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Elasticity and Plasticity Behaviors of the Orthodontic Arch Wires

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الخلاصة

أهداف الدراسة :تهدف الدراسة لتقدير قيمة المعدل ومقارنة المطاطية مع المرونة لأسلاك النيكل تيتانيوم والاجينول بعد غمسها في اللعاب الاصطناعي لفترة واحد ، اثنان و أربعة أسابيع. **المواد والطرائق:** العينة تتكون من أربع مجاميع (10 أسلاك لكل مجموعة) من أسلاك النيكل تيتانيوم والاجيلويل. الأسلاك اختبرت في الحلات التالية: القياسية، وغمسها فى اللعاب الاصطناعي لمدة واحد، اثنين، ثلاثة و اربعة أسابيع وقد تم احتساب قوة الشد وتم رسم منحنى القوة والمقاومة وثم إيجاد حد معامل والمرونة. وحللت النتائج احصائيا بالقيمة المعنوية بما يساوى او اقل من 0.05. **النتائج:** أظهرت النتائج أن معامل المطاطية وحد المطاطية والمرونة لأسلاك النيكل تيتانيوم والاجيلويل تقل بقيمة معنوية بزيادة فترة الغمس فى اللعاب الاصطناعى. **الاستنتاجات:** انخفاض الصفات الميكانيكبة (معامل المطاطية وحد المطاطية والمرونة) للأسلاك النيكل تيتانيوم والاجيلويل بزيادة فترة الغمس فى اللعاب الاصطناعي لا تشجع استخدامها سريريا لفترة طويلة.

مفتاح الكلمات: معامل المطاطية، حد المطاطية وحد المرونة.

ABSTRACT

Aims: To evaluate the mean value and compare the: elasticity and plasticity of the Nickel Titanium and Elgilloy arch wires after emersion in artificial saliva for one , two and four weeks. **Materials and Methods:** The sample consisted of 80 piece of Nickel Titanium and Elgilloy wires; Each wire divided into four groups (10 wires for each group: control. one, two and four weeks of emersion in artificial saliva). The specimens were tested with tensile procedure and plotted the load stress– strain curve, form this curve can calculate the elasticity modulus, elasticity limit and plasticity limit. The results were subjected to the descriptive statistics, ANOVA and Duncan's Multiple range analyses at $p \leq 0.05$ significant level. **Results:** The Results demonstrated that the modulus of elasticity, elasticity limit and plasticity limit of the Nickel Titanium and Elgilloy arch wires decrease significantly as the emersion time in the artificial saliva increase. **Conclusions:** The decrease of the biomechanical properties (modulus of elasticity, elasticity limit and plasticity limit) of the Nickel Titanium Elgilloy arch wires which subjected to the artificial saliva did not encourage the using of these arch wires clinically for long time.

Key words : Modulus of elasticity, elasticity limit, plasticity.

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INTRODUCTION

Fundamental mechanical properties of metals are related to the amounts of deformation which metals can withstand under different circumstances of force application.[1] The archwire should behave elastically over a period of weeks to months.[2] Elastic modulus is the measure of the stiffness of a material and high numbers are unusual for this property.[3] Klump *et al*.[4] stated that as the modulus of elasticity value increases, the wire stiffness increases too. The slope of the straight–line portion of the stress –strain curve gives a measure of the modulus of elasticity.[5]

The maximum deformation that a body (e.g. wire or appliance part) can undergo before the permanent (plastic) deformation occurs.[6] The resilience is the capacity of the material to absorb energy when its deformed elastically.[7] Ductility indicates the amount of plastic deformation or strain that can occur before the material fracture.[8]

The aims of this study are planned to evaluate and compare the mean values of the elasticity and plasticity of the Elgyloy and Nitinol arch wires which are immersed in artificial saliva for one, two and four weeks.

MATERIALS AND METHODS

The samples comprised of 80 piece wires (40 piece of wires for each of Nickel Titanium and Elgilloy wires. Nickel Titanium wire (0.016″ × 0.016″ Rocky Mountain Orthodontics, U.S.A) and Elgilloy wire (Remanium 0.016″ × 0.016″ Dentarum , Germany) . each type of wires divided into four groups (10 wires of each), The first ,second ,third and fourth groups of the both arch wires were tested at the following conditions: non treated wire (control group),one, two, and four weeks immersion in artificial saliva (PH 6.75±0.015)[9] with incubation at 37 degree centigrade (Incubator; Isotemp; Germany) the most revenant mouth temperature.

