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The Effect of Acidulated Phosphate Fluoride on the Loading Force of Gold Plated Arch Wires: An *In vitro* Study

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ABSTRACT

Background: *Orthodontic treatment may have deleterious effects on the teeth structures. So, patients are advised for regular usage of prophylactic mouthwashes in order to prevent dental caries or periodontal diseases.* ***Aim:*** *The aim of this study was to assess and correlate the effects of acidulated phosphate fluoride on the load deflection of conventional, gold-plated nickel titanium and stainless steel arch wires.* ***Materials and methods:*** *Total 80 pieces of 0.016 inches round arch wires were received from IOS Company, USA, 40 sections from each type of arch wires. These pieces were divided into 8 groups with 10 cut pieces for each group, half of the groups were examined in wet conditions after being immersed with acidulated phosphate fluoride at temperature about 37°C for approximately 60 minutes, and the other half were tested in dry conditions. By using the Instron universal testing machine, a 3-point bending test was achieved, each specimen were loaded and examined with 0.5 mm, 1.0 mm, 1.5 mm, and 2.0 mm of deflection. ANOVA and post-hoc Tukey's test were used for the data analysis.* ***Results:*** *The loading forces of the conventional nickel titanium and stainless steel archwires were significantly reduced after immersion in acidulated phosphate fluoride. Gold-plated nickel titanium and stainless steel archwires have been distinguished of not being long-lasting and, as a result, have a trend to deteriorate or rub off leaving the nickel titanium or stainless steel core exposed.* ***Conclusion:*** *Conventional nickel-titanium and stainless steel archwires can be damaged with the use of acidulated phosphate fluoride; while the gold layer was rubbed off from the gold-plated archwires. Hence, the patient and the dentist should carefully use the fluoride-containing products.*

Keywords: Load deflection, Fluoride, Gold-plated archwires

INTRODUCTION

Various modern aesthetic archwires have been offered continuously into clinical application, and there have been few published research about the features of coated nickel titanium and stainless steel wires [1]. One of these arch wires is a gold-plated arch wire for the purpose of reducing roughness and porosity of the surface and increasing esthetic [2].

Through the orthodontic treatments that continue for several months, many of microorganisms stick around the orthodontic appliance [3]. That needs the use of oral hygiene care and prophylactic agents to prevent dental and periodontal disease [4]. One of these prophylactic agents is fluoride that has been used to prevent demineralization and enhance remineralization of teeth. However, fluoride ions have the ability to cause degradation of mechanical qualities of orthodontic arch wires and corrosion and that leads to a decrease in suitable orthodontic force during treatment and affect the straightening of malposed teeth [5].

This *in vitro* study aims to evaluate the effects of exposure to acidulated phosphate fluoride on the load deflection of gold-plated and conventional nickel titanium and stainless steel arch wires.

PATIENTS AND METHODS

The samples of the study involved 0.016 inches upper round preformed arch wires from IOS® company (International Orthodontic Services, Stafford, USA), they were gold-plated nickel-titanium and stainless-steel (Royal Wires)™ with conventional nickel-titanium and stainless-steel (The Ultimate Wire)™. The immersion media was acidulated phosphate fluoride solution (1.23%, Colgate Oral Pharmaceutical, New York, U.S.A.) which consisted of phosphoric acid, hydrofluoric acid and sodium fluoride 225 ppm, and pH=4.2. The samples involved 80 cut pieces of 3 cm length

gained by cutting the straight distal posterior portion of preformed upper round arch wire using a cutter (Figures 1 and 2) [6,7].

