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Biomechanical Behaviors of the Orthodontic Wires

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ABSTRACT

Aims: To evaluate and compare the yield, ultimate and failure stresses of the untreated and the treated super–elastic Nickel titanium and Spring hard stainless steal orthodontic arch wires with artificial saliva for one, two and four weeks. **Materials and Methods:** The sample consisted of four groups (10 wires for each group): the control group, one, tow and four weeks of emersion in artificial saliva groups, for each of the nickel titanium and spring hard stainless steal orthodontic arch wires. The specimens were tested with tensile procedure and plotted the load stress– strain curve, from this curve the yield, ultimate and failure stresses elasticity modulus can be calculated. The data were subjected to the descriptive statistics, ANOVA and Duncan's analyses at $p \leq 0.05$ significant level. **Results:** The biomechanical properties (yield, ultimate and failure stresses) of Super–elastic Nickel titanium and Spring hard stainless steal orthodontic arch wires demonstrated significant decrease as the immersion time in artificial saliva increased. **Conclusions:** The orthodontic arch wires (super–elastic nickel titanium and spring hard stainless steal) are recommended to be used intra–orally for short period to avoid reaching the complete loss of the biomechanical properties.

Key words: Yield stress, Ultimate stress, Failure stress.

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INTRODUCTION

The biomechanical properties of an arch wire are considered by stress/strain characteristic of wires loaded in tension, stress is the property of the force applied per unit area of the wire while, strain is the change in the length relative to the original length of the wire.

Yield Strength is the point at which a wire no longer behaves elastically when a load is applied, but begins to undergo plastic deformation[1]. Noort[2] defined yield stress as stress at which plastic deformation begins, and it is defined as the stress required to produce a certain amount of plastic strain[3].

Ultimate Tensile stress is the greatest stress that may be induced in a material at the point of rupture[4].Beyond this point, even if the wire is no longer stressed, it will continue to demonstrate a change in strain, expressed by Newton (N/mm^2)[1]. Kusy[5] defined ultimate tensile strength as maximum engineering strength experienced by a material in tension.

The Point of fracture is that point beyond the ultimate tensile stresses where the wire continue to demonstrate strain and rapidly reaches the point of failure, expressed by (N/mm ^2) [1].

The aims of the study are to evaluate and compare the yield, ultimate and failure stresses of the untreated nickel titanium and Elgilloy orthodontic arch wires and the treated arch wires with artificial saliva for one, two and four weeks.

MAERIALS AND METHODS

The samples comprised super elastic NiTi (0.016″ × 0.016″ Rocky Mountain Orthodontics, U.S.A) and Elgilloy (Remanium 0.016″ × 0.016″ Dentarum, Germany) arch wires. Each group of wires included 40 wires and divided into four groups (10 wires for each), the first, second, third and fourth groups of both arch wires were tested at the following conditions: no treated wire group (control group), one, two, and four weeks immersion in artificial saliva groups (pH 6.75±0.015)[6] with incubation at 37 degree centigrade (Incubator: Isotemp, Germany) which is the most revenant mouth temperature. Tensile stress is one of the most useful mechanical tests because of the data that can be obtained from it represent the mechanical properties which describe the behavior of the material subjected to the mechanical force[7], as it is recommended in ADA specification[8] No. 32.

All the specimens were tested with tensile testing machine (Zweigle model 73, Belgique). The speed of the machine was adjusted to 0.5 mm/sec. There is a special ruler build in the machine for detecting the change in the length of the specimen until rupture.

The tensile stress transferred from Kg to N by N =Kg × 9.8 and then to Mecapascal (Mpa) by stress = load in N/ surface area of the specimen 2 mm^2. Plotting the load stress–strain curve from this curve most of the mechanical properties can be obtained such as the assessment of the yield stress by drawing a line from 0.2 of the gauge length of the spacimen parallel to the curve line; the inter section point represents the yield point (0.2 offset yield stress), the highest point in the load–strain curve represents the ultimate stress, and the point at which fracture occurs represents failure stress[7].