Tensile 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.[10] It is recommended in American Dental Association (ADA) specification.[11] All the specimens were tested with tensile testing machine (Zweigle model 73, Belgique). The speed of the machine adjusted as 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 × 10. and then to Mpa by stress = (load in N)/ (surface area of the specimen 2 mm^2). Plotting the load stress – strain curve (Figure 1) from this curve most the mechanical properties can be obtained such as the point at which fracture occurs represents failure stress, the elastic limit (represents the area between zero stress and the yield stress), the plastic limit (represents the area between yield and failure stress) and the modulus of elasticity (which represents tan Ø =stress/strain).[10] The results analyzed by using the Descriptive and (ANOVA and Duncan's Multiple range analyses at $p \leq$ 0.05 significant level).

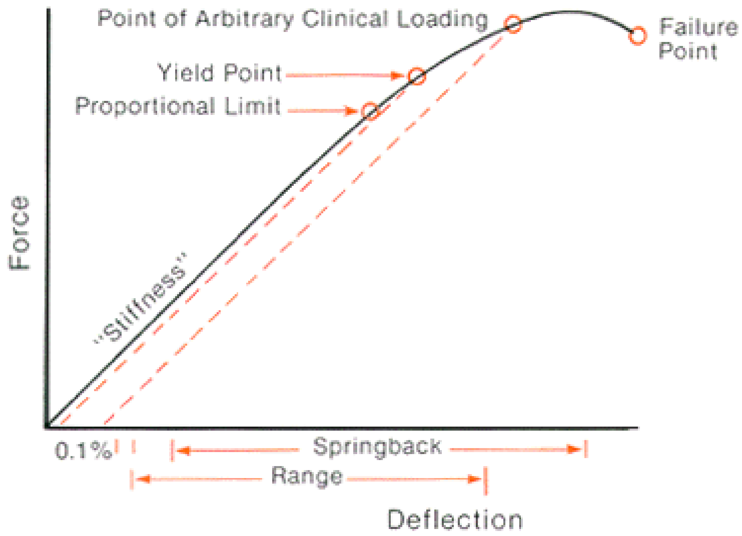

Figure (1): The curve to calculate the modulus of elasticity, elastic limit and plastic limit . Staggers and Margeson[10] Asgharnia and Brantley[11].

RESULTS

The descriptive statistics, ANOVA and Duncan's Multiple range analyses the of modulus elasticity, elastic and plastic limits (mechanical properties) of the Nitinol and Elgilloy arch wires disclosed in (Tables 1, 2, 3 and 4). Both the wires displayed a decrease significantly in their mechanical properties as increasing the arch wire immersion time.

Table (1): The Descriptive analyses and Anova test of the Nitinol wire.

Property	Groups	N	Mean	±SD	Min value	Max value	Anova F–value	Sig
Modulus of elasticity (MPa) x10^3	Control group	10	123.50	2.677	118	127	118.17	S
	1 week after	10	120.20	2.098	115	127		
	2 weeks after	10	116.10	2.558	105	125		
	4 weeks after	10	109.40	3.273	98	120		
Elastic limit (Mpa) x10^3	Control group	10	531.90	1.792	530	535	4173.472	S
	1 week after	10	506.90	1.449	505	510		
	2 weeks after	10	486.40	1.647	480	490		
	4 weeks after	10	470.20	1.687	451	480		
Plastic limit (Mpa) x10^3	Control group	10	1266.00	2.000	1263	1269	2946.999	S
	1 week after	10	1236.20	2.251	1215	1250		
	2 weeks after	10	1217.90	10.148	1107	1241		
	4 weeks after	10	1169.70	2.163	1062	1268		

S: Significant difference (p= 0.001).

Table (2): Duncan`s multiple analysis range test for the NiTi wire.

Property	Groups	N	Mean	Duncan group*
Modulus of elasticity (MPa) x10^3	Control group	10	123.50	D
	1 week after	10	120.20	C
	2 weeks after	10	116.10	B
	4 weeks after	10	109.40	A
Elastic limit (Mpa) x10^3	Control group	10	531.90	D
	1 week after	10	506.90	C
	2 weeks after	10	486.40	B
	4 weeks after	10	470.20	A
Plastic limit (Mpa) x10^3	Control group	10	1266.00	D
	1 week after	10	1236.20	C
	2 weeks after	10	1217.90	B
	4 weeks after	10	1169.70	A

* Different letters mean significant difference at $p \leq 0.05$.

