The relation of load deflection of nickel titanium orthodontic wires and the application of different fluoride containing tooth paste (an in vitro study)

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ABSTRACT

Background: This study was designed to find the relation of load deflection of round 0.012 inch nickel titanium orthodontic wires, the application of different fluoride containing tooth paste, and the effect of immersion time in these fluoride containing tooth pastes on the load deflections of nickel titanium orthodontic wires.

Materials and method: The straight portion of preformed (arch form) round 0.012 inch nickel titanium orthodontic arch wire was cut and immersed either in one of the tested fluoride containing tooth pastes or in the controlled medium "artificial saliva", where incubated at 37°C in special incubator at 2 time intervals (60 and 90 minutes).The load deflections of the wires were measured with a specially designed test apparatus based on the mechanism of 3-point bending test.

Results: The nickel titanium arch wire after immersion in acidulated monoflurophosphate tooth paste reveals lowest load deflection among the immersion test media (tooth paste), while the immersion in neutral sodium fluoride containing tooth paste reveals intermediate load deflection, and the immersion in stannous fluoride containing tooth paste reveals highest load deflection which is closest to that in artificial saliva. F- test by ANOVA table shows that there is a highly significant difference ($P< 0.0001$) between all chemical reagents at the mean 2 time intervals for the mean load deflections of nickel titanium arch wires, and there is a significant difference at 60 minutes between all chemical reagents at $P< 0.05$, and there is a highly significant difference at 90 minutes between all chemical reagents for the mean load deflections of Ni-Ti arch wires at $P< 0.0001$. Using fluoride containing tooth paste with nickel titanium arch wire could decrease the load deflection; in addition to the fact that there is an inverse relation between the immersion time and the load deflection of nickel titanium arch wire. This may contribute to prolong orthodontic treatment.

Conclusions: The stannous fluoride containing tooth paste seems to be the best fluoride containing tooth paste because it shows no detrimental effect on the load deflection of nickel titanium arch wire. So during the long period orthodontic treatment, both patient and clinical doctor should carefully use the fluoride containing products (teeth pastes, topical prophylactic agents, etc…).

Keyword: Load deflection, nickel titanium wire, Fluoride, Toothpaste. **(J Bagh Coll Dentistry 2007; 19(1): 115-121)**.

INTRODUCTION

Ever since round 0.012 inch nickel titanium orthodontic arch wire can be engaged early in first stage of treatment with minimum pain and discomfort especially in severe cases of crowding. The uniqueness of mechanical properties of titanium alloys allows clinicians to increase their efficiency by decreasing the number of visits needed for each patient [1,2]. In addition to the high mechanical strength, titanium has favorable corrosion resistance because of its high chemical reactivity. It forms a thin, stable oxide (TiO_2) layer within very short period of exposure to air [3]. This phenomenon is called passivation. This surface oxide does not breakdown under physiological conditions [4], because it prevents further diffusion of oxygen, resulting in excellent corrosion resistance.

In addition, the corrosion resistance of titanium is lost in solutions that contain fluoride (prophylactic agents and dental rinses) [5].

Many orthodontists prescribe a daily prophylactic fluoride treatment [6], the daily use of fluoride containing tooth pastes in addition to foods and drinks such as tea containing fluoride (although in very small amount) and low pH, may cause degradation and fracture (hydrogen embrittlement) of Ni-Ti orthodontic wires, which are used under severe environmental conditions (as in oral cavity). [7] The aims of the study of this study were:

1. To find a relation of load deflection of round 0.012 inch nickel titanium orthodontic wires with the application of different fluoride containing tooth paste[immersion test media] (acidulated monoflurophosphate tooth paste, neutral sodium fluoride tooth paste and stannous fluoride tooth paste) in comparison with artificial saliva [immersion control medium].

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2. To find the effect of immersion time in these fluoride containing tooth pastes, on the load deflection of nickel titanium orthodontic wires.

