxy coated wires from USOP/USA companies.

With two wire dimension 0.016×0.022 inches and 0.019×0.025 inches.

Five samples for each wire size.

A group of 30 maxillary right premolar ceramic brackets (Hubit) with a 0.022” slot were selected for the test. Ligature elastics were supplied from IOS Company seventy custom-made acrylic blocks cut by CNC laser machine for accurate dimensions of the block with dimensions of 40 mm × 15 mm × 9 mm where used and the guiding positioner frame for more accuracy on the positioning of the brackets (Figure 1).

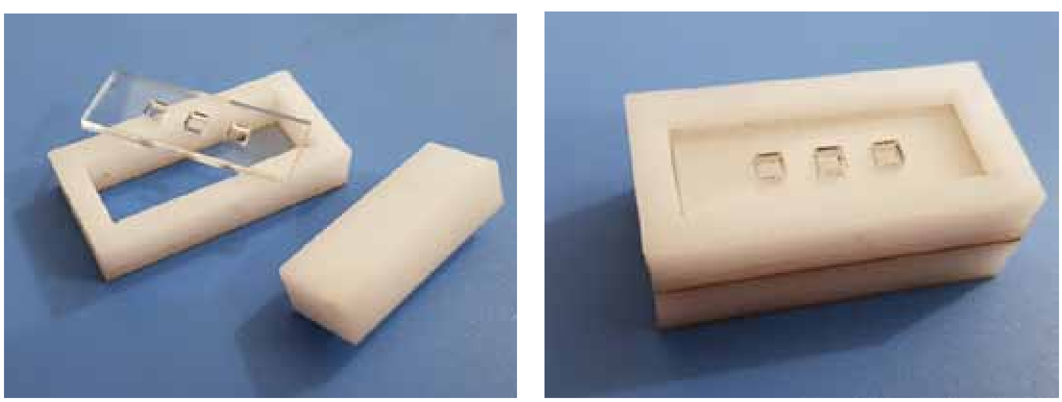


Figure 1: Acrylic block and the acrylic bracket positioner guide.

Devices: Atomic force microscope (AFM) was used for measurement of surface topography of wires coating layer. Computerized Intron Tenuis Olsen testing machine with a load cell 10 Newton (N) was used for measurement of static frictional resistance forces.

Procedures:

Frictional resistance/coated arch wires were prepared by, cutting the wires from the straight posterior ends to a length of 50 mm using a ruler and wire cutter. Every three brackets were fixed to the acrylic blocks with the use of bracket holder and cyanoacrylate adhesive in a straight alignment with inter-bracket distance of 8 mm with the aid of a custom-made plastic template and a straight stainless-steel wire segment of 0.0215 × 0.025 inch to properly reproduce the same angles and locations of brackets (Figure 2).

Figure 2: The setting of brackets

Every wire segment was ligated to the set of brackets and ligation was done with the use of an artery forceps. Hand gloves and tweezer were used to avoid contamination of wire surfaces. By the universal testing machine, a tensile test was used, the acrylic blocks with the adhered brackets and ligated wire was griped firmly by the lower jaw of the testing machine and the end of the wire was attached to the clamp of upper movable part (Figure 3).

Figure 3: Wire-brackets block system fixed to machine.

The specification of this test was done according to many studies[17,18] and as follows:

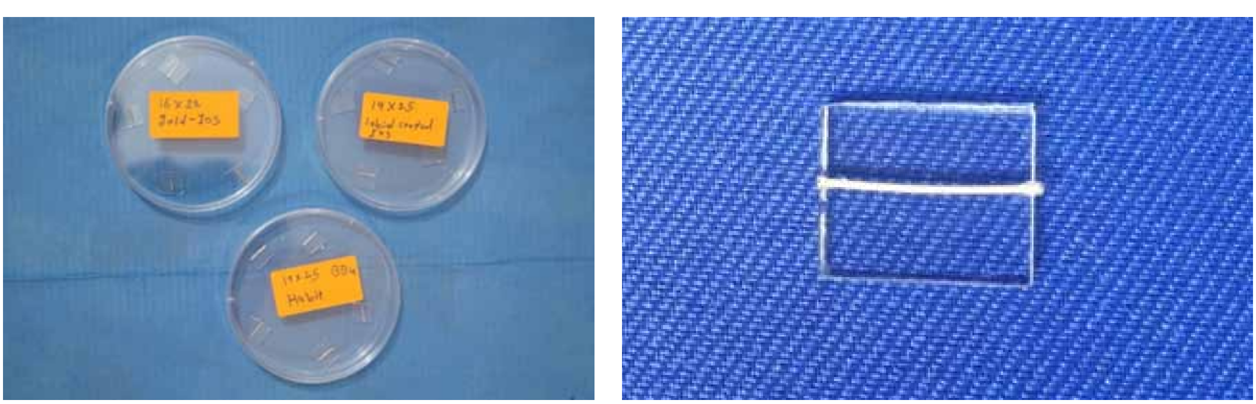
- The crosshead rate of the machine was set at 5 mm/min.
- The wire was pulled through a distance of 5 mm
- For every group of wires five bracket-block combination were used and every block was used one times to exclude any expected wearing of brackets and the wires were used only once.
- All measurements were performed under dry conditions at room temperature.

