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The Mechanical Properties of the Extra Hard Spring Arch Wire Subjected to the Artificial Saliva

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ABSTRACT

Aims: To evaluate and compare the value of the mechanical properties of the extra hard spring stainless steel arch wire immersed in artificial saliva. **Materials and Methods:** The sample consisted of 40 extra hard spring stainless steel arch wires (Remanium, 0.016″ × 0.016″, Dentarum, Germany) divided into; control wires group and experimental group (ten wires for each group). The experimental group was immersed in artificial saliva (PH 6.75+ 0.015)) and incubated at 37 for one, two and four weeks respectively. The curve of tensile strength for the control and experimental groups was performed using the tensile testing machine. The mechanical properties of the arch wire have been derived. The results were analyzed using the statistics of descriptive, Anova and Duncan's Multiple Range Analysis tests. **Results:** The results showed that the mechanical properties (ultimate tensile strength, elastic modulus, springiness (springback) ,elastic limit, plastic limit (ductility) of the extra spring hard stainless steel arch wire significantly decrease as the immersion time in artificial saliva increase when compared with the control group. **Conclusions:** It is recommended not utilize the extra spring hard stainless steel arch wire for long periods during orthodontic treatments.

Key words: Yield stress, ultimate tensile, elastic modulus, springiness, elastic limit, plastic limit.

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INTRODUCTION

Hibbeler [1] defined the mechanic of material as the study of the relationship between the external loads applied to a deformable body and the intensity of the internal force acting within the body. Changes in the field of mechanotherapy have largely been made possible with the emergence of new orthodontic materials; arch wire materials formed a large part of these changes. Selecting the appropriate arch wire requires a thorough knowledge of arch wire biomechanical and clinical application [2].

The important mechanical properties of the orthodontic arch wires include: Yield stress [3], ultimate tensile strength [4], springiness (springback) [5], elastic limit [6], plastic limit (ductility) [7]. Understanding the basic material characteristics became essential for selecting wires for use in the treatment [8]. Changes in the mechanical properties of orthodontic alloy were studied in a simulated oral environment across time [9].

The aims of this study are to compare the mechanical properties of the extra spring hard stainless steel arch wire; which were subjected to artificial saliva for one week, two weeks and one month.

MATERIALS AND METHODS

The sample consisted of 40 extra spring hard stainless steel arch wires (Remanium, 0.016″ × 0.016″, Dentarum, Germany) divided into; control wire group (ten wires) and three experimental wire groups (ten wires for each group). The samples were washed with distal water and immersed in 70 % ethanol for 4–5 sec and then immersed in acetone (act as a volatile organic solvent) and dried by air. The control wire group consisted of new arch wires. The three experimental groups were immersed in artificial saliva (PH 6.75+ 0.015) [10] and incubated at 37 (the most revenant mouth temperature [11] for one, two, and four weeks respectively.

Tensile testing is one of the most

useful mechanical tests because of the data that can be obtained using it. These data represent the mechanical properties which describe the behavior of the material that is subjected to the mechanical force [12]. These properties are related to the amount of deformation which the specimen can withstand under different circumstances of force application. The tensile testing machine used was (Zweigle) model 73. The speed of the machine was adjusted to 0.5 mm/sec. The curve of the tensile strength of the control and experimental groups was performed using the tensile testing machine. The mechanical properties of the arch wire have been derived according to the author suggestions [12] (Figure 1).

The results were analysed using the statistics of descriptive, Anova and Duncan's Multiple Range Analysis tests at $p \leq 0.05$ signficant level.

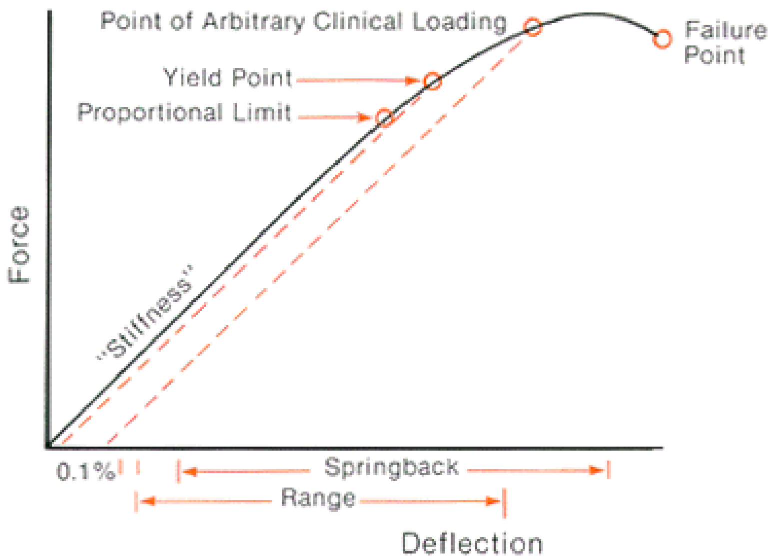

Figure (1): The load tensile curve. (Staggers and Margeson [9] Asgharnia and Brantley [10].

RESULTS

The results of descriptive statistics (mean, standard deviation, menimum and maximum values), Anova and Duncan's Multiple Range Analysis are demonstrated in Tables (1,2).

The mechanical properties (yield stress, ultimate tensile stress, springiness, elastic limit and plastic limit) of the extra spring hard stainless steel arch wire groups which were immersed in artificial saliva for one, two and four weeks disclosed significant less values as compared with the control wire group.

These differences increased as the immersion time increases.

Table (1): The Descriptive statistics of the mechanical properties of the extra hard spring SS arch wire.

