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Factors Affecting on Permanent Deformation of Orthodontic Arch wires (An In vitro Study)

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الخلاصة

الأهداف: تهدف الدراسة الى قياس معدل الانحرافات الدائمية في أنواع مختلفة من أسلاك التقويم وكذلك تأثير كل من الفترات الزمنية والظروف الفموية المماثلة على كمية الانحرافات الدائمية في أنواع من أسلاك النيكل تيتانيوم والفولاذ الصلب. **المواد وطرائق العمل:** تتكون العينة من خمسة أنواع من أسلاك التقويم (الفولاذ النابض عالي الصلابة ، الفولاذ النابض الصلب ، الفولاذ متعدد الألياف ، أسلاك النيكل تيتانيوم نوع nitinol و النيكل تيتانيوم عالي المرونة) من قياس (٠.٠١٦)انج ذات المقطع الدائري .ثبتت الأسلاك في الحاصرات التقويمية المثبتة في قوالب خاصة ثم وضعت في وعاء زجاجي محكم الإغلاق وأضيف إليها(٢٠٠) مليليتر من محلول اللعاب الصناعي وتم حفظ العينات في الحافظة بدرجة حرارة ٣٧ درجة سيليزية. وفي نهاية مدة الحفظ، أخذت القوالب وتم فتح السلك وتم قراءة مقدار الانحراف ألدائمي بواسطة استخدام المجهر. ثم أجريت العمليات الإحصائية على النتائج. **النتائج:** أظهرت نتائج البحث بأن الفولاذ النابض الصلب في فترة (٢٨) يوم أعطى أعلى قيمة للانحرافات الدائمية بينما سلك النيكل تيتانيوم عالي المرونة في ساعة واحدة أعطى اقل قيمة وبقية المجاميع توزعت إحصائيا مابين أعلى و اقل قيمة. **الاستنتاجات:** اظهر سلك النيكل تيتانيوم عالي المرونة اقل انحرافات دائمية بالمقارنة بأسلاك الفولاذ الصلب وتزداد مقدار الانحرافات الدائمية في أسلاك عديدة كلما زادت المدة في الظروف الفموية المماثلة.

ABSTRACT

Aims: To measure the amount of permanent deformation of different types of orthodontic arch wires and to study the effect of both time interval and simulated oral environment on amount of permanent deformation of different types of nickel titanium and stainless steel orthodontic arch wires. **Materials and Methods:** The sample consisted of five types of orthodontic arch wires (extra spring hard stainless steel , spring hard stainless steel, multi strand stainless steel ,nitinol nickel titanium and super elastic nickel titanium), 0.016 inch of round section were deflected into orthodontic brackets fitted in acrylic models put in a closely packed glass container and 200 ml artificial saliva added to them and the samples stored in incubator at 37 °C . At the end of incubation period, the acrylic block take and the wire deactivated and the amount of permanent deformation measured by using Stereo microscope. The results were subjected to the descriptive statistics and to the ANOVA and Duncan's Multiple Range Analysis Tests to detect the changes among these groups. Results The findings of the present study showed that spring hard stainless steel wires at 28 days gave rise to the highest mean values of permanent deformation, while the super elastic wires at 1hr gave rise to the lowest one. The remaining groups distributed on statistical levels of significant difference ($P \leq 0.05$) between the upper and lower levels. **Conclusions:** The super elastic nickel titanium wires exhibited better spring back characteristics and less permanent deformation than the stainless steel. Several wires increased deformation as deflection time increased in simulated oral environment.

Key word: orthodontic wires ,permanent deformation.

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INTRODUTION

Certain metallic alloys can restore its original shape after being submitted to unusually large strains.(1) Ideal aligning arch wires should be able to move teeth with light, continuous forces over prolonged periods of time and long distances. Light orthodontic forces produce the same amount of tooth movement as heavier forces and are physiologically acceptable.(2,3) For the initial leveling and aligning stages of orthodontic treatment, practitioners are still using traditional arch wires made from stainless steel (SS) or conventional nickel titanium (NiTi) that is martensite stabilized. Additionally, pseudoelastic (so-called super elastic) NiTi alloys are engineered to provide a constant force during tooth movement.(3,4) Alternative leveling products include Multistranded stainless steel wires that deliver ultra-low forces (5) and esthetically pleasing products such as glass-fiber composites and polymer-coated wires.[6]

The ideal properties of leveling arch wires include high strength , low stiffness to deliver low forces per unit of deactivation, and high range(spring back) to maximize activations.[5,7] Clinically, it is the unloading or deactivation forces that produce orthodontic tooth movement. In other words, when the stress is removed, the shape memory properties allow the phase transformation to reverse, and, as the wire returns to its original shape, it generates tooth movement.[8,9]