MATERIALS AND METHODS

The materials used in this in vitro study could be classified into two major categories: the orthodontic materials and the materials that are used as chemical reagents.

Orthodontic materials

Round 0.012 inch (0.30mm) nickel titanium (rematitan "LITE") with dimple preformed lower orthodontic arch wires were used. Each wire specimen was cut from the straight portion of the preformed orthodontic arch wire (supplied by Dentaurum Company); the brackets are Ultratrimm 0.022x0.030 inch (0.56x0.76 mm) edgewise brackets. (Supplied by Dentaurum Company); and ligature elastics are Dentalastics-Personal, transparent (clear) in color (supplied by Dentaurum Company).

Chemical reagents

These materials that are used as test and control immersion media in the present study include:

A. Fluoride containing tooth paste, used as test media:

1. 1.14% monofluorophosphate "pH=2.8 and fluoride =1500 PPM" (Colgate-Herbal-Palmolive, Brazil).
2. 0.332% neutral sodium fluoride gel, "pH =6.7 and fluoride =1450PPM" (Colgate-Total-Palmolive,Arabia).
3. 0.4% stannous fluoride, "pH =3.2 and fluoride =970PPM"(Colgate-Gel Kam-Hamburg,Germany).

B. Artificial saliva that used as control medium: 1.44 gm/l $NaHCO_3$, 0.21gm/l $CaCl_2$ and 0.46gm/l $NaNH_2PO_4$ were diluted in 1000ml deionized water "pH=7".

Equipment and instruments

A. Equipment and instruments used for orthodontic purposes. Bracket clamping tweezers (Dentaurum,Germany);How pliers (Dentaurum, Germany); Mosquito forceps (Dentaurum, Germany); Double-ended ligature tucker (Dentaurum, Germany); Side cutter (Dentaurum, Germany); "Munchner design" Dental vernier (Dentaurum, Germany); Dental probes (Stainless steel, Japan);Tweezers (Products-Dentaires S.A.-Vevey Suisse); and Kidney dishes (Stainless steel, Japan).

B. Mechanical equipment and instruments

Dynamometer (force gauge), measuring range 28.35gm-450gm, compression side with guide slot and fork (Anthogyr, France); Dial gauge, measuring range 0.01-5mm, (Henri Hauser-Bienne-Suisse); small by pass vertical studs for attachment of brackets and arch wire; and Magnetic base with horizontal/vertical arms, holder and clamps (Germany) .

C. Other equipment and instruments

Incubator, measuring range 20-80C^o, (Fischer Scientific, Germany); Inert plastic container (10 ml, capacity), (Afma-Dispo, Italy); Plastic container rack (Italy);Thermometer, measuring range 10-110C^o, (Labortherm-N Skalenwert 1K,Germany); Timer (Casio, Japan); Disposable hypodermic Syringe of 10ml capacity, (Medeco-Pharma-Plan International, Germany); A pH Indicating paper "MN-Universal-Indikatorpapier", pH measuring range 1-14, (Macherey-Nagel, Germany); and Cyanoacrylate adhesive (Quickstar, China).

Load deflection test apparatus

A new test apparatus was specially designed [8] (Figures 1-4) for measurement of the force deflection behavior of the orthodontic arch wires (after incubation of arch wires in the chemical reagents). The entire dynamometer "force gauge", dial gauge and the stainless steel vertical studs were stable in 3 planes of space; the dynamometer and the dial gauge were placed in situ by adjustable clamps, to have adjustable distances from the stainless steel by pass vertical studs. The data regarding this test apparatus were collected according to previously designed apparatus by [9-11].