The results were analyzed using the Descriptive and ANOVA and Duncan's Multiple Analysis Range test at $p \leq 0.05$ significant level.

RESULTS

The descriptive statistics and the results of ANOVA and Duncan's Multiple Analysis Range test are displayed in the Tables (1–4).

The biomechanical properties (yield, ultimate and failure stresses) of the nickel titanium and spring hard stainless steal orthodontic arch wires appeared to decrease significantly when the immersion time of the wires in artificial saliva increase.

Table (1): The Descriptive and ANOVA Analyses of the NiTi Wire.

Property	Groups	N	Mean	±SD	Min value	Max value	ANOVA F–value	Sig.
Yield stress (MPa)x10^3	Control group	10	1063.90	3.635	1060	1070	4614.357	S
	1 week after	10	1032.80	3.259	1010	1040		
	2 weeks after	10	972.20	2.700	0960	0990		
	4 weeks after	10	938.00	2.789	0903	0940		
Ultimate tensile stress (Mpa)x10^3	Control group	10	1478.60	4.789	1470	1485	5148.977	S
	1 week after	10	1423.20	4.733	1415	1430		
	2 weeks after	10	1254.70	8.486	1240	1270		
	4 weeks after	10	1218.90	2.644	1215	1225		
Failure stress (Mpa)x10^3	Control group	10	1478.60	4.789	1470	1485	5148.977	S
	1 week after	10	1423.20	4.733	1415	1430		
	2 weeks after	10	1254.70	8.486	1240	1270		
	4 weeks after	10	1218.90	2.644	1215	1225		

N: number; SD: standard deviation; S: significant difference ($p \leq 0.05$).

Table (2): Duncan`s Multiple Analysis Range Test for NiTi Wire.

Property	Group	N	Mean	Duncan's group*
Yield stress (MPa) X 10^3	Control group	10	1063.90	D
	1 week after	10	1032.80	C
	2 weeks after	10	972.20	B
	4 weeks after	10	938.00	A
Ultimate tensile stress (Mpa) X 10^3	Control group	10	1478.60	D
	1 week after	10	1423.20	C
	2 weeks after	10	1254.70	B
	4 weeks after	10	1218.90	A
Failure stress (Mpa) X 10^3	Control group	10	1478.60	D
	1 week after	10	1423.20	C
	2 weeks after	10	1254.70	B
	4 weeks after	10	1218.90	A

N: number; * Different letters mean significant difference at $p \leq 0.05$.

Table (3):The Descriptive and ANOVA Analyses for the spring hard S.S.

Property	Groups	N	Mean	±SD	Min value	Max value	Anova F–value	Sig.
Yield stress (MPa)X 10^3	Control group	10	1613.50	85.960	1375	1690	17.083	S
	1 week after	10	1557.60	3.893	1550	1570		
	2 weeks after	10	1496.50	47.332	1400	1600		
	4 weeks after	10	1419.40	48.551	1312	1470		
Ultimate tensile stress (Mpa) X 10^3	Control group	10	1872.05	43.519	1750	1900	64.903	S
	1 week after	10	1779.20	10.108	1730	1870		
	2 weeks after	10	1650.00	37.431	1610	1850		
	4 weeks after	10	1612.90	6.674	1600	1725		
Failure stress (Mpa)X 10^3	Control group	10	1872.05	43.519	1750	1900	64.903	S
	1 week after	10	1779.20	10.108	1730	1870		
	2 weeks after	10	1650.00	37.431	1600	1850		
	4 weeks after	10	1612.90	6.674	1600	1725		

N: number; SD: standard deviation; S: significant difference ($p \leq 0.05$).

Table (4): Duncan`s Multiple Analysis Range Test for the spring hard S.S.