In the typical implementation of an orthodontic arch wires elastic deformation of the wire produces a force that is used to move a tooth into more desirable position .As the tooth slowly moves, the wire spring back towards a relaxed configuration. The relationship between force (or stress) and the flexural displacement (or stain)of the wires is linear within the elastic limit of the constituent material,[10] However some materials are often characterized by viscoelastic or time dependent stress –strain behavior. Clinically, this behavior would cause decrease in the amount of spring back that would be available for tooth movement. [11]

MATERIALS AND METHODS

A variety of 0.016-inch round section orthodontic wires were tested and the sample comprised of five types of orthodontic arch wires include (extra spring hard stainless steel, spring hard stainless steel, multi strand stainless steel, nitinol nickel titanium and super elastic nickel titanium.[12] The specimens' numbers used in this study were (250), 10 wires for each wire types and time interval. The specimens' length of the arch wires used in this study was 50 mm.[13]

These wires engaged in the acrylic models in which a 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 mm occlusogingival discrepancy between the center bracket and the adjacent one as in Figure (1).

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

This distance determines the amount of displacement of wires. This method was described by Burstone *et al*.[14] and Quintto *et al*[15] and Van *et al*. [4]

After that the specimen of each wire type was taken and secured to brackets on acrylic block by ligature elastics, so the wire subjected to three mm displacement, ten blocks made and then these blocks put in a closely packed glass container and filled with 200 ml of artificial saliva and the samples store in incubator at 37 °C.

By the same procedure other samples are prepared for each wire type and for each time interval, so each glass container corresponds to one time interval and one type of wire. [14-16]

The formula used for preparation of artificial saliva solution was described by Barrett *et al*..[17] 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 replacement of the artificial saliva solution was performed every week to avoid saturating the artificial saliva medium with corrosion product. [17]

At end of each incubation periods

(1hr,24hr ,72hr, 7 days, 28 days), the wire specimens were taken to study the amount permanent deformation of wires.

Measurement Method :

The measurement of the amount of permanent deformation done in technical institute of mosul ,departments of technology, laboratory of metals by using Stereo microscope (Zeisis,Co.,Germany) (Figure 2).

Figure (2): Stereo microscope (Zeisis,Co.,Germany)

The lens of the microscope degreed in micron and the magnification of microscope was set at (20X).Then the measurement was recorded and divided to obtain the amount of permanent deformation in millimeter.

The amount of permanent deformation measured from the line drawn from the center of bracket A and the center of bracket B and the inner border of the wires (Figure 3).

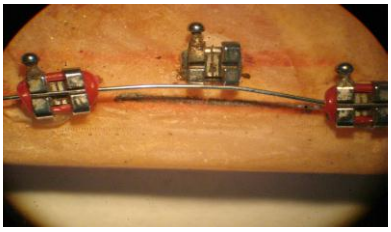

Figure (3): Measurement method under stereo microscope

At the end of each incubation periods, each acrylic block take and the wire disengaged from bracket C by removal of ligature elastic, then the acrylic block put under the lens of microscope and measurement done by measuring the distance between the line drawn from the center of the bracket A to the center of the bracket B and the inner border of the wire. This distance represented the permanent deformation [14,16,18] Figure (3).

RESULTS

The descriptive statistics that include mean, standard deviation, minimum and maximum values of the amounts of permanent deformation in millimeter are listed in Table (1) .

The findings of the present study showed that spring hard stainless steel wires at 28 days of incubation showed to the highest mean values of permanent deformation, while the super elastic nickel titanium wires at 1hr of incubation period gave rise to the lowest one.

The remaining groups were distributed on statistical levels between the higher and lower level of mean, minimum and maximum values.

The one way analysis of variance (ANOVA) for the permanent deformation values of wires showed significant difference at ($P < 0.001$) among the groups as in Table (2).

The result of Duncan's multiple range test (Table 3) showed that the spring hard stainless steel wires at 28 days had the highest rate of permanent deformation with significant difference ($P \leq 0.05$) with other types of wires, while the super elastic nickel titanium wires at 1hr gave rise to the lowest one with significant difference ($P \leq 0.05$) from other groups. The remaining groups distributed on statistical levels of significant difference ($P \leq 0.05$) between the upper and lower levels.

Table (1): The descriptive statistic of the amounts of permanent deformation in mm (means, minimum, maximum values and standard deviation).