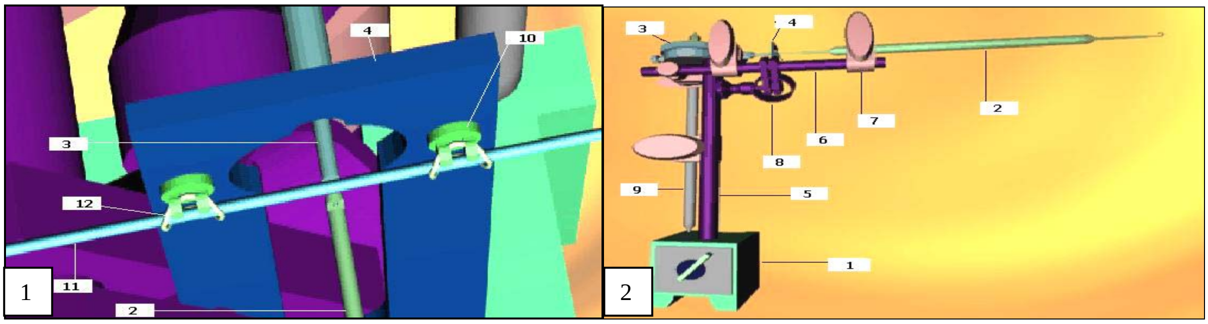
The data was analyzed using a computer program (mechanical Autocad, 2006) to have accurate details for designing the test apparatus and to know any unanticipated error, also we used a computer program (3D MAX,V8) to have a theoretical 3 dimensional model of the test apparatus for accuracy.

Mechanism of action of the test apparatus

The mechanism of action is coinciding with three-point bending test [2, 8, 12, 13]**.** (Figure 5, 6)

Studying the effects of fluoride containing tooth paste on nickel titanium arch wire deflection:

Each wire specimen was cut from the straight portion of the preformed round 0.012 inch nickel titanium orthodontic arch wire, and the number of cut pieces was 80 cut pieces. The length of each piece was 40 mm [14]. Then these 80 cut pieces of the wire were divided into 4 group "20 cut pieces for each group" (1 control group was subjected to immersion in the artificial saliva and 3 test groups were subjected to immersion in the fluoride containing tooth paste), then each group was subdivided into 2 subgroups "10 cut pieces for each subgroup" (2 subgroups represent the 2 time intervals "60 and 90 minutes").



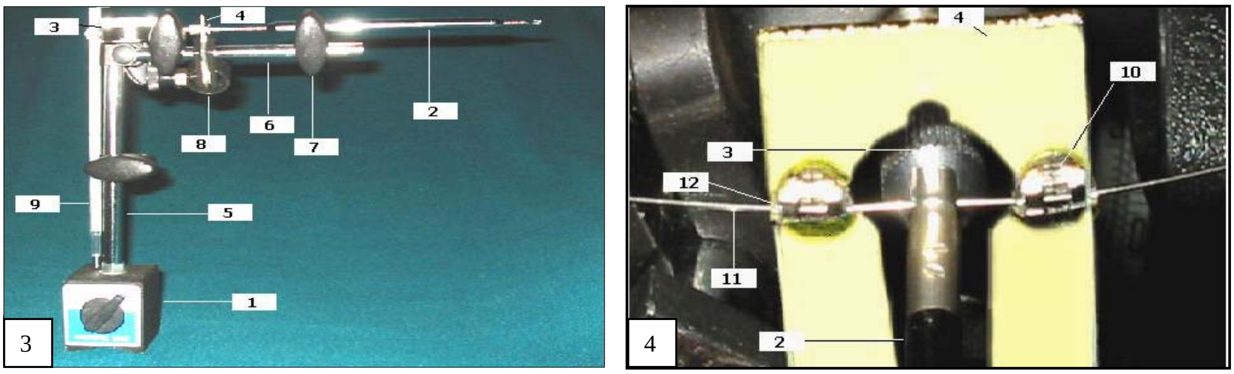
Figures 1 and 2: Front view, and magnified view of the test apparatus (Drawn using 3D Max).