A load extension curve was displayed in the attached computer with the required static frictional forces measured in Newton unit.

AFM for analysis/Preparation of the Slides, needs to use small slides instead of regular ones. The slides were cut into small sections about (1 cm × 1 cm) after being measured with the Vernier.

Fixing the Samples After mixing epoxy steel adhesive, each wire segment was then affixed on the new slide with a very small amount of the adhesive. Subsequently, about 2.5 mm was cut from each end as it was not needed and its surface might be affected during handling [15] (Figure 4A).

Then, the samples were held in petri dishes in a specific way -using a tape- that they would not move in any direction assuring their surfaces would not be affected during carriage, samples were then rinsed with distilled water, allowed to dry in air and kept in closed petri dishes. (Figure 4 B).



A **B**

Figure 4: (A) Fixing the Samples on slides and (B) Preparation of the Samples held in petri dishes.

Throughout all the experiment, the wire segments were handled carefully to prevent any scratch to their surfaces.

Tapping mode was used to analyze the surface topography of the test wires under ambient conditions(16). For each specimen, three areas on the archwire had been scanned with a scanning area of 25 µm ×25 µm: one in the center of the wire, one 2 mm left, and one 2 mm right to obtain more ideal results. However, for labial coated wires, wires were scanned three times on each of the surfaces (lingual uncoated, labial coated, and lateral surfaces). However, it became clear that the lateral surfaces represented an inconsistent mix of coated and uncoated surfaces and therefore was excluded from analysis.(19)

The mean value on each specimen was used. Two numerical values were determined in each scan: Ra (roughness average) and Ry (maximum peak-to-valley roughness height), to elucidate its surface roughness (13).

Each specimen was fixed to a piezo scanner with three translatory degrees of freedom. Subsequently, the 3D view of archwire was shown on the monitor of the attached computer representing the surface of the specimen. Using proprietary software supplied with the AFM, the images were processed(20).

Load deflection test: A computerized Instron H50KT Tinius Olsen testing machine (England) with a10 N load cell was used for the experiments in the ministy of science and technology where it was poroperly maintained and calibrated prior to testing. the machine consists of upper and lower jaws; the fulcrum was attached to the lower jaw while the intender was screwed to the upper movable part of the machine the lower jaw is considered as the base for the custom made block with dimensions of 40mm×15mm×9mm which have two fixed fulcrums (0.1mm thickness) on which the wire is placed (Figure 5).

