Effect of Different Fluoride Agents on the Load Deflection Characteristics of Heat Activated Nickel Titanium Arch Wires (An *in Vitro* Study)

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ABSTRACT

Background: Hydrogen absorption and related degradation in the mechanical properties of Ni-Ti based orthodontic wires has been demonstrated following exposure to fluoride prophylactic agents. This study was designed to investigate the effects of three fluoride containing agents on the load deflection characteristics of heat activated nickel titanium arch wires during unloading phase.

Material and method: Eighty specimens of heat activated nickel titanium arch wires were obtained from Ortho Technology Company, half of which had a 0.016 inch round and 0.019x0.025 rectangular. Ten specimens from both wire size were immersed in one of the tested fluoride prophylactic agents (neutral sodium fluoride gel, stannous fluoride gel or phos-flur mouth rinse) or in the controlled medium “normal saline”, and incubated at 37˚C for sixty minutes.

A Wp 300 universal material testing machine was modified and used to perform a three point bending test in a water path at 37˚C ±1˚C.The statistical difference between the different agents were analyzed using ANOVA and LSD tests.

Results: The unloading forces at 0.5, 1.0, and 1.5 mm where significantly reduced especially in neutral sodium fluoride treated specimens.

Conclusion: Based on the results founded in th study it might be preferred to use prophylactic agent with the least fluoride ions concentration.It can be concluded that the tested agents have only a limited effect on the load deflection behavior of the heat activated Ni-Ti wires, in a way that they do not have a clinically significant effect on the mechanical behavior of these wires.

Key words: Fluorides, load-deflection, Heat activated Ni-Ti wires.**(J Bagh Coll Dentistry 2017; 29(1):160-164)**

INTRODUCTION

Orthodontic wires made from titanium alloys provide light continuous force with large amount of activation for long periods. This makes them extremely useful as initial or intermediate wires between the first alignment and finishing stages of treatment[1].

Heat-activated nickel titanium wires have been gaining popularity in the orthodontic practice during the last decade. These so called third generation wires have been marketed with clinically useful shape memory property which is the capability of Ni-Ti wires to be plastically deformed in their martensitic phase**,** in addition to the low stiffness, high spring back and super elasticity [1,2].

Fluoride prophylactic agent, such as acidulated phosphate fluoride (APF), have been used extensively to prevent demineralization or do re-mineralization of white spot lesionsaround orthodontic brackets and bands; however, the fluoride ions in the prophylactic agents have been reported to cause corrosion and discoloration of titanium and its alloys [3]. Degradation in the mechanical properties lead to a reduction in appropriate orthodontic force, thereby causing delayed straightening of irregular teeth[4].

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This is an *in vitro* study is to evaluate the effect of three different fluoride agentson the load deflection of heat- activated nickel titanium arch wires.

MATERIALS AND METHODS

The samples comprised eighty pieces of 4cm length obtained by cutting the straight, posterior portion of preformed upper heat-activated nickel titanium arch wire using a cutter.Forty pieces were 0.016" and forty pieces were0.019x0.025" (Ortho Technology Co., CA, U.S.A.). These samples were divided into four groups, each group contains 20 pieces (10 pieces of 0.016" and 10 pieces 0.019x0.025") according to immersion medium:

1)Control medium (normal saline 0.9% w/v pH=7).

2)0.4% Stannous fluoride gel (Dental Technologies alpha-dent, Lincolnwood, Illinois, U.S.A with pH=3.3)

3) 0.044%w/v Phos-flur mouth rinsed (Colgate Oral Pharmaceutical, New York, U.S.A withpH=4.2)

4) 1.1% Neutral sodium fluoride gel (DentMat Holdings, Lompoc, California, U.S.A with pH=7).

All samples were incubated at 37˚C in inert plastic tubes of 10ml capacity for sixty minutes (60 minutes=1 minutes per day topical fluoride application for two months). Then the samples were removed from their respective test media washed with normal saline and placed in a new, clean, and individually labeled plastic tubes before mechanical testing.

The three point bending test was carried out to test the load deflection characteristics of the selected arch wires. The samples were mounted into a three point bending test fixture (stainless steel jig with two barreled rods set 15 mm apart) the mid portion of the wire were loaded to 2mm deflection by rotating the hand wheel of the WP300 universal testing machine (G.U.N.T. Gerätebau GmbH, Hamburg, Germany) in clock wise direction then very gently unwind the hand wheel in counter clock direction to unload to zero deflection. For statistical analysis the unloaded forces at 1.5, 1, 0.5 mm were used since unloading phase of the wire represent the necessary forces to achieve tooth movement. To simulate aqueous oral environment the test was carried out in a water bath at 37˚C ±1˚C the temperature was controlled by using a digital thermometer.