$_1$. Magnetic base , with adjustable vertical $_5$. / horizontal arms $_6$. clamps $_7$. and holder $_8$. , the horizontal arm carries the loading cell (dynamometer "force gauge", dial gauge and by pass vertical studs) ,while the vertical arm carries the horizontal arm and a thermometer $_9$.

$_2$. Dynamometer "force gauge", measuring range from (28.35-450gm), [placed in situ on horizontal arm by a clamp].

$_3$. Dial gauge: this gauge is measuring the deflection of the arch wire, measuring range (0.01-5mm), [placed in situ on horizontal arm by a clamp].

$_4$. Stainless steel by pass vertical studs [placed in situ on horizontal arm by holder].The brackets $_{10}$ are bonded on the by pass vertical studs. Then the arch wire $_{11}$ is ligated to these brackets by ligature elastics $_{12}$.



Figures 3 and 4: Front view, and magnified view of the test apparatus (real view).

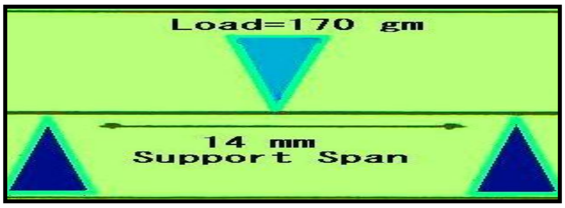


Figure 5: Three point bending condition (Modified from [2])

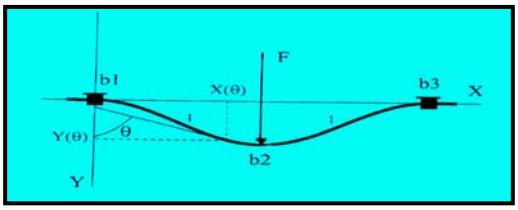


Figure 6: Schematic drawing of 3 point bend fixture configuration [12].

Each cut piece was then subjected to immersion separately in one of the tested fluoride containing tooth pastes (acidulated monoflurophosphate, neutral sodium fluoride, and stannous fluoride), or in the control medium "artificial saliva" [15]. All were incubated in AFMA–Dispo inert plastic container of 10 ml capacity [2] at 37 ^{o}C [16; 17] at 2 time intervals (60 and 90 minutes), then each wire piece was immediately removed from its individual container, cleaned by a piece of clean cotton, and any wire was tested by the following steps [in coincidence with three-point bending test fixture configuration]:

1) The arch wire was ligated centrally to the brackets using ligature elastics (inter-bracket distance was 14 mm) [13].
2) A stable compression force was applied through the force gauge "170gm".
3) The amount of deflection was measured by mounted sensitive dial gauge.

The specified readings in the dial gauge (load deflection) was recorded, collected and analyzed statistically to know the effect of fluoride containing tooth paste on nickel titanium arch wire, after comparing with the control group (artificial saliva).

RESULTS AND DISCUSSION

A. The load deflection of Ni -Ti arch wire

The immersion in artificial saliva (ASA):The mean load deflection of Ni-Ti arch wire after immersion in ASA is the same value at the 2 time intervals (60 and 90 minutes) and of highest mean deflection values among the chemical reagents. The range of load deflection is 4, which is considered to be high, which means that the flexibility of Ni-Ti arch wire is still high and not affected after immersion in ASA and this expressed by unaffected mean load deflection of Ni-Ti arch wire, as shown in table 1 .

The immersion in acidulated monoflurophosphate tooth paste (AMF): The mean load deflection of Ni-Ti arch wire after immersion in AMF is decreasing with increasing time of immersion and of lowest mean deflection values among the chemical reagents. The range of load deflection is 1-2, which means that the flexibility of Ni-Ti arch wire is low after immersion in AMF with decreasing in flexibility with increasing time of immersion. The decreasing in flexibility is expressed by reduction in the mean load deflection of Ni-Ti arch wire, as shown in table 2 .

