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Evaluation of The Effect of Immersion Periods in The Artificial Saliva on The Surface Roughness of Three Types of orthodontic Arch Wires

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ABSTRACT

Aims: To evaluate the effect of immersion periods in artificial saliva on the surface roughness of an arch wire. **Materials and Methods:** The roughness of three types of orthodontic arch wires: stainless steel (SS), titanium molybdenum alloy (TMA) and composite coated wire (CC) were first measured at dry condition then incubated in artificial saliva at 37 ^{o}C with saliva pH (7.25) for different immersion periods (1, 14 and 28 days). Then the surface roughness was measured by using Taylor Hobson Profilometer (Talysurf type 10). **Results**: There was a significant increase in surface roughness of the three types of wires during the first day of immersion but as the immersion periods increased, it showed a non significant difference in the roughness of SS and TMA. The roughness of CC however, increased. **Conclusions:** It was concluded that the surface roughness of SS and TMA wires increased during the first day of immersion, such increase is not significant after that, while in case of CC, as the immersion periods increase the surface roughness significantly increased.

Key Words: Surface roughness, arch wire, artificial saliva, sliding.

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INTRODUCTION

Intra–orally placed materials (i.e. wires, brackets) exhibit a pattern of continuous reaction with the environmental factors present in the open oral cavity (1). The oral environment is particularly ideal for the biodegradation of metals because of its thermal, microbiologic and enzymatic properties (2). These environmental conditions of the oral cavity might alter the morphological, structural and compositional characteristics, force delivery of arch wires, super elasticity and fracture of orthodontic alloys (3). According to the method of production, all surfaces have their own characteristics which are collectively referred to as surface texture (4). Surface texture is the pattern of surface which deviates from a nominal surface. The deviations may be repetitive random and may result from roughness, waviness, lay and flaws (5). Roughness: Consists of the finer irregularities of the surface texture, usually including those irregularities that result from the inherent action of the production process (5). Waviness: It is a more widely spaced irregularities, it is also called macro–texture (6). Lay: It is the direction of the predominant surface pattern, normally determined by the production method (5). Flaws: They are unintentional, unexpected, and unwanted interruptions in the topography typical of a part surface (5). The terms of surface finish and surface roughness are used very widely in the industry, and are generally used to quantify the smoothness of a surface finish (5). Surface roughness is a parameter influencing the coefficient of friction between bracket and arch wire during orthodontic tooth movement by sliding mechanics. It may also influence plaque accumulation on the orthodontic appliances and teeth as well as the degree of corrosion of metallic appliance (7). Dental materials have to withstand mechanical, thermal and chemical stresses in the patient mouth and most have a sufficient biocompatibility in this aggressive environment. Consequently, the surface quality, i.e. the surface roughness of dental material is of outmost importance, as this determines the area of contact surface and thus influences the corrosion behavior and the biocompatibility [8]. In orthodontics, surface roughness of orthodontic arch wires may also affect the esthetics of the appliance and the performance of sliding mechanics by its influence on the coefficient of friction [9]. Rough surfaces also can host in their fissures and pockets, an environment which is often more deterrent than the surrounding oral one [10]. The aim of the study is to evaluate the effect of immersion periods in the artificial saliva on the surface roughness of an arch wire.

MATERIAL AND METHODS

Arch wire materials of three types: Stainless steel (SS), Titanium molybdenum alloy (TMA) and Composite coated (CC), which is rectangular in cross section, size (0.017×0.025 inch) (Dentaurum, Germany) were used in this study, the following equipment and materials were also used: Tweezers (Derfla, Germany), Parallel action diagonal cutter (USA), Dental vernier, Chemical substances used for artificial saliva preparation (NaCl 400mg/L, KCL 400mg/L, CaCl2.2H2O 795mg/L, NaH2PO4.H2O 690mg/L, Na2S.9H2O 5mg/L, Urea 1000 mg/L and Deionized water, Digital pH Meter (Metrohm, Japan), Glass containers (Petri dish) (England), Glass pipette (Germany), Glass cylinder (Germany), Glass Funnel (England), Glass rod (Germany), Electronic balance (mettler toledo), PG503–S (Switzerland), Thermometer (–100 ^{o}C–+1100^{o}C, China), Incubator (Memmert, Germany), Profilometer: surface roughness measurement machine (Taylor Hobson type 10, U. K. Leicester, England).

The Stainless Steel, Titanium Molybdenum Alloy and Composite Coated wires were cut into pieces (tested samples) by using a wire cutter, each piece of 4cm in length. The tested samples were divided into two main groups (Dry and Wet condition groups), the dry condition group included (SS, TMA and CC) each of 10 tested samples, while the wet condition group included the tested samples that immersed in artificial saliva pH 7.25 for different immersion periods as follow: 1. SS immersed for 1, 14 and 28 days. 2. TMA immersed for 1, 14 and 28 days. 3. CC immersed for 1, 14 and 28 days. Each of 10 tested samples. The total tested samples of the dry and wet condition groups are 120. For the wet condition group, the artificial saliva is prepared according to Huang [11], and then each group (10 samples) was immersed in a glass container that contains 50 ml of artificial salvia. The tested samples were then incubated for a different immersion periods (1, 14 and 28 days) in the artificial saliva at 37 ^{o}C by using an incubator, then the surface roughness was measured by using a profilometer. The surface roughness of the dry condition group was also measured using a profilometer.