One way analysis of variance (ANOVA) was used to examine whether any significant difference at *p<0.05*exist between the four tested groups. Further, LSD was used to compare among tested groups.

RESULTS

Table 1 showedthe means and standard deviations of forces at intervals of 0.5 mm deflection during unloading for 0.016" and 0.019x0.025" heat activated nickel titanium arch wire. F-test by ANOVA table showed that there was statistically a highly significant difference in the load defection of 0.016" and 0.019x0,025 " heat activated nickel titanium arch wires immersed in different fluoride agents during unloading at 1.5, 1.0, 0.5 mm *p <0.001*.

Table 2 showed the results of LSD after ANOVA for 0.016" and 0.019x0.025" heat activated arch wire.

The load deflection graphs for heat-activated nickel titanium arch wires after being immersed in tested agents in comparison with the control group are presented in figure (1).

Table 1: Descriptive statistics of load in (gm.) during unloading phase and groups' difference for HANT arch wires.

Arch wires dimension	Deflection (mm.)	Descriptive statistics								Media difference	
		NaCl		SnF_2		APF		NF			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	F-test	*p*-value
0.016"	1.5	64.25	1.42	61.9	1.20	60.15	2.87	58.1	4.05	9.728	0.000
	1	47.5	1.18	43.4	2.84	43.5	2.17	41.5	3.24	10.333	0.000
	0.5	40.1	2.16	38.35	2.22	38.6	1.43	36.35	3.38	4.123	0.013
0.019x 0.025"	1.5	174	3.64	173.20	6.72	171.60	8.60	158.10	2.95	16.015	0.000
	1	113.20	4.26	113.60	6.88	111.10	9.90	97.20	3.88	13.579	0.000
	0.5	106.65	6.05	108.95	5.44	107.70	10.03	91.55	6.58	12.684	0.000

Table 2: LSD after ANOVA for 0.016" and 0.019x0.025"heat activated arch wire

Deflection (mm.)	0.016"				0.019x0.025"	
	Groups		Mean Difference	*p*-value	Mean Difference	*p*-value
1.5	NaCl	SnF_2	2.35	0.055 (NS)	0.80	0.764 (NS)
		APF	4.1	0.001 (HS)	2.40	0.370(NS)
		NF	6.15	0.000 (HS)	15.90	0.000 (HS)
	SnF_2	APF	1.75	0.148 (NS)	1.60	0.549 (NS)
		NF	3.8	0.003 (HS)	15.10	0.000 (HS)
	APF	NF	2.05	0.092 (NS)	13.50	0.000 (HS)
1	NaCl	SnF_2	4.1	0.001 (HS)	-0.40	0.894 (NS)
		APF	4	0.001 (HS)	2.10	0.487 (NS)
		NF	6	0.000 (HS)	16.00	0.000 (HS)
	SnF_2	APF	-0.1	0.929 (NS)	2.50	0.409 (NS)
		NF	1.9	0.096 (NS)	16.40	0.000 (HS)
	APF	NF	2	0.080 (NS)	13.90	0.000 (HS)
0.5	NaCl	SnF_2	1.75	0.112 (NS)	-2.30	0.483 (NS)
		APF	1.5	0.171 (NS)	-1.05	0.748 (NS)
		NF	3.75	0.001 (HS)	15.10	0.000 (HS)
	SnF_2	APF	-0.25	0.817 (NS)	1.25	0.702 (NS)
		NF	2	0.071 (NS)	17.40	0.000 (HS)
	APF	NF	2.25	0.043 (HS)	16.15	0.000 (HS)

NS:*p>0.05* (Not significant) S: *p<0.05* (Significant) HS: *p<0.001* (Highly significant).