The immersion in neutral sodium fluoride tooth paste (NSF): The mean load deflection of Ni-Ti arch wire after immersion in NSF is decreasing with increasing time of immersion. The mean load deflection of Ni-Ti arch wire after immersion in NSF at 60 minutes is high, and this mean load deflection value is closer to that in ASA, while the mean load deflection of Ni-Ti arch wire after immersion in NSF for 90 minutes shows low values. The range of load deflection is 2, which means that the flexibility of Ni-Ti arch wire at 60 minutes is high, while at 90 minutes is low, and the flexibility is decreasing with increasing time of immersion. This is expressed by reduction in the mean load deflection of Ni-Ti arch wire, as shown in table 3 .

The immersion in stannous fluoride tooth paste (SF): The mean load deflection of Ni-Ti arch wire after immersion in SF is decreasing with increasing time of immersion, and at 60 and 90 minutes are the highest mean deflection values among the immersion test media, which are closest to that in ASA. The range of load deflection is 2-3, which means that the flexibility of Ni-Ti arch wire is relatively not highly affected after immersion in SF, and this is approved by highest mean load deflections values among the immersion test medium which are closest to that in the ASA, as shown in table 4.

Table 1: Load deflection of Ni-Ti arch wire after immersion in ASA at 2 time intervals.

Time	Min.(mm)	Max.(mm)	Mean(mm)	SD	SE
60 minutes	0.05	0.09	0.064	0.0140	0.0044
90 minutes	0.05	0.09	0.064	0.0140	0.0044

Table 2: Load deflection of Ni-Ti arch wire after immersion in AMF at 2 time intervals.

Time	Min.(mm)	Max.(mm)	Mean(mm)	SD	SE
60 minutes	0.05	0.06	0.048	0.0042	0.0013
90 minutes	0.04	0.06	0.045	0.0055	0.0017

Table 3: Load deflection of Ni-Ti arch wire after immersion in NSF at 2 time intervals.

Time	Min.(mm)	Max.(mm)	Mean(mm)	SD	SE
60 minutes	0.05	0.07	0.054	0.0073	0.0023
90 minutes	0.04	0.06	0.049	0.0045	0.0014

Table 4: Load deflection of Ni-Ti arch wire after immersion in SF at 2 time intervals.

Time	Min.(mm)	Max.(mm)	Mean(mm)	SD	SE
60 minutes	0.05	0.08	0.058	0.0094	0.0029
90 minutes	0.05	0.07	0.056	0.0069	0.0022

n=10 Range=Maximum load deflection value-Minimum load deflection value.

B. Mean comparison for the load deflection

Comparison between all chemical reagents:

The results of the F test by ANOVA as demonstrated in table 5, show that there is a highly significant difference between all chemical reagents **(**ASA, AMF, NSF and SF**)** at the mean 2 time intervals for the mean load deflections of Ni-Ti arch wires at $P< 0.0001$. This may be due to the highest concentration of fluoride (PPM) and hydrogen ions (pH) in AMF, high concentration of fluoride ions in NSF and least concentration of fluoride ions in SF.

Therefore, fluoride ions could affect the titanium oxide film on the surface and attacked corrosion morphology because of degradation and loss of the titanium oxide film expose the underlying alloy; subsequently the absorption of hydrogen ions from the aqueous tooth paste (AMF) because of high affinity of titanium with hydrogen and this agrees with Yokoyama et al [18].

Comparison between time intervals:

The results of F-test by ANOVA as demonstrated in table 6, show that there is a significant difference($P< 0.05$) at 60 minutes, and there is a highly significant difference ($P< 0.0001$) at 90 minutes between all chemical reagents for the mean load deflections of Ni-Ti arch wires. It can be deduced that the immersion time which is the exposure time of Ni-Ti arch wire to fluoride ions in the fluoride containing tooth paste plays an important role in corrosion production and subsequently in the amount of Ni-Ti arch wire load deflection, since it has been reported that the immersion time plays an important role in the amount of absorbed hydrogen in Ni-Ti arch wire (after immersion in acidulated phosphate fluoride solution) and subsequent degradation in performance [18;19] and this could agree with the results of this study.