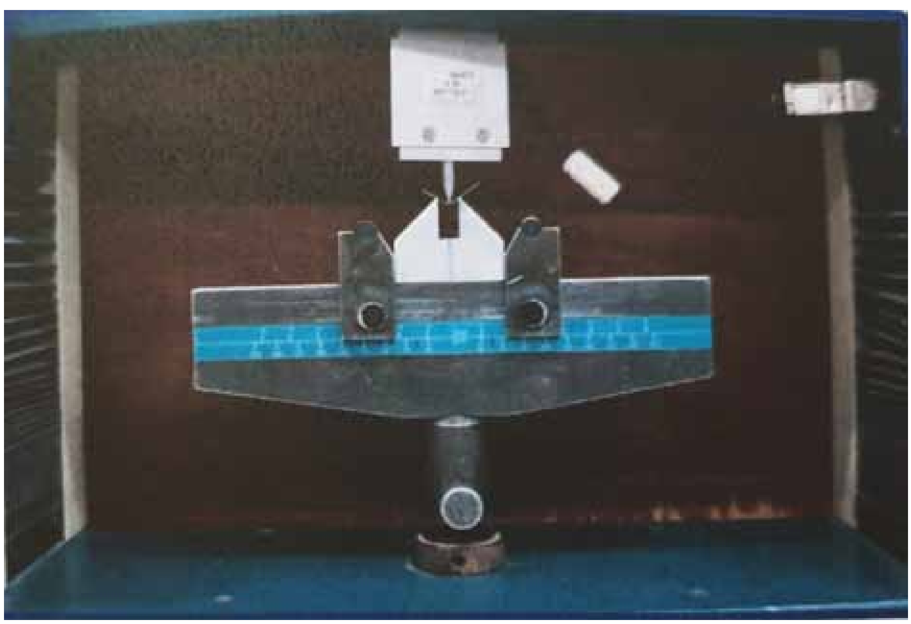


Figure 5: Wire segment within the machine

Every wire segment was fixed onto the fulcrum with the help of the marked points .then by a computer-controlled stepper motor loading was achieved through movement of a metal loading device (intender) adapted on the machine downward to the center of the wire and fulcrum to start bending test till a permanent deflection of a minimum of 2 mm was reached the resultant curve represented the force loading curve(9).

Results

Table 1 revealed the mean values of static frictional forces for both sizes 0.016''×0.022'' and 0.019''×0.025''arch wires.

ANOVA test for both wire dimensions showed a statically significant result on 0.016''×0.022'' size and highly significant difference on 0.019”x0.025” sizes.

For(0.016''×0.022'') friction was higher for the control, epoxy coated wires in a descending order Table 2.

However, for (0.019''×0.025'') the epoxy wire showed significantly larger friction than the uncoated wires, then control and gold wires in descending order

Turkey's test performed for comparison between each two types of arch wires.

For (0.016×0.022) there was no significant difference between control wire and gold wire and between gold and epoxy wires at P<0.05 .and there was no significant difference between the others. while for (0.019×0.025)there was a highly significant differences between control wire and gold and between gold and epoxy wires at P<0.01 and no significant difference between the others.

Table 1: Descriptive statistics and ANOVA tests for the static friction of 0.016''×0.022''and 0.019''×0.025'' arch wires.

Wires	0.016''×0.022''							0.019''×0.025''					
	Descriptive statistics					Comparison		Descriptive statistics				Comparison	
	N	Mean	SD	Min	Max	f-test	p-value	Mean	SD	Min	Max	f-test	p-value
Control (uncoated)	5	4.2080	.28517	3.80	4.50	8.409	.005	5.6580	.29175	5.35	6.13	15.044	.001
Orthotechnology (gold plated)	5	3.2560	.37826	2.76	3.70			4.1780	.50504	3.40	4.79		
USOP (Epoxy coated)	5	4.0360	48449	3.25	4.40			5.8700	.71207	5.06	6.67		

Table 2- revealed the mean values of (Ra) for both arch wires dimensions. The (Ra) value for both wire dimension for the all wires was higher than the control wires However, for gold wires on both wire dimensions the coated surface was higher on average roughness than epoxy wires and lastly the control wires in descending order.

Tukey test was performed for comparison, for 0.016''×0.022'' there was no significant differences between all types of wires while; for 0.019''×0.025'' they showed highly significant difference between all types of wires at P<0.01.

Table 2: Descriptive statistics and ANOVA tests, average roughness (Ra) for 0.016"x0.022" and 0.019"x0.025" arch wires.(Ra In ηm)

Wires	0.016''×0.022''							0.019''×0.025''					
	Descriptive statistics					Comparison		Descriptive statistics				Comparison	
	N	Mean	SD	Min	Max	f-test	p-value	Mean	SD	Min	Max	f-test	p-value
Control (uncoated)	5	29.9567	26.15428	10.24	59.63	4.347	.069	11.6047	3.25341	8.95	15.23	292.943	.000
Orthotechnology (gold plated)	5	67.6647	7.41303	59.63	74.23			71.5530	3.28951	68.90	75.23		
USOP (Epoxy coated)	5	34.4833	11.77853	20.90	41.90			35.0980	2.57439	32.50	37.65		

Table -3- showed the mean, standard deviation and ANOVA test results for the load force of 0.016×0.022 and 0.019×0.025 inch arch wires.

For 0.016×0.022 wires the highest loading value represented by epoxy coated wire then control then gold then control wire in descending order.