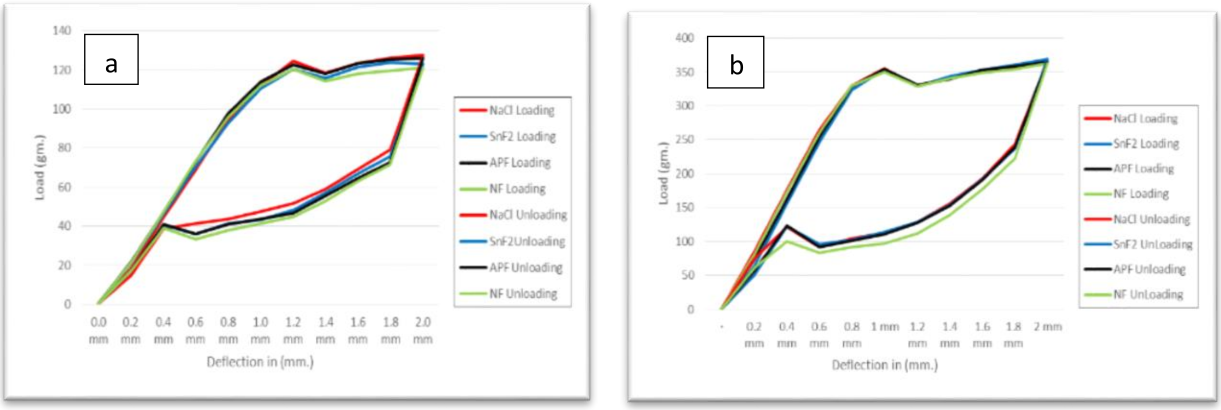

Figure 1: Load deflection curve for a) 0.016 ", b) 0.019x0.025" HANT arch wires.

DISCUSSION

Within one millisecond exposure to air, titanium-based alloys form a nanometer thickness layer of titanium oxide"10-20nm", in a process called passivation [5,6]. However, this protective layer may be degraded following exposure to fluoride prophylactic agents. Topical fluoride agents have been reported to cause corrosion of titanium based arch wires [4,5,7-10].It should be understood that the fluoride related effect depends on concentration of fluoride ions in the agent being used, the pH level of the agent, the duration of immersion, and the wires manufacturing characteristics [11].

In the current study,the three point bending test is conducted. It is a standardized testing method useful for purely theoretical evaluations, offers a high level of reproducibility and allows comparison with other studies [12-14].The beam tests was carried out using a jig machined from stainless steelwith two barreled rods that set 15 mm apart to simulate a typical interbracket span [15].

In the currrent study, a commercially available heat activated nickel-titanium archwires were tested with two cross sections 0.016" and 0.019x0.025". These arch wire gauges were selected because of their clinical popularity foraligning andlevelingphase to generate low force levels due to material properties which was adopted by the MBT method [16].Wire deflections of 2mm and then the unloading forces at 0.5mm interval were selected because of its possible occurrence under clinical conditions[2].

In the current study, the fluoride agents that were used differ in their fluoride ion concentration and pH value and according to manufacturer instructions they usedfor one minute per day topical application. The NaCl were used as a control medium because Ni-Ti based arch wires has high corrosion resistance in NaCl solution [17]. NaCl has adopted as a control medium by previous studies [18,19].

The results of the current study are in agreement withother findings [23-25].

Sabane*et al.*[23] and Koushik*et al.*[24]foundsignificant reduction in unloading mechanical properties of Ni-Ti and Cu Ni-Ti following exposure to fluoride agents after ninety minutes immersion time.

Ahrari*et al.* [25]found significant reduction in the unloading forces at lower deflection following immersion of Ni-Ti and Cu Ni-Ti in 0.2% Sodium fluoride solution for 24 hour.

The results of the current study are in contrast to the finding by others[4,20-22].Walker *et al.*[4]reported that the application of acidic and neutral fluoride treatments have no significant effect on Cu Ni-Ti (copper Ni-Ti that show a thermal properties) mechanical properties compared with distilled-water control treatment, but a reduction in the unloading mechanical properties of Ni-Ti wires was observed. It was assumed that the copper component in the Cu Ni-Ti archwires partially inhibit the activity of hydrofluoric acid; therefore, prevent fluoride related degradation in the mechanical properties of Cu Ni-Ti wires. Walker and his coworkers have noticed surface corrosion in Ni-Ti and Cu Ni-Ti arch wires in their study.

Ramalingam*et al.*[22]reported that the mechanical properties of Cu Ni-Ti archwires retrieved from patients who used a fluoride gel and phos-flur rinse for 30 days were not affected by fluoride agents but Ni-Ti wires had a reduction in the unloading force especially in gel group.

Schiff *et al.*[20,21]indicated that Ni-Ti wires were more susceptible to corrosion than Cu Ni-Ti wires.

In the current study, it seems that the fluoride related hydrogen embrittlement of titanium based alloysaffecting the wire unloading –related phase shift(4,10,26). Hydrogen absorption and subsequent diffusion through the interstitial sites, dislocations, and grain boundaries reacting with lattice atoms forming titanium hydride which form a body centered tetragonal structure could interfere with the lattice's ability to undergo the unloading phase shift from the martensitic form to the austenitic form. This might be considered to be the cause of related degradation of mechanical properties of the alloy (4,24,27).This phenomenon might account for statistically significant differences in the unloading properties of the wires.