The data were subjected to statistical analysis which included: Descriptive Statistics, Analysis of Variance (ANOVA) and Duncan Multiple Analysis Range Test.

RESULTS

The descriptive statistics that includes mean, standard deviations, standard error, minimum and maximum values of surface roughness at dry condition are listed in Table (1).

The findings of the present study showed that CC gave rise to the highest mean of surface roughness in comparison with remaining materials, while SS gave rise to the lowest one.

Table (1): Descriptive Analysis (Mean, Standard Deviations, Standard Error, Minimum and Maximum Value) of surface roughness at Dry Condition.

No.	Materials	N	Mean*	SD	SE	Min.	Max.
1	CC	10	0.2370	0.01252	0.00396	0.22	0.25
2	SS	10	0.0350	0.00707	0.00224	0.03	0.05
3	TMA	10	0.1510	0.01197	0.00379	0.11	0.15

* Mean unit is micron**.**

The analysis of variance (ANOVA) for the surface roughness of the three materials in dry condition showed a significant difference (P<0.001) among them as shown in Table (2).

The result of Duncan Multiple Analysis Range Test, Table (3) showed that CC gave rise to the highest mean of surface roughness with a significant difference (P≤0.05) in comparison with SS and TMA, while SS gave rise to the lowest mean of SR with significant difference when compared with CC and TMA.

Table (2): One–Way ANOVA Analysis of Dry Condition.

	Sum of Squares	Degree of freedom	Mean Square	F–test	Sig.
Between Groups	0.204	2	0.102		
Within Groups	0.003	27	0.000	875.771	<0.001
Total	0.207	29			

Table (3): Duncan's Test of Dry Condition.

Materials	Mean*± SE	Duncan groups**
SS	0.0350±0.00224	A
TMA	0.1510±0.00379	B
CC	0.2370±0.00396	C

*Mean unit is micron;**Different letters mean significant difference at P≤0.05.

The descriptive statistics that includes mean, standard deviations, standard error, minimum and maximum value of surface roughness for SS, TMA and CC that immersed for one day in artificial saliva are listed in Table (4).

This study showed that CC gave rise to the highest mean of surface roughness in comparison with SS and TMA, while SS gave rise to the lowest mean.

The analysis of variance (ANOVA) for the three materials showed a significant difference (P<0.001) among the three materials as presented in Table (5).

Table (4): Descriptive Analysis (Mean, Standard Deviations, Standard Error, Minimum and Maximum Value) of surface roughness for SS, TMA and CC that immersed for one day.

No.	Materials	N	Mean*	SD	SE	Min.	Max.
1	**CC**	10	0.2990	0.00876	0.00277	0.29	0.32
2	**SS**	10	0.0750	0.00707	0.00224	0.06	0.08
3	**TMA**	10	0.2310	0.00738	0.00233	0.22	0.24

*Mean unit is micron.

Table (5): One–Way (ANOVA) Analysis of SS, TMA and CC that immersed for one day.

	Sum of Squares	Degree of freedom	Mean Square	F–test	Sig.
Between Groups	0.264	2	0.132		
Within Groups	0.002	27	0.000	2184.736	<0.001
Total	0.265	29			

The results of Duncan Multiple Analysis Range Test, Table (6) showed that CC gave rise to the highest mean of surface roughness with a significant difference (P≤0.05) in comparison with SS andTMA, while SS gave rise to the lowest mean of surface roughness with significant difference when compared with CC and TMA**.**

Table (6): Duncan's Test of SS, TMA and CC that immersed for one day.

Materials	Mean*±SE	Duncan groups**
SS	0.0750±0.00224	A
TMA	0.2310±0.00233	B
CC	0.2990±0.00277	C

*Mean unit is micron; ** Different letters mean significant difference at P≤0.05.

The descriptive statistics that includes mean, standard deviations, standard error, minimum and maximum value of surface roughness for SS, TMA and CC that immersed for 14 days are listed in Table (7).

The findings of the present study showed that CC gave rise to the highest mean of surface roughness in comparison with SS and TMA, while SS gave rise to the lowest one.

Table (7): Descriptive Analysis (Mean, Standard Deviations, Standard Error, Minimum and Maximum Value) of surface roughness for SS, TMA and CC that immersed for 14 days.

No.	Materials	N	Mean*	SD	SE	Min.	Max.
1	**CC**	10	0.2980	0.01398	0.00442	0.28	0.32
2	**SS**	10	0.0770	0.00823	0.00260	0.06	0.09
3	**TMA**	10	0.2220	0.01751	0.00554	0.20	0.24

*Mean unit is micron.