Comparison between control medium and test media:

Student t-test between the chemical reagents **(**ASA and AMF,NSF and SF**)** at 2 time intervals for the mean load deflections of Ni-Ti arch wires were performed as shown in table 7. From these results it can be deduced that the AMF has the highest effect among the immersion test media because it affects on both time intervals (60 and 90 minutes) followed by NSF because it affects at 90 minutes only, and SF has no significant effect at both time intervals in the amount of Ni-Ti arch wires load deflections. This may be due to the difference in fluoride ions concentrations (PPM) and hydrogen ions(pH)that are present in AMF,NSF and SF respectively to cause considerable amount of corrosion and subsequent degradation in Ni-Ti arch wire load deflection, in addition to difference in immersion times (the exposure times) which plays an important role in the amount of absorbed hydrogen and fluoride ions. These results agree with the results of Yokoyama et al [18]

Comparison between 2 different immersion media:

F-test by ANOVA between 2 different immersion media at the mean 2 time intervals for the mean load deflections of Ni-Ti arch wires were performed as shown in table 8. The results of this test show that there are highly significant differences between AMF, ASA and SF, and this probably due to the fact that AMF has highest fluoride concentration among the immersion test media which is 1500 PPM. Probably this fluoride concentration could cause considerable amount of corrosion and subsequent degradation in Ni-Ti arch wire load deflection in comparison with least fluoride concentration in SF which is 970PPM. There are significant differences between NSF, and AMF, SF and ASA and this probably is due to the fact that NSF has intermediate concentration of fluoride among the immersion test media which is 1450 PPM and this fluoride concentration could not cause sufficient corrosion and subsequent degradation in Ni-Ti arch wire load deflection, and there is no significant difference between SF and ASA this probably is due to the fact that SF has the least concentration of fluoride among the immersion test media which is 970 PPM which may not be sufficient to cause considerable amount of corrosion and subsequent degradation in Ni-Ti arch wire load deflection and this agrees with Huang [15] who stated that there is no considerable influence observed on Ni-Ti arch wire in lower fluoride concentration test environments. Therefore, there was no significant difference between ASA and SF in the amount of Ni-Ti arch wire load deflection, in addition to the fact that fluoride concentration in immersion environments seemed to play a more important role on surface changes than environmental acidity.

C. LSD Comparison between immersion media

The results of Post Hoc-LSD (least significant difference) test as demonstrated in table 9 show there are no significant differences (at $P> 0.05$) between NSF, SF and ASA at 60 minutes because this exposure time is not sufficient to cause considerable amount of corrosion and subsequent degradation in load deflections of Ni-Ti arch wires in relation to moderate fluoride concentration in NSF and least fluoride concentration in SF, while there were significant differences (at $P< 0.05$) between NSF, SF and ASA at 90 minutes because this exposure time is not sufficient to cause considerable amount of corrosion and subsequent degradation in load deflections of Ni-Ti arch wires in relation to their fluoride concentrations in NSF and SF respectively. There were significant differences (at $P< 0.05$) between AMF, ASA and SF at 60 and 90 minutes time intervals because AMF and SF represent the extreme in fluoride ions concentrations which are 1500 and 970 PPM respectively.