For 0.019×0.025 inch wires, the highest loading values represented by gold wire then control then epoxy coated wire in descending order.

ANOVA test showed a highly significant difference on both wire dimensions.

Tukey's test between three wires showed: For (0.016×0.022) wires, there was significant different between control and gold wires at P<0.05 and there was highly significant difference between control wires and epoxy coated wire at p<0.01.

Table 3: Descriptive statistics and ANOVA tests, loading force for 0.016"x0.022" and 0.019"x0.025" arch wires.(in N)

Wires	0.016''×0.022''							0.019''×0.025''					
	Descriptive statistics					Comparison		Descriptive statistics				Comparison	
	N	Mean	SD	Min	Max	f-test	p-value	Mean	SD	Min	Max	f-test	p-value
Control (uncoated)	5	3.6667	.26502	3.37	3.88	13.997	.005	6.2000	.44238	5.92	6.71	29.942	.001
Orthotechnology (gold plated)	5	2.8567	.40673	2.43	3.24			6.7533	51598	6.17	7.15		
USOP (Epoxy coated)	5	2.4267	.13868	2.31	2.58			3.6133	.61849	3.10	4.30		

Discussion

The present study showed that the static friction was generally greater on the 0.019''×0.025'' dimension rather than 0.016''×0.022'' dimension to the same type of wires and this indicate that static frictional forces were increased with larger wire dimension of all coated and uncoated arch wires, this agreed with many studies(19).

The maximum static frictional forces of the coated wires were lesser to or higher than those of the uncoated wires (control), and there was a variation in the degree of change related to multiple factors such as arch wire dimension, type and thickness of coating, hardness, surface roughness, and modulus of elasticity as it is reported by many studies(3,18).

These results come in agreement with some studies who concluded that friction of the coated wires is affected by the total cross section and inner core dimension and not by surface roughness and suggest that the high elastic modulus of wires may increase the wire binding at the edges of the bracket(18).

There was a significant difference between all types of the tested archwires and the surface roughness of the coated wires in the present study was higher in compared with their uncoated conventional control nickel titanium counterpart, which is consistent with the previous studies(18,19, 22).

For gold wire,this study showed increase in surface roughness due to ion implantation was confirmed by a many previous studies(22).

On the other hand; the ion implanted wires had highest average roughness than control and less frictional force than control wires,

According to current investigation the results revealed no correlation between surface roughness and friction illustrates this lack of relationship between surface roughness and friction with a wide scatter of data and no discernible pattern, and friction of the coated wires was influenced by the total cross-sectional and inner core dimensions, inner core nano hardness, inner core elastic modulus, and elastic modulus, but not by surface roughness. As revealed by many studies(18, 19).

Concerning the load deflection behavior, most of aesthetic coated archwires for both wire dimensions 0.016×0.022 and 0.019×0.025 inch delivered statistically significant lower loading forces than uncoated wires of some dimensions for both wire dimension and these result came on agreement with most previous studies(13,14,4).

On the other hand among the ion implanted wires, the gold wire showed about the same loading force level to the control wire while in (0.016×0.022)wire the epoxy coated wires showed loading force lower than control wire and this and this may be due to manufacturing process and our in investigation was disagreed with Katic V et al.(21).

Conclusion

- Ion implanted arch wires (gold) plated had lower frictional forces than both coated and control (uncoated) arch wires.

- Surface roughness of coated arch wires was higher than non-coated wires.
- It appeared that frictional forces does not correlated with the surface roughness.

Declarations: Conflict of Interest the authors declare that there are no potential conflicts of interest related to the study.

Source of Funding: Nil

Ethical Clearance: This research has exemption as it a routine treatment (no new materials were used).

