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Effect of Artificial Salvia on Force Values of Two Types of Nickel Titanium Orthodontic Arch Wires

Afrah K Al -Hamadani
BDS, MSc (Asst Prof.)
Dept of Pedod, orthod, and Prev Dentistry
College of Dentistry, University of Mosul

Enas T Al-Jwary
BDS, MSc (Lec.)
Dept of Pedod, orthod, and Prev Dentistry
College of Dentistry, University of Mosul

الخلاصة

ألأهداف: تهدف هذه الدراسة إلى قياس تأثير اللعاب الصناعي للأسلاك التقويمية من نوع النيكل – تيتانيوم عالي المرونة و النيتينول خلال ثلاث فترات زمنية على مقدار القوة. استخدم في هذه الدراسة نوعان من الأسلاك التقويمية نوع النيكل – تيتانيوم عالي المرونة و النيتينول من قياس 0.16 انج. كل نوع من الأسلاك قسم إلى مجموعتين تضم : المجموعة الضابطة والمجموعة ألاختباريه التي غمرت فيها الأسلاك في محلول اللعاب الصناعي لثلاث فترات زمنية (3ايام ،7 أيام ،28يوم). وبعد انقضاء الفترة تم قياس مقدار القوة للأسلاك التقويمية باستخدام جهاز الشد الفاحص العام. **النتائج:** أظهرت النتائج فروقا معنوية في مقدار القوة للأسلاك التقويمية من نوع نيتينول مابين المجموعة الضابطة والمجموعة ألاختباريه كما أظهرت الدراسة إن المجموعة الاختيارية لفترة 28 يوم أعطت اقل مقدار للقوة مع وجود فروقا معنوية في مقدار القوة للأسلاك التقويمية بالمقارنة مع المجاميع الأخرى . كما أظهرت الدراسة إن المجموعة الضابطة لأسلاك النيكل – تيتانيوم عالي المرونة أعطت أعلى مقدار للقوة بينما إن المجموعة الاختبارية لفترة 28 يوم أعطت اقل مقدار للقوة مع وجود فروقا معنوية في مقدار القوة بالمقارنة مع المجموعة الضابطة وعدم وجود فروقا معنوية مع المجموعتين الاختباريتين للفترتين 3 أيام و 7 أيام. **الاستنتاجات:** إن أسلاك النيتينول تتأثر بصورة مستمرة في محلول اللعاب وتحتاج إعادة تفعيل خلال فترات زمنية منتظمة بينما مقدار القوة لأسلاك النيكل – تيتانيوم عالي المرونة تتغير خلال 3 أيام وتبقى ثابتة بعد ذلك .

ABSTRACT

Aims: To study the effect of artificial saliva and time interval on the amount of force values of nitinol and superelastic NiTi wires. **Materials and Methods:** Two types of orthodontic wires chosen for the study nitinol and superelastic NiTi wires of a guage of 0.016 inch in diameter (Dentaurum, Germany). Specimens of the wires were divided in to two groups ;the control group(dry condition) contained the wires as - received condition and experimental groups for the study of the force value of wires which subjected to artificial saliva for three time incubation periods (3 days, 7 days, 28 days) . At end of each incubation periods ,the wire specimens were tested for the effect of artificial saliva on force values of the wire. The measurement of force values of arch wires done with a universal tensile testing machine ,the force values of specimens were evaluated with the help of three point bending test. The results were subjected to the descriptive statistics and to the ANOVA and Duncan's Multiple Range Analysis Tests to detect the amount of changes among these groups . **Result:** The findings of the present study showed that the control group of nitinol wires had the highest rate of force value with significant difference ($P \leq 0.05$) with experimental groups, while the experimental group after 28 days gave rise to the lowest one with significant difference ($P \leq 0.05$) from other groups. For the superelastic nickel titanium the result showed that the control group had the highest rate of force value while the experimental group after 28 days gave rise to the lowest one with significant difference ($P \leq 0.05$) from control and non significant difference ($P > 0.05$) with the experimental groups after 3 days and 7 days. **Conclusion:** The nitinol wires showed a continuous change in force values with increase time in artificial saliva, so this required reactivating or changing the wire at a certain interval of use. While force values of the superelastic nickel titanium wires decreased after 3 days interval and remained constant after that .