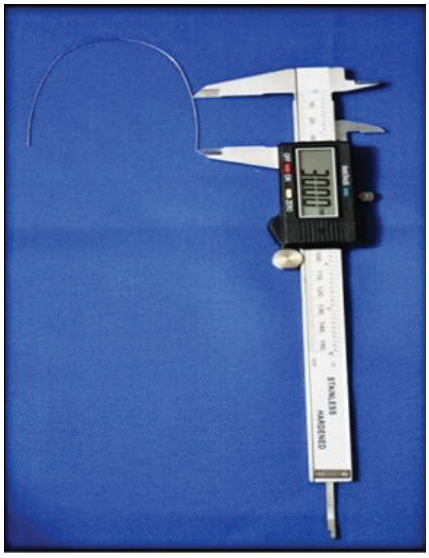

Figure 1 Measuring the sample length

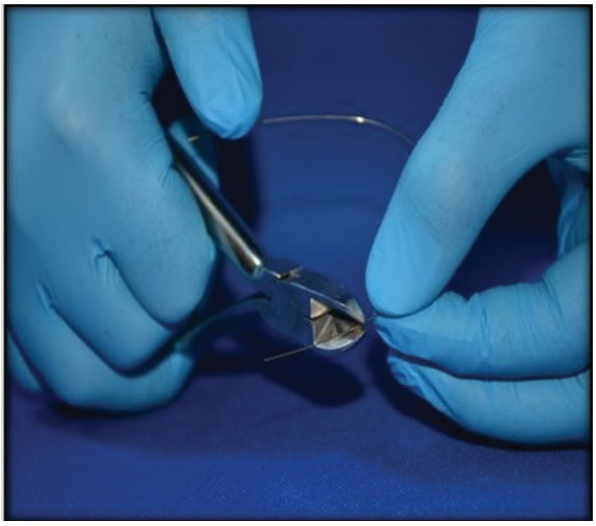

Figure 2 Cutting the sample

They were divided into 8 groups, each group consisting of 10 cut pieces of archwires. Half of them were examined in a dry condition while another half was tested in wet condition with acidulated sodium fluoride. The samples tested in wet conditions were placed in a plastic container with a capacity of 10 ml with about 5 ml of acidulated phosphate fluoride solution with an incubator at 37°C for approximately 60 minutes which was equal to 2-month (60 minutes=1 minutes per day topical fluoride solution application for 2-months) [5,8,9]. Then the samples were withdrawn from the test media and washed with normal saline and placed in a new, clean, and individually labeled plastic tube before mechanical testing [5].

The 3-point bending test was taken out to test the load-deflection properties of the selected archwires. It has been done by using the Instron universal testing machine, the cut piece of wire was located at the center of the stainless steel block and it was deflected at its midpoint to 2 mm deflection which is presented in Figure 3. Deflection was measured with a computer attached to the machine. For statistical analyses, ANOVA and HSD tests were used.

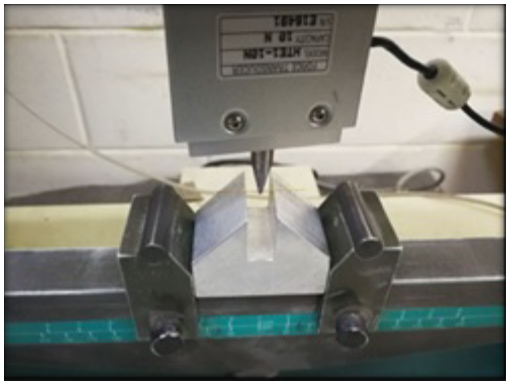

Figure 3 Gold arch wire segment within the machine

RESULTS

Table 1 showed the mean and standard deviation and the effects of APF on the load deflection of conventional nickel-titanium and stainless steel wires.

Table 1 Descriptive statistics of the load deflection and effect of fluoride on the conventional NiTi and stainless wires

Wire Type	Deflection (mm.)	Descriptive Statistics				Comparison (d.f.=18)	
		Dry		Wet			
		Mean	S.D.	Mean	S.D.	t-test	p-value
NiTi	0.5	122.361	12.019	31.957	9.709	18.503	0.000
	1.0	205.978	12.764	121.100	8.346	17.600	0.000
	1.5	231.573	9.716	182.110	5.339	14.109	0.000
	2.0	259.002	8.928	207.020	10.358	12.021	0.000
SS	0.5	241.120	15.682	226.938	15.719	2.020	0.059
	1.0	423.179	8.666	411.961	4.856	3.571	0.002
	1.5	577.548	10.745	529.071	18.829	7.071	0.000
	2.0	753.196	15.807	725.698	13.384	4.198	0.001

Both conventional nickel-titanium stainless steel wire, there was a gradual increase of loading force as the deflection increased. However, there was a significant decrease in the loading force after immersion in APF in all deflections (0.5 mm, 1 mm, 1.5 mm, 2 mm) for conventional nickel-titanium wire. While conventional stainless steel arch wires, the fluoride has reduced the load deflection significantly in all deflection except for 0.5 mm that showed a non-significant difference (Figure 4).