Property	Groups	N	Mean	±SD	Min value	Max value
Yield stress (MPa) X 10^3	**Control group**	10	1558.70	8.247	1540	1570
	1 week after	10	1492.00	6.749	1490	1515
	2 weeks after	10	1406.45	3.059	1460	1470
	4 weeks after	10	1302.40	3.307	1428	1437
Ultimate tensile stress (Mpa) X 10^3	**Control group**	10	2186.90	3.281	2180	2190
	1 week after	10	1936.25	2.595	1930	1940
	2 weeks after	10	1861.40	6.293	1850	1870
	4 weeks after	10	1849.15	16.228	1840	1895
Springiness	**Control group**	10	7.110	.0738	7.0	7.2
	1 week after	10	6.982	.0621	6.9	7.1
	2 weeks after	10	6.628	.0598	6.5	7.1
	4 weeks after	10	6.451	.1005	6.4	7.2
Elastic limit (Mpa) X 10^3	**Control group**	10	779.30	4.084	770	785
	1 week after	10	745.50	10.331	720	757
	2 weeks after	10	699.40	1.578	690	735
	4 weeks after	10	645.00	1.414	644	718
Plastic limit (Mpa) X 10^3	**Control group**	10	1872.20	5.412	1860	1880
	1 week after	10	1716.20	10.401	1687	1722
	2 weeks after	10	1663.60	3.836	1657	1670
	4 weeks after	10	1642.30	3.401	1635	1645

Table (2): Aonova and Duncan`s tests for the mechanical properties of the four groups of extra hard spring SS arch wire.

Property	Groups	N	Mean	Anova test F value	Anova test P value	Duncan 's Test
Yield stress (MPa) X 10^3	**Control group**	10	1558.70	870.174	.000	D
	1 week after	10	1492.00			C
	2 weeks after	10	1406.45			B
	4 weeks after	10	1302.40			A
Ultimate tensile Stress (Mpa) X 10^3	**Control group**	10	2186.90	3081.084	.000	D
	1 week after	10	1936.25			C
	2 weeks after	10	1861.40			B
	4 weeks after	10	1849.15			A
Springiness	**Control group**	10	7.110	10.995	.000	D
	1 week after	10	6.982			C
	2 weeks after	10	6.628			B
	4 weeks after	10	7.451			A
Elastic limit (Mpa) X 10^3	**Control group**	10	779.30	225.439	.000	D
	1 week after	10	745.50			C
	2 weeks after	10	699.40			B
	4 weeks after	10	645.00			A
Plastic limit (Mpa) X 10^3	**Control group**	10	1872.20	2687.815	.000	D
	1 week after	10	1716.20			C
	2 weeks after	10	1663.60			B
	4 weeks after	10	1642.30			A

Anova test (Significant at $p< 0.001$); Different letters mean significant difference at $p\leq 0.05$.

DISCUSSION

There was a significant decrease in all mechanical properties of the extra spring hard SS arch wire groups (one, two and four weeks immersion periods). The significance in the lowering values increased as the immersion time increased; this could be due to the fact that arch wire properties are affected by immersion in artificial saliva which is due to the effect of corrosion on the surface of the arch wire [(13)]. The amount of each property is arranged from a high to low and as follows: control group, 1 week after, 2 weeks after and 4 weeks after.

It was stated that the yield stress and elastic limit properties of the extra spring hard SS arch wire are affected by intra oral exposure. The topography and the structure of the alloy surface alters through attacks in the form of pitting, crevice corrosion or the formation of integument on the surface of arch wire [(14)]. The results are in accordance with that of Tang *et al*., [(15)], who stated that all arch wires suffer degradation of their mechanical properties within 7 days only and were in contrast to that of Smith *et al*.,[(16)], who reported that no significant differences could be detected between new and used arch wires.

The significant decrease in mechanical properties of the wire were seen among the groups of each property. This indicates that the longer the immersion time in artificial saliva , the higher the degradation in the mechanical property. This came in agreement with the findings of Shin and Hwang [(17)], who stated that corrosion product increased as immersion time increase on the surface of the arch wire as a result of corrosion and the occurrence of the metal release [(17)], they also demonstrated that the level of metal release as a result of corrosion reaches the peak at 7 days and all releases complete within 4 weeks. However this disagrees with that of Eliades *et al*., [(18)] who stated that corrosion dose not affect the mechanical properties of arch wire alloy.

For the ultimate tensile stress, 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 the stress crack corrosion of the arch wire [(14)]. The significant decrease in the fourth group is more than the second and third groups; the third group is also significantly decreased compared to the second group; this indicates that the mechanical properties are decreased as the immersion period increases. This agrees with that of others [(17,19)], who stated that when SS adsorbs the hydrogen ion, degradation of the mechanical properties occur and the tensile strength decreases. This also agrees with Acharya and Jayade [(20)] who stated that there is a significant decrease in the stress relaxation (plastic limit) after exposure to saliva. However, this disagrees with that of Praymak *et al*.,[(21)] who stated that SS arch wire has constant mechanical properties; that is corrosion does not affect the mechanical property of arch wire alloy.

The springiness property represents a relation between the yield stress and the modulus of elasticity, hence the environment that affect yield stress and the modulus of elasticity will affect it; also as the yield stress and the modulus of elasticity are affected by the immersion in the saliva. The results agree with that of Tang *et al.*,[(15)]. This however is in contrast with that of Smith *et al*.,[(16)].

The decrease in the fourth group is more significant than the second; the decrease in the third group is also more significant than the second group. This indicates that both properties are decreased as the immersion period increases; this agrees with that of Han and Quick [(22)] but disagrees with that of Eliades *et al*., [(18)].

CONCLUSIONS

The mechanical properties (yield stress, ultimate tensile stress, modulus of elasticity, modulus of elasticity, springiness, elastic limit, plastic limit) of the extra hard spring SS significantly decrease with increasing immersion in artificial saliva.

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