In rectangular wires the load deflection mean during unloading was significantly reduced in all selected deflection points in NF gel group which has the highest concentration of fluoride among the test groups. The same condition was noticed in the round arch wires, NF gel caused reduction in the unloading forces at all deflection points. It also noticed that the SnF_2gel and APF rinse influenced on the round wires more than the rectangular wires. This could be attributed to the fact that 'the absorbed hydrogen in titanium alloys diffuses from the surface inward even at room temperature, and diffusion distance depends on the coefficient of hydrogen diffusion in materials; therefore, for thinner nickel-titanium and beta titanium wires, degradation in performance caused by hydrogen absorption probably occurs for a short immersion time'(26), which is in consistent with the results of the current study.

In the current study, the reduction in the unloading forces might not be large enough to be clinically significant, since the wire was still exerting force levels within the optimal force range to produce tooth movement.The statistically significant difference occurred only after 60 minutes of fluoride exposure.In clinical situation, the real exposure time may be longer than 60 minutes because the patients are usually instructed to apply the fluoride agent before bed time and not to rinse their mouths, eat or drink for at least thirty minutes thereafter. Also, the orthodontic arch wire could be kept in mouth for longer duration which increase the overall exposure time.In the current study, the margin of difference in the load values in fluoride agents was in-between 6gm to 16gm compared to control group. Although there was a statistically significant difference the amount of reduction, clinically, in the load was small. Therefore, using fluoride agents seems to be suitable when using heat activated nickel titanium wires especially agents with lower concentration of fluoride ion such as phos-flur rinse and stannous fluoride gel agents.

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الخلاصة

مقدمة:أصبح لأسلاك النيكل-تيتانيوم ذات النشاط الحراري شعبية متزايدة في ممارسة تقويم الأسنان بسبب قدرتها على إنتاج قوة مستمرة خفيفة قادرة على تحقيق إستجابة بيولوجية مرغوب بها لتحريك الأسنان، ونظرا"لأهمية المحافظة على نظافة الفم والاسنان لمرضى تقويم الأسنان،فأخصائي تقويم الأسنان يصفون مجموعة متنوعة من المنتجات الوقائية من بينها التي تحتوي على الفلورايد.

هدف البحث:هدفت هذه الدراسة إلى التحقيق في آثار ثلاثة منتجات وقائية تحتوي على الفلوريد على خصائص انحراف تحميل الأسلاك ذات النشاط الحراري أثناء مرحلة التفريغ.

المواد والطرق:ثمانين قطعة من الأسلاك الحرارية من شركة اورثوتكنولوجي ، نصفها كان بحجم 0.016 بوصة مستديرة المقطع العرضي والأخر 0.019×0.025بوصة مستطيل المقطع العرضي كانوا منغمسين في أحد منتجات الفلورايد الوقائية (فلوريد الصوديوم المتعادل جل ، و فلوريد القصدير جل أو فلوريد الفوسفات الحامضي مضمضة فموية) أو في وسط ضابط كلورايد الصوديوم "المحلول الملحي العادي" في أنابيب مختبرية، تم وضعها في حاضنة في 37 درجة مئوية لمدة ستين دقيقة. تم إختبار العينات بواسطةجهاز مختبري قائم على أساس الأنحناء النقطي الثلاثي في حوض مائي و تم قياس القوى أثناء التفريغ (التعطيل) عند مستوى الإنحناء 1.5 ملم ,1 ملم و0.5 ملم. تم تحليل الفرق الإحصائي بين عوامل مختلفة بإستخدام إختبارات LSD و ANOVA

النتائج:إحصائيا، تشير النتائج إلى أن استخدام الفلوريد يمكن أن يتسبب في إنقاص التفريغ من الأسلاك وخصوصا في مجموعة الفلورايد المتعادل.

الإستنتاج:بناءاً على النتائج التي تأسست في هذه الدراسة فاقترح استخدام عامل وقائي مع تركيز أقل لأيون فلوريد.كمايمكن الاستنتاج بأن منتجات الفلورايد لها تأثير محدود على سلوك انحراف تحميل الأسلاك الحرارية، بطريقة ليس لديهم تأثير كبير سريرياً على السلوك الميكانيكي للأسلاك، كما وجدت في هذه الدراسة.