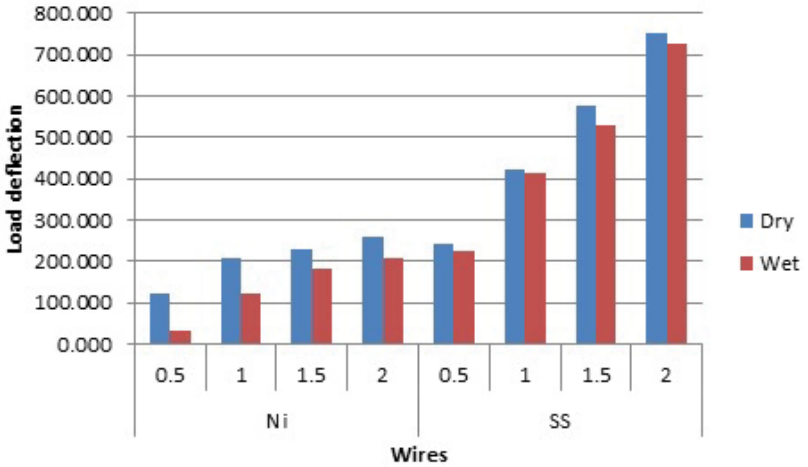

Figure 4 Loading force of conventional NiTi and S.S archwires at all deflections in dry and wet conditions

Table 2 showed the load deflection of gold plated nickel-titanium and stainless steel wires. There was a significant reduction in load deflection of gold plated nickel titanium wire after immersion in the acidulated fluoride solution for all deflections (0.5 mm, 1 mm, 1.5 mm, 2 mm).

Table 2 Descriptive statistics of the load deflection and effect of fluoride on the gold plated NiTi and stainless wires

Wire Type	Deflection (mm.)	Descriptive Statistics				Comparison (d.f.=18)	
		Dry		Wet			
		Mean	S.D.	Mean	S.D.	t-test	p-value
NiTi	0.5	126.134	5.608	83.206	6.918	15.243	0.000
	1.0	220.969	10.420	174.955	11.196	9.514	0.000
	1.5	249.519	9.043	233.410	13.845	3.081	0.006
	2.0	262.571	8.749	240.683	12.472	4.543	0.000
SS	0.5	305.184	7.029	270.221	15.392	6.534	0.000
	1.0	422.669	7.770	418.08	6.800	1.405	0.177
	1.5	651.142	15.985	634.509	15.537	2.360	0.030
	2.0	888.414	14.977	817.063	16.470	10.136	0.000

Basically, load deflection of gold plated stainless steel wire showed a highly significant effect after immersion in the acidulated fluoride solution by reducing the loading force in 0.5 mm, 1.5 mm and 2 mm deflections while it did not affect it in 1 mm (Figure 5).

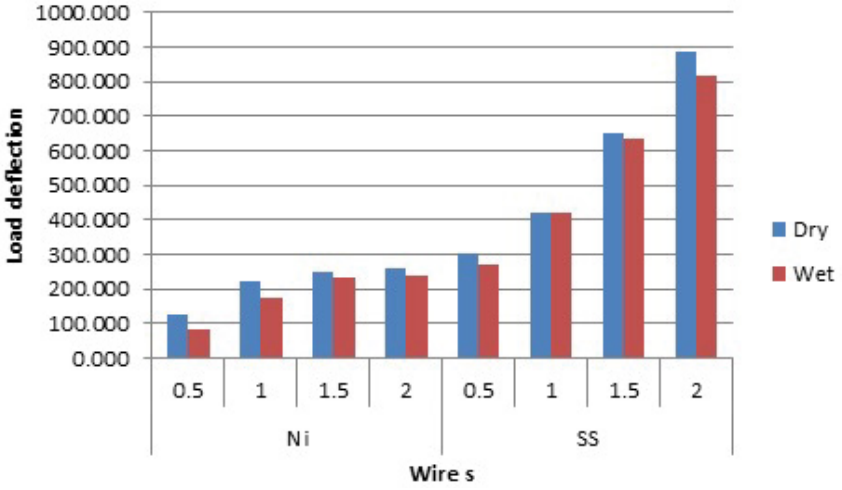

Figure 5 Loading force of gold-plated NiTi and S.S archwires at all deflections in dry and wet conditions