Table (3): The Descriptive analyses and Anova test of the Elgilloy wire

Property	Groups	N	Mean	±SD	Min value	Max value	ANOVA F–value	Sig
Modulus of elasticity (MPa) x10^3	Control group	10	207.60	2.757	205	212	55.163	S
	1 week after	10	204.60	2.875	200	210		
	2 weeks after	10	200.80	2.616	198	205		
	4 weeks after	10	193.00	2.000	190	195		
Elastic limit (Mpa) x10^3	Control group	10	766.10	1.595	765	770	67.335	S
	1 week after	10	741.60	3.565	735	755		
	2 weeks after	10	717.80	32.286	672	777		
	4 weeks after	10	694.20	34.714	534	750		
Plastic limit (Mpa) x10^3	Control group	10	1623.70	1.767	1620	1626	.782	S
	1 week after	10	1591.20	1.317	1560	1634		
	2 weeks after	10	1563.20	1.814	1490	1596		
	4 weeks after	10	1513.60	39.84	1405	1541		

S: significant difference (p= 0.001).

Table (4): Duncan`s multiple analysis range test for the Elgilloy wire.

Property	Groups	N	Mean	Duncan agroup*
Modulus of elasticity (MPa) x10^3	Control group	10	207.60	D
	1 week after	10	204.60	C
	2 weeks after	10	200.80	B
	4 weeks after	10	193.00	A
Elastic limit (Mpa) x10^3	Control group	10	766.10	D
	1 week after	10	741.60	C
	2 weeks after	10	717.80	B
	4 weeks after	10	694.20	A
Plastic limit (Mpa) x10^3	Control group	10	1623.70	D
	1 week after	10	1591.20	C
	2 weeks after	10	1563.20	B
	4 weeks after	10	1513.60	A

* 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 for the Nickel titanium (NiTi) and Elgilloy (Elg) arch wires, could be due to the effect of saliva on arch wire which coats the arch wire with proteniaceous integument. The proteniaceous integument masks the alloy surfaces to an extent that it could depend on the immersion time.[12] The arch wire properties affected in 7 days.[13] The saliva potentially corrodes alloys and the maximum ion release always occurs in 1st day.[14] The decrease in the fourth group is more significant than the second and the third; and the decrease in the third group is also significant than the second group; this indicates that the properties decrease by increase of the immersion period; and this conforms with that of authors.[15,16]

For the modulus of elasticity, elastic limit properties of the NiTi arch wire; the significant decrease of these properties in all intervals compared with control group is due to the corrosion effect of saliva[14] , and arch wire properties are affected in 7 days.[13] Pitting and crevices corrosion occur on the surface of the arch wire,[12] and due to the effect of electrolyte media,[17] this agrees with Kapila *et al.*[18] who suggested that the use of arch wire may be associated with a decrease in the elasticity of arch wire. The researchers[14,19] stated that NiTi arch wire should be removed after 4 weeks; however; disagrees with Buckthal and Kusy.[20] For the plastic limit; the NiTi arch wire gives rise to a significant decrease in the amount of change of mechanical property; this could be due to high stability of the titanium oxide on the surface of the arch wire as stated by Zavanilli *et al*[21] that maximizes the corrosion resistance of the alloy in addition to that titanium has the ability to resynthesis of the passivation film and this agrees with Canay *et al.*[22] who reported that repassivation will be observed on the NiTi arch wire in artificial saliva. The plastic limit properties intra oral exposure of the arch wire causes embrittlement of hydrogen ion in the saliva and leads to degradation of the mechanical properties due to stress crack corrosion of the arch wire.[19] The results are in accordance with that of Tang *et al.*[13] and in contrast to that of Smith *et al.*[23]

The significant decrease in all mechanical properties of the Elgiloy arch wire in all intervals when compared with the control group; could be due to that the arch wire properties are affected by immersion in artificial saliva which is due to the effect of the corrosion on the surface of the arch wire.[24] The modulus of elasticity and elasticity limits of the Elgilloy arch wire are affected by the immersion in the saliva the results are in accordance with that of Tang et al.[13] and in contrast with that of Smith *et al*.[23] (1992) who reported that the Elgilloy wire do not significantly affected by the immersion in saliva. The plastic limit properties intra oral exposure of the arch wire causes embrittlement of hydrogen ion in the saliva and leads to degradation of the mechanical properties due to stress crack corrosion of the arch wire.[19] The results are in accordanced with that of Tang *et al*.[13] and in contrast to that of Smith *et al.*[23]

CONCLUSIONS

The conclusions of this study are that the elasticity and plasticity of the Nickel Titanium and Elgilloy arch wires are decrease significantly when increasing the immersion time. It is recommended to not elongate the time of using these arch wires in the clinical treatment.

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