Property	Group	N	Mean	Duncan's group*
Yield stress (MPa) X 10^3	Control group	10	1613.50	D
	1 week after	10	1557.60	C
	2 weeks after	10	1496.50	B
	4 weeks after	10	1419.40	A
Ultimate tensile stress (Mpa) X 10^3	Control group	10	1872.05	D
	1 week after	10	1779.20	C
	2 weeks after	10	1650.00	B
	4 weeks after	10	1612.90	A
Failure stress (Mpa) X 10^3	Control group	10	1872.05	D
	1 week after	10	1779.20	C
	2 weeks after	10	1650.00	B
	4 weeks after	10	1612.90	A

N: number; * Different letters mean significant difference at $p \leq 0.05$.

DISCUSSION

The significant decrease of all mechanical properties in all intervals in comparison with control group, could be due to the effect of the components of the artificial saliva on arch wire which coats the arch wire. The proteniaceous integument masks the alloy surfaces to an extent that it could depend on the immersion time [9]. The arch wire properties affected in 7 days[10].

For the yield stress of the nickel titanium (NiTi) arch wire, the significant decrease among the second, third and fourth groups; and between the third and second groups is also as the effect of corrosion caused by the artificial saliva and as the immersion time increases the corrosion increases, this agreed with the finding of Walker *et al*.,[11] that pitting and crevices corrosion of the arch wire occur[9,12] due to the effect of electrolyte media[14]. This agrees with Staffolani *et al.,*[13] who stated that NiTi arch wire should be removed after 4 weeks, and disagrees with Lee and Change[14] who stated that there are no changes in NiTi arch wire properties after immersion in artificial saliva.

For the ultimate tensile stress and failures stress of the NiTi, there was significant decrease in all intervals in comparison with control group, this could be due to the effect of artificial saliva on arch wire, this comes in accordance with Jenesen *et al*., [15] who stated that the electrolyte media corroded the alloys.

The NiTi arch wire demonstrates a sign of corrosion which will affect the mechanical properties[16], as a result of the occurrence of hydrogen absorption in saliva at 37 degree[17]. When NiTi arch wire absorbs H_2 it prevents phase transformation causing reduction in the tensile strength[18] by formation of hybrid layer which is reported to form a body centered tetragonal structure responsible for causing degradation of the mechanical properties[11].

Corrosion affected the properties by the surface, as roughness increases corrosion increases too; and this determines the stability of passivation layer[19]. This disagrees with other authors[14,20] who reported that NiTi arch wire does not corrod in the the saliva due to the presence of passivity layer. The significant decrease in the stress among the fourth group, the second and the third and between the third and second is also due to the effect of saliva and duration of incubation; which agrees with Harries *et al*.,[21] who stated that duration of incubation is an important factor, as immersion time increases the corrosion increases too[11].

The significant decrease in all properties of the spring hard stainless steel (S.S) arch wire in all intervals when compared with the control group, this could be due to the fact that the arch wire properties are affected by the immersion in artificial saliva which is due to the effect of the corrosion on the surface of the arch wire[15].

Intra oral exposure of the arch wire alters the topography and the structure of the alloy surface through attacks in the form of pitting and crevice corrosion or the formation of integument on the surface of arch wire[16]. The results are in contrast with that of Smith *et al*.,[22] who reported that the biomechanical properties of the spring hard S.S. arch wire does not differ significantly intra–orally.

The decrease in the fourth group is more significant than the second and the third groups and the decrease in the third group is also more significant than the second group; this indicates that the mechanical properties decreases by increases the immersion period. This goes in agreement with the findings of Shin and Hwang[23], who stated that the corrosion product increases as immersion time increases on the surface of the arch wire as result of corrosion and metal release occurrence.

Shin and Hwang[23] demonstrated that level of metal release as a result of corrosion peak at 7 days and all releases were completed within 4 weeks; this disagrees with that of researchers[12,24] in stating that corrosion does not affect the mechanical properties of arch wire alloy.

CONCLUSIONS

The biomechanical properties of the orthodontic arch wires (super–elastic nickel titanium and spring hard stainless steal) decreased significantly and it is recommended to use them intra–orally for short period to avoid reaching the complete lossof the biomechanical properties.

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