Keywords: Artificial Salvia, Nickel Titanium Wires, Force value

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INTRODUCTION

A vital component of the fixed orthodontic appliance is the orthodontic arch wire.[1,2] Recent advances in orthodontic wire alloys have resulted in a varied array of wires and these include stainless steel, cobalt chromium, nickel – titanium, beta – titanium and multistranded stainless steel wires.[3] In early 1960s, a nickel-titanium alloy was developed by W. F. Buchler at USA Naval Ordnance Laboratory in Silver Springs.[4] The first nickel-titanium alloy known as nitinol, the name nitinol was derived from **N**icket- **T**itanium **N**aval **O**rdinance **L**aboratory.[5] Evans and Durning (1996)[6] stated that there are three types of commercially available nickel titanium wire:

. Martensitic Stable (conventional Alloy)

. Austenitic Active (Pseudo-elastic)

. Martensitic Active (Thermo-elastic)

Intra-orally placed materials (i.e. wires, brackets) exhibit a pattern of continuous reaction with the environmental factors present in the open oral cavity. [7-8] These environmental conditions of the oral cavity might alter the morphological, structural and compositional characteristics, force delivery of archwires, superelasticity and fracture of orthodontic alloy.[9]

These oral environments include saliva, acids arising from degradation and decomposition of food (PH), oral flora and its by products, temperature change and stress.[10, 12] The quantity and quality of saliva may influence corrosion.[13, 14] The anticorrosion properties of nickel – titanium arch wires are due to the formation of oxide layers on the surface of alloys, which inhibit further corrosion. On Ti alloys several oxides are formed upon exposure to air, including TiO_2, TiO and Ti_2O_5 with TiO_2 being the most dominant.[7, 15] The Ti oxide layer formed on titanium alloys such as the NiTi wires is more stable than the chromium oxide, particularly in environments containing chloride anions.[16] So, the general mechanism for the corrosion and subsequent release of metal ion involve the loss of passivated layer (oxide layer) so when the oxide layer dissolve, the onset of surface corrosion begins.[17]

MATERIALS AND METHODS

Two types of orthodontic wires were taken included nitinol and superelastic NiTi wires(Dentaurum, Germany). The 0.016 inch wires were selected because its popularity with the clinicians for initial leveling and aligning and because these are the most likely wires to be recycled.[18] The specimens' length of the archwires used in this study was 50 mm.[19] These specimens of the wires were divided in to two groups ;the control group contained the wires as - received condition (dry condition) and experimental groups for the study of the force values of wires which subjected to artificial saliva for three time intervals (3 days, 7 days, 28 days) . The formula used for preparation of artificial saliva solution was described by Barrett *et al*. [20] and this includes: 0.4 gm NaCl, 1.21 gm KCl, 0.78 gm $NaH_2PO_4.2H_2O$, 0.005gm $Na_2S.9H_2O$, 1 gm urea $[CO(NH_2)_2]$ and 1000 ml distilled and deionized water.The PH of the artificial saliva was adjusted by using pH meter to 6.75 ± 0.15 with 10N sodium hydroxide. The pH value was coincided with that reported for human saliva. The wires engaged in the acrylic models as in Figure (1) in which three brackets fixed with a light cure composite resin (XRV Herculite). The standard edgewise stainless steel brackets (0.018 x 0.030 inch) fixed in about five mm inter proximally and three millimeters infero –superior discrepancy between the center bracket and the adjacent one .This distance determines the amount of displacement of wires. As described by Burstone *et al.*[21]

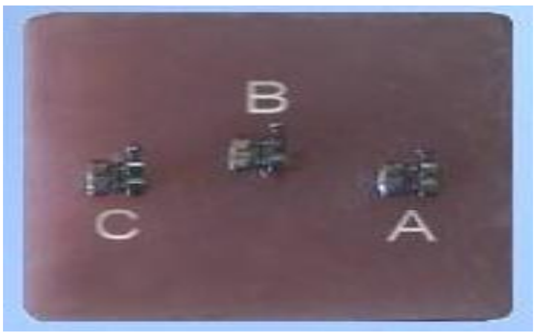

Figure (1): Acrylic Block on which a Standard Stainless steel Brackets Fixed.

After that the specimen of each wire type was then taken and secured to brackets on acrylic block by ligature elastics, so the wire subjected to 3 mm deflection, ten blocks made and then the samples put in a closely packed glass container and 200 ml artificial saliva added to them, the samples were stored in incubator at 37 °C. At end of each incubation periods (3 days, 7 days, 28 days), the wire specimens were taken to study the effect of artificial saliva on force values of the wire. The measurement of force of archwires was done with a sal tensile testing machine (Festigkeits-Prufmaschine F 410, Germany) Figure(2) with a full scale range of 2000 gm in a 5 gm graduation.