Types of wires	**Time intervals**	**mean**	**Std.deviation**	**Minimum**	**maximum**
Extra spring hard stainless steel	1hr	1.339	2.614	1.29	1.35
	24hr	1.380	2.479	1.35	1.40
	72hr	1.882	1.549	1.88	1.88
	1wk	2.086	3.098	2.05	2.11
	28day	2.249	2.409	2.24	2.29
spring hard stainless steel	1hr	1.294	5.164	1.29	1.29
	24hr	1.300	4.216	1.30	1.30
	72hr	1.784	4.216	1.76	1.80
	1wk	2.050	4.216	2.05	2.05
	28day	2.294	4.216	2.29	2.29
Multistranded stainless steel	1hr	0.1176	4.216	0.12	0.12
	24hr	0.37	2.582	0.35	0.40
	72hr	0.8113	2.493	0.76	0.82
	1wk	0.8235	4.216	0.82	0.82
	28day	0.9410	4.216	0.94	0.94
Nitinole nickel titanium	1hr	0.117	4.216	0.12	0.12
	24hr	0.3	4.216	0.3	0.3
	72hr	0.47	4.216	0.47	0.47
	1wk	0.5294	4.216	0.53	0.53
	28day	0.5882	4.216	0.59	0.59
Super elastic nickel titanium	1hr	0.088	1.033	0.09	0.09
	24hr	0.24	2.108	0.20	0.25
	72hr	0.2936	8.433	0.29	0.29
	1wk	0.3529	4.216	0.35	0.35
	28day	0.4012	2.222	0.36	0.41

Std: standard deviation, hr: hour, wk: week.

Table (2): (ANOVA) for Demonstrated permanent deformation of Different Orthodontic Wires Types.

	Sum of Square	**df**	**Mean Square**	**F- value**	***P***
Between groups	131.888	24	5.495		
Within groups	4.943	225	2.197	25016.339	$P < 0.001$
Total	131.937	249			

Table (3): The Duncan Multiple Analysis Rang Test.

Types of wires	**Time intervals**				
	1hr	**24hr**	**72hr**	**1wk**	**28day**
Extra spring hard stainless steel	h	g	e	c	b
spring hard stainless steel	i	i	f	d	a
Multistranded stainless steel	t	p	k	k	j
Nitinole nickel titanium	t	r	n	m	l
Super elastic nickel titanium	u	s	r	q	o

hr: hour, wk: week, Different letters mean significant difference ($P \leq 0.05$).

DISCUSSIONS

This study focused on one mechanical property (permanent deformation) as a function of time. The results are relevant to the practicing orthodontist. The results of the present study showed that the spring hard stainless steel wires displayed a significantly higher amount of permanent deformation than other types of wires due to the mechanical properties of stainless steel wires which characterized by high strength, high stiffness, low flexibility and low spring back action. This finding is similar to the result obtained by Hudgins *et al* (16) who found that the stainless steel arch wires exhibited less spring back characteristics and more permanent deformation than other types of wires. A similar result was reported by Tang *et al* (19) who found that the stainless steel wires suffered a higher deformation than other types of wires. The present study also showed the super elastic nickel titanium wires deformed with limited amount when compared with the nitinol and stainless steel wires due to high spring back and low stiffness and high flexibility, This result agreed with Burstone *et al.* (14)

All types of wires showed a time dependent deformation, due to the effect of simulated oral environment on mechanical properties of wires, Similarly in oral environment, all wires suffered degradation of their mechanical properties. The spring hard stainless steel wire at 28 days demonstrated a significantly higher amount of permanent deformation comparing with the super elastic nickel titanium wires at 1hr incubation time which demonstrated a less amount of a time dependent deformation and this result come in agreement with Hudgins *et al* (16) who found that all nickel titanium arch wires exhibited better spring back characteristics and less permanent deformation than the stainless steel. Also Barrows (20) found that distortion of wires increased 7% after 8 weeks when compared to the 1hr time interval, also Sarmad (21) found that as the exposure time of the orthodontic arch wire in the oral environment is increased, the amount of loss of the mechanical properties could be increased, Also Eliades and Christoph(22) found that the environmental conditions of the oral cavity ,might alter the morphologic, structural and compositional characteristic and mechanical properties of orthodontic alloys and polymers.

The super elastic nickel titanium wires exhibited less permanent deformation than the original nitinol wire. This result was in agreement with Burstone *et al* (14) and Miura *et al* (23) who found Chinese nickel titanium wire and Japanese nickel titanium wires exhibited less permanent deformation than did nitinol.

In this study, The nitinol wires show time dependent deformation and this result was similar to a research obtained by Lopez *et al* (24) who found that nitinol experienced time dependent deformation. also Harris *et al* (25) studied mechanical properties of nitinol after 1, 2 and 4 months of deformation and found degradation of mechanical properties. On other hand this result was disagreed with Andreasen and Morrow (26) who found that no permanent deformation was observed when nitinol wire was bended for less than 1 hour.

CONCLUSIONS

The super elastic nickel-titanium wires exhibited a better spring back characteristics and less permanent deformation than the stainless steel wires. Several wires increased deformation as time increased in simulated oral environment. From a clinical perspective, this decrease might be clinically relevant because the unloading forces of the wire produce the orthodontic tooth movement. Therefore, in patients mouth ,the increased deformation could contribute to prolonged orthodontic treatment.

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