DISCUSSION

Conventional Nickel-Titanium Archwires

A significant reduction in load deflection of nickel-titanium wire was recorded after immersion in APF; it seems that fluoride in the acidic environment can dissolve the oxide layer founded on the surface of nickel-titanium wire, so it leaves the underlying alloy core exposed to corrosion and reduction in mechanical properties which can occur as described by Yokoyama, et al., [10].

Alkhatieeb, et al., and Al-Joubori used acidulated phosphate fluoride at the same concentration of this study and reached to a significant decrease in mechanical features of conventional nickel-titanium wires that confirm the finding of this study [11,12]. In an acidic environment, fluoride causes the corrosion rate to be increased and that agrees with Kaneko, et al., and House, et al., who stated that titanium-based archwires have elevated corrosion rate in an acidic environment; that cause further reduction of mechanical properties of nickel-titanium archwire [8,13].

The finding of the current study disagrees with Srivastava, et al., who declare that load deflection of archwire was not affected by APF solution (Phosflur mouth rinse), and mechanical properties of nickel-titanium wire were not affected [14].

Conventional Stainless Steel Archwires

The loading force of S.S archwires has declined significantly after the immersion in APF for 60 minutes. This can be attributed to the effect of APF on the coating layer of stainless steel that cause dissolution of the chromium oxide coating layer in accordance with Pulikkottil, et al., who pronounced that stainless steel archwire corrosion resistance can drastically be decreased with the presence of fluoride since the chromium oxide layer reacts with fluoride [15].

Furthermore, Castro, et al., who affirmed that the fluoride ion is a destructive one which means it has the ability to degrade the protective chromium oxide layer formed on a stainless steel wire surface [16]. As a consequence of the complex production of metal-fluoride units on the surface of the wire, the protective oxide layer is consequently weakened; as a result, the effects of decreased pH and presence of fluoride on SS archwires might have a negative impact by the prolongation of orthodontic treatment time.

The results of the current study are in contrast to the finding with Srivastava, et al., who describe that Phosflur mouth rinse has no effect on mechanical properties and load deflection of stainless steel wires [14].

Gold-Plated Nickel-Titanium and Stainless Steel Archwires

Basically, gold-plated archwires consist of nickel-titanium or stainless steel archwires plated with 24 karats gold. In the literature, there was no article or study about the effect of fluoride on the loading force of gold-plated archwires or any study that examine this effect. However, the only difference between the gold-plated and conventional archwire is the coating layer of gold about 0.2 μm to 0.5 μm in thickness with the same core material [17].

In the current study, load-deflection of both types of gold-plated archwire (nickel-titanium and stainless steel arch wires) has been significantly declined, which shows that acidulated phosphate fluoride affects the load deflection of latter archwires but the effect is less than that of the conventional archwires. It may be related to the protecting effect of coating gold layer on the wire surface that minimized the effect of fluoride in comparison with the conventional one.

CONCLUSION

According to the result of this study, there was a significant decrease in the loading force of conventional nickel-titanium and stainless steel archwires after applying acidulated phosphate fluoride. This has clinically significant features since a decrease in the forces could cause an elongation of orthodontic tooth movement which needed time. While gold-plated NiTi and S.S. archwires should be used with caution in the presence of APF because this solution had the ability to deteriorate the coating layer and cause a reduction in the loading force of these archwires.

The APF containing products should be used with caution to minimize the damage and deterioration of the archwires particularly if the same archwire is being used for a long period of time that is more than 2-months inside the oral cavity.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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