Figure(2) : Universal Tensile Testing Machine

The force values of specimens were evaluated with the help of three point bending test as described by Miura *et al*. ,and Taneja *et al*.[19, 22] A three point bending test was performed on the especially designed fixture Figure (3) which was prepared according to the design described by previous studies by Miura *et al* and Krishnan and Kumar.[22, 23]

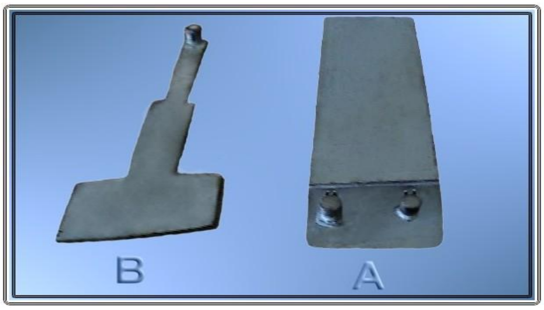

Figure (3): Special Design Fixture

The wire specimen is attached to the brackets on the two poles Figure (3) by ligature elastics (Orthomatrix, USA). The stage of single pole was attached to a movable head of a universal tensile testing machine, so that the single pole was on the center of the wire span. The mid portion of the wire was then deflected by the pressure of the single pole with a cross head speed of 0.5 mm/sec and the force value was measured at each deflection distance; So ten wires of each type were measured during loading (activation) of wires to 3mm deflections. All the tests were performed at room temperature at 30±0.5°C. The statistical analysis used in this study includes descriptive statistics to show mean, standard deviation and standard error for each. Analysis of variance (ANOVA) was used to assess the significant difference among the groups at 0.01 of significance level. Duncan's Multiple Range Test was used to locate the significant differences among the groups at 0.05 significant level.

RESULTS

Effect of artificial saliva on force values of nitinol wire: The descriptive statistics that include mean, standard deviation, standard error, minimum and maximum values of force rate related to gram (gm) at 3 mm deflection during loading for control and experimental groups are listed in (Table 1).

Table (1): Descriptive statistics demonstrate loading force (gm) at 3 mm deflection of nitinol wire after subjected to artificial saliva.

Groups	No.	Mean	Standard Error	Standard Deviation	Minimum	Maximum
Control	10	424.000	0.666	2.108	420.000	425.000
Experimental after 3 days	10	409.000	0.666	2.108	405.000	410.000
Experimental after 7 days	10	389.000	0.666	2.108	385.000	390.000
Experimental after 28days	10	344.000	0.666	2.108	340.000	345.000
Total	40	391.500	4.831	30.554	340.000	425.000

The findings of the present study showed that the control group gave rise to the highest mean values of force rate while the experimental group after 28 days gave rise to the lowest one. The one way analysis of variance (ANOVA) for the force value of wire among control and experimental groups showed significant difference ($P< 0.001$) among them as in (Table 2).

Table (2): (ANOVA) for Statistics Demonstrate Loading Force (gm) at 3 mm Deflection of Nitinol Wire After Subjected to Artificial Saliva.

	Sum of Square	df	F- value	Mean Square	*P*
Between groups	36250.0	3	2718.750	12083.333	$P< 0.001$
Within groups	160.0	36		4.444	
Total	36410.0	39			

The result of Duncan's multiple range test (Table 3) showed that the control group had the highest rate of force value with a significant difference ($P\leq 0.05$) when compared with experimental groups, while the experimental group after 28 days gave rise to the lowest one with significant difference ($P\leq 0.05$) from other groups.

Table (3): Duncan's Multiple Range Test for Statistics Demonstrate Loading Force (gm) at 3 mm Deflection of Nitinol Wire after Subjected to Artificial Saliva.

Groups	No.	Mean ± SE (Force in gm)	Duncan Groups*
Control	10	424.000 ±0.666	a
Experimental after 3 days	10	409.000 ±0.666	b
Experimental after 7 days	10	389.000 ±0.666	c
Experimental after 28 days	10	344.000 ±0.666	d

* Different litters mean significant difference ($P \leq 0.05$).

Effect of artificial saliva on force values of superelastic wire: The descriptive statistics that include mean, standard deviation, standard error, minimum and maximum values of force rate related to gram (gm) at 3 mm deflection during loading for control and experimental groups are listed in (Table 4).

Table (4): Descriptive Statistics Demonstrate Loading Force (gm) at 3 mm Deflection of Superelastic Nickel- Titanium Wire After Subjected to Artificial Saliva.

Groups	No.	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Control	10	401.000	2.108	0.666	400.000	405.000
Experimental after 3 days	10	395.500	2.108	0.666	395.500	400.000
Experimental after 7 days	10	395.000	0.000	0.000	395.000	395.000
Experimental after 28 days	10	395.000	0.000	0.000	395.000	395.000
Total	40	398.000	3.358	0.531	395.000	405.000

The findings of the present study showed that the control group gave rise to the highest mean of force, while the experimental groups gave rise to lowest one. The one way analysis of variance (ANOVA) for the force value of wire between control and experimental groups showed significant difference ($P< 0.001$) among them as in (Table 5).

Table (5): (ANOVA) for Statistics Demonstrate Loading Force (gm) at 3 mm Deflection of Superelastic Nickel- Titanium Wire After Subjected to Artificial Saliva.