References

1. Huang ZM, Gopal R, Fujihara K, Ramakrishna S, Loh PL, Foong WC, Ganesh VK, Chew CL. Fabrication of a new composite orthodontic archwire and validation by a bridging micromechanics model. Biomaterials. 2003 Aug 1;24(17):2941-53.
2. Washington, Bradford, et al. "Contemporary esthetic nickel-titanium wires: do they deliver the same forces?" The Angle Orthodontist, Vol. 85, No. 1, 2014, pp. 95-101.
3. Choi S, Park DJ, Kim KA, Park KH, Park HK, Park YG. In vitro sliding-driven morphological changes in representative esthetic NiTi archwire surfaces. Microscopy research and technique. 2015 Oct;78(10):926-34.
4. Elayyan F, Silikas N, Bearn D. Mechanical properties of coated superelastic archwires in conventional and self-ligating orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics. 2010 Feb 1;137(2):213-7.
5. Kusy, R.P., 2005. Influence of force systems on archwire-bracket combinations. American journal of orthodontics and dentofacial orthopedics, 127(3), pp.333-342.
6. Braga LC, Vedovello Filho M, Kuramae M, Valdrighi HC, Vedovello SA, Correr AB. Friction force on brackets generated by stainless steel wire and superelastic wires with and without IonGuard. Dental Press Journal of Orthodontics. 2011 Aug;16(4):41-e1.
7. Vande Berg, James R. Effects of ligation on orthodontic friction with first-order misalignments. Diss. Saint Louis University, 2008.
8. Rudge P, Sherriff M, Bister D. A comparison of roughness parameters and friction coefficients of aesthetic archwires. European journal of orthodontics. 2015 Feb 1;37(1):49-55.
9. Hossein A.,etal. "Comparison of load-deflection characteristic of aesthetic and conventional super elastic niti orthodontic arch wire." J Clin Diagn Res,10(12),ZC06-ZC09
10. Farronato G, Maijer R, Carìa MP, Esposito L, Alberzoni D, Cacciatore G. The effect of Teflon coating on the resistance to sliding of orthodontic archwires. The European Journal of Orthodontics. 2012 Aug 1;34(4):410-7.
11. Kusy RP, Whitley JQ. Friction between different wire-bracketconfigurations and materials. InSeminars in orthodontics 1997 Sep 1 (Vol. 3, No. 3, pp. 166-177). WB Saunders.
12. Mendes K, Rossouw PE. Friction: validation of manufacturer's claim. InSeminars in orthodontics 2003 Dec 1 (Vol. 9, No. 4, pp. 236-250). WB Saunders.
13. Kaphoor AA, Sundareswaran S. Aesthetic nickel titanium wires—how much do they deliver?. The European Journal of Orthodontics. 2012 Oct 1;34(5):603-9.
14. Garro-Piña H, Jiménez-Cervantes MC, Ondarza-Rovira R, Justus R, García-López S. Evaluation of the Loading, Unloading, and Permanent Deformation of Newly Available Epoxy Resin Coated Ni-Ti Wires Using Self-Ligating Brackets. International journal of dentistry. 2017 May 23;2017.
15. Da Silva DL, Mattos CT, Sant'Anna EF, de Oliveira Ruellas AC, Elias CN. Cross-section dimensions and mechanical properties of esthetic orthodontic coated archwires. American Journal of Orthodontics and Dentofacial Orthopedics. 2013 Apr 1;143(4):S85-91.
16. JABER LC, Rodrigues JA, AMARAL FL, FRANÇA FM, Basting RT, Turssi CP. Degradation of orthodontic wires under simulated cariogenic and erosive conditions. Brazilian oral research. 2014;28(1):1-6.
17. Husain N, Kumar A. Frictional resistance between orthodontic brackets and archwire: an in vitro study. J Contemp Dent Pract. 2011 Mar 1;12(2):91-99.
18. Muguruma T, Iijima M, Yuasa T, Kawaguchi K, Mizoguchi I. Characterization of the coatings covering esthetic orthodontic archwires and their influence on the bending and frictional properties.

The Angle Orthodontist. 2017 Jul;87(4):610-7.

19. Rudge P, Sherriff M, Bister D. A comparison of roughness parameters and friction coefficients of aesthetic archwires. European journal of orthodontics. 2015 Feb 1;37(1):49-55.
20. Iijima M, Muguruma T, Brantley W, Choe HC, Nakagaki S, Alapati SB, Mizoguchi I. Effect of coating on properties of esthetic orthodontic nickel-titanium wires. The Angle Orthodontist. 2012 Mar;82(2):319-25.
21. Katić J, Metikoš-Huković M. Correlation between electronic and corrosion properties of the passive oxide film on nitinol. Acta chimica Slovenica. 2014 Jun 1;61(2).
22. Kim IH, Park HS, Kim YK, Kim KH, Kwon TY. Comparative short-term in vitro analysis of mutans streptococci adhesion on esthetic, nickel-titanium, and stainless-steel arch wires. Angle Orthodontist. 2014 Jul;84(4):680-6.