There was significant difference (at $P< 0.05$) between AMF and NSF at 60 minutes time interval, while there was no significant difference (at $P> 0.05$) at 90 minutes in the amount of Ni-Ti arch wire load deflections, because both of immersion media represent relatively high concentration of fluoride which are 1500 and 1450 respectively if compared with SF. We reached to the fact that the immersion time which is exposure time of Ni-Ti arch wire to fluoride ions and to less extent hydrogen ions plays an important role in the amount of Ni-Ti arch wire load deflection and when the time of immersion increases, the difference and the degradation in Ni-Ti arch wire load deflection will increase also. It can be deduced from these results that the highest effect on corrosion production and subsequent degradation in Ni-Ti arch wire load deflection occurs in case of AMF, while the lowest effect in case of SF and an intermediate effect in case of NSF.

Clinical application

Enamel decalcification and subsequently caries production is a well recognized problem associated with clinical orthodontic treatment, therefore all orthodontists in the world are focusing on the tooth brushing with the best fluoride containing tooth pastes.

Since orthodontic tooth movement is produced by light continuous force in order to execute an individualized treatment plane and to generate an optimum orthodontic force which will produce a maximum desirable biological response with minimum tissue damage, resulting in rapid tooth movement in the presence of fluoride treatment for the teeth.

Table 5: F-test by ANOVA table between all chemical reagents at the mean 2 time intervals (60 and 90 minutes) for the mean load deflection of Ni-Ti arch wire.

	F-test	p-value	Sig
All chemical reagents	6.594	0.000	HS

df =39 HS: P<0.0001(High significant)

Table 6: F-test by ANOVA table between time intervals of all chemical reagents for the mean load deflection of Ni-Ti arch wire.

Time	F-test	p-value	Sig
60 minutes	5.087	0.006	S
90 minutes	8.357	0.000	HS

df=19 S: P<0.05(Significant)

Table 7: Student t-test between the chemical reagents (ASA and AMF, NSF and SF) at 2 time intervals for the mean load deflection of Ni-Ti arch wire.

Media	Time	t-test	p-value	Sig
ASA&AMF	60 minutes	3.561	0.002	S
	90 minutes	3.986	0.001	S
ASA&NSF	60 minutes	2.094	0.051	NS
	90 minutes	3.319	0.004	S
ASA&SF	60 minutes	1.122	0.277	NS
	90 minutes	1.714	0.104	NS

df =18 NS: P>0.05 (Not significant) S: P<0.05(Significant) HS: P<0.0001(High significant)

Table 8: F-test by ANOVA table between 2 different immersion media at the mean 2 time intervals for the mean of the load deflection of Ni-Ti arch wire.

Media	F-test	P-value	Sig
ASA&AMF	11.998	0.000	HS
ASA&NSF	6.885	0.001	S
ASA&SF	1.407	0.262	NS
AMF&NSF	5.617	0.004	S
AMF&SF	12.017	0.000	HS
NSF&SF	5.267	0.005	S

d f =3 NS: P>0.05 (Not significant), S: P<0.05(Significant)

Table 9: Post Hoc-LSD test between the chemical reagents (NSF and ASA, AMF and SF) at 2 time intervals for the mean load deflection of Ni-Ti arch wire.

Media	Time	p-value	Sig
ASA&AMF	60 minutes	0.012	S
	90 minutes	0.002	S
ASA&NSF	60 minutes	0.061	NS
	90 minutes	0.014	S
AMF&NSF	60 minutes	0.050	S
	90 minutes	0.111	NS
AMF&SF	60 minutes	0.001	S
	90 minutes	0.007	S
NSF&SF	60 minutes	0.225	NS
	90 minutes	0.013	S

NS: P>0.05 (Not significant) S: P<0.05 (Significant) HS: P<0.0001(High significant)

As always, the results of an in vitro investigation should be viewed cautiously because laboratory testing can not exactly model clinical situations. Although the exposure time to fluoride containing tooth paste at 2 time intervals (60 and 90 minutes) represents a trial for fluoride applications in tooth paste, and the exposure time to fluoride would be repeated, shorter exposures rather than continuous exposure time. However, this in vitro study is a first step in understanding whether exposure to fluoride containing tooth paste affects the load deflection of nickel titanium arch wire.

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