	Sum of Square	df	Mean Square	F- value	*P*
Between groups	360.0	3	120.000		
Within groups	80.0	36	2.222	54.000	$P< 0.001$
Total	440.0	39			

The result of Duncan's multiple range test (Table 6) showed that the control group had the highest rate of force value with significant difference ($P\leq 0.05$) with other groups while the experimental group after 28 days gave rise to the lowest one with significant difference ($P\leq 0.05$) from control and non significant difference ($P> 0.05$) with the experimental groups after 3 days and 7 days.

Table (6): Duncan's Multiple Range Test for Statistics Demonstrate Loading Force (gm) at 3 mm Deflection of Superelastic Nickel- Titanium Wire After Subjected to Artificial Saliva.

Groups	No.	Mean ± SE (Force in gm)	Duncan Groups*
Control	10	401.000 ±0.666	a
Experimental after 3 days	10	395.500 ±0.666	B
Experimental after 7 days	10	395.000 ±0.000	b
Experimental after 28 days	10	395.000 ±0.000	b

* Different litters mean significant difference ($P \leq 0.05$).

DISCUSSION

The Effect of Artificial Saliva on force value on nitinol wire: The results of the present study showed that the control group (dry condition) displayed a significantly higher force value during loading than the experimental groups and this finding is similar to the result obtained by Harris *et al.*[24] who attributed this finding to corrosive attack in chloride environment, this attack was a pitting type of corrosion that affect the surface of the wires and result in degradation of their mechanical properties, so the long term use of nitinol wire would appear to be associated with decreased performance of the wire particularly the elasticity of the wire. A similar result was reported by Kapila *et al.*[25] who found that when nitinol wire is subjected to clinical use it demonstrates a significantly lower force during loading than control group. Also, Lee and Chang[26] concluded that the martenistic nickel titanium wire demonstrated a significant change in force values of recycle wire.

This result was not coincident with Sarkar and Schwaninger[27] who found that there was no change in force values and mechanical properties of nitinol after long term immersion in a 1 % sodium chloride solution. In their study, Smith *et al.*[18] reported that no clinically significant difference in force values between as – received and used wires and they suggested that the NiTi wire could be recycled at least once.

The Effect of Artificial Saliva on force value on Superelastic Nickel - Titanium Wire:

The results of the present study showed that the control group displayed a significantly higher force value during loading than the experimental groups and this finding was similar to the result obtained by Tang *et al.*[28] who found that the superelastic wire suffered degradation of their mechanical properties and that the force generation capacity decreased in oral environment. It was also supported by Kapila *et al*.[25] who displayed that the recycled NiTi wires were associated with reduced forces during loading and unloading than control wire and this was attributed to the increased pitting corrosion of the wire after clinical exposure and the authors concluded that alteration in characteristic of NiTi wire require more frequent activations or earlier arch wire changes than would normally be expected with control wires. Eliades and Bourauel[9] stated that the intraoral exposure of NiTi wires alter the structure of alloy through surface attack in the form of pitting and crevice corrosion and these structural changes might have a potent effect on the mechanical performance of the material. In addition, this result agreed with Kapila and Sachdeva[3] who observed a change in the characteristics of the 3 – point bending test after placing NiTi wires in vivo.

On the other hand, the present finding disagrees with Lee and Chang[26, 29] who reported that the superelastic NiTi wire demonstrated no significant change in the mechanical properties after clinical recycling. It also disagrees with Han and Quick and Benyahia *et al* , Fragou and Eliades[30, 32] who stated that the superelastic was highly resistant to degradation of mechanical properties in stimulated oral environment and this would appear to present a distinct clinical advantage.

The results of the present study showed that all experimental groups displayed non significant differences in force values at those three times intervals and this may attributed to the formation of a stable passive oxide layer (TiO_2) Bentahar *et al*[33] and Al-Joboury[34], while Wever *et al*.[35] found that the daily released of nickel from NiTi alloy is strongly decreased after the first day of soaking. In addition, this result was attributed to the ability of NiTi alloy to be repassivated. A study conducted by Cioffi *et al*.[36] showed that NiTi surface was composed of titanium oxide and nickel oxides and nickel might dissolved more easily than the titanium because its oxide which is not stable. So after some initial dissolution of nickel from the surface, the NiTi alloy might eventually repassivated forming a surface containing mainly titanium oxide in outer layer and nickel oxide in inner layer.

CONCLUSION

The artificial saliva was significantly affect the force values of the two types of the nickel titanium wires and there was a significant decrease in force values. The nitinol wire showed a continuous change in force values with increase the immersion time in artificial saliva, so this required reactivating or changing the wire at a certain interval of use. While superelastic nickel titanium showed a constant force value with increase the immersion time in artificial saliva and this was attributed to the formation of a stable passive oxide layer (TiO_2).

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