The analysis of variance (ANOVA) for the three materials showed a significant difference (P<0.001) among them as presented in Table (8).

The results of Duncan Multiple Analysis Range Test, Table (9) showed that CC gave rise to the highest mean of surface roughness with significant difference (P≤0.05) in comparison with SS and TMA, while SS gave rise to the lowest one.

Table (8): One–Way (ANOVA) Analysis of SS, TMA and CC that immersed for 14 days.

	Sum of Squares	Degree of freedom	Mean Square	F–test	Sig.
Between Groups	0.252	2	0.126		
within Groups	0.005	27	0.000	663.526	<0.001
Total	0.257	29			

Table (9): Duncan's Test of SS, TMA and CC that immersed for 14 days.

Materials	Mean*± SE	Duncan groups**
SS	0.0770±0.00442	A
TMA	0.2220±0.00554	B
CC	0.2980±0.00442	C

*Mean unit is micron; ** Different letters mean significant difference at P≤0.05.

The descriptive statistics that includes mean, standard deviations, standard error, minimum and maximum value of surface roughness for SS, TMA and CC that immersed for 28 days are listed in Table (10).

The findings of the present study showed that CC gave rise to the highest mean of surface roughness in comparison with SS and TMA, while SS gave rise to the lowest one.

Table (10): Descriptive Analysis (Mean, Standard Deviations, Standard Error, Minimum and Maximum Value) of surface roughness for SS, TMA and CC that immersed for 28 days.

No.	**Materials**	**N**	**Mean***	**SD**	**SE**	**Min.**	**Max.**
1	**CC**	10	0.3790	0.01287	0.00407	0.36	0.40
2	**SS**	10	0.0730	0.00823	0.00260	0.06	0.08
3	**TMA**	10	0.2220	0.01619	0.00512	0.20	0.24

*Mean unit is micron.

The analysis of variance (ANOVA) for the three materials showed a significant difference (P<0.001) among them as demonstrated in Table (11).

The results of Duncan Multiple Analysis Range Test, Table (12) showed that CC gave rise to the highest mean of surface roughness with a significant difference (P≤0.05) in comparison with SS and TMA, while SS gave rise to the lowest one

Table (11): One–Way (ANOVA) Analysis for SS, TMA and CC that immersed for 28 days.

	Sum of Squares	**Degree of freedom**	**Mean Square**	**F–test**	**Sig.**
Between Groups	0.468	2	0.234		
Within Groups	0.004	27	0.000	1417.460	<0.001
Total	0.473	29			

Table (12): Duncan's Test of SS, TMA and CC that immersed for 28 days.

Materials	**Mean*± SE**	**Duncan groups****
SS	0.0730±0.00260	A
TMA	0.2220±0.00512	B
CC	0.3790±0.00407	C

*Mean unit is micron; ** Different letters mean significant difference at P≤0.05.

The analysis of variance (ANOVA) of SS that immersed for (1, 14 and 28) showed non significant difference (P<0.001) among the three periods as shown in Table (13).

The analysis of variance (ANOVA) of the TMA that immersed for (1, 14 and 28) showed non significant difference (P<0.001) among the three periods as presented in Table (14).

Table (13): One–Way (ANOVA) Analysis of SS that immersed for (1, 14 and 28 days).

	Sum of Squares	**Degree of freedom**	**Mean Square**	**F–test**	**Sig.**
Between Groups	0.000	2	0.000		
Within Groups	0.002	27	0.000	0.647	0.532
Total	0.002	29			

Table (14): One–Way (ANOVA) Analysis of TMA that immersed for (1, 14 and 28 days).

	Sum of Squares	Degree of freedom	Mean Square	F–test	Sig.
Between Groups	0.001	2	0.000		
Within Groups	0.006	27	0.000	1.299	0.289
Total	0.006	29			

The analysis of variance (ANOVA) of the CC that immersed for (1, 14 and 28 days) showed a significant difference (P<0.001) among them as demonstrated in Table (15).

Table (15): One–Way (ANOVA) Analysis of CC that immersed for (1, 14 and 28 days).

	Sum of Squares	Degree of freedom	Mean Square	F–test	Sig.
Between Groups	0.043	2	0.022		
Within Groups	0.004	27	0.000	148.043	<0.001
Total	0.047	29			

The results of Duncan Multiple Analysis Range Test, Table (16) showed that CC that immersed for 28 gave rise to the highest mean of surface roughness with a significant difference (P≤0.05) in comparison with CC that immersed for one day and CC that immersed for 14 days, while both CC that immersed for 14 days and CC that immersed for 1 day gave rise to the lowest mean of surface roughness with a non significant difference in between, but with a significant difference when compared with CC that immersed for 28 days.

Table (16): Duncan's Test of CC that immersed for (1, 14 and 28 days).

Methods	Mean*± SE	Duncan groups**
CC immersed for 1 day	0.2990±0.00277	A
CC immersed for 14 days	0.2980±0.00442	A
CC immersed for 28 days	0.3790±0.00407	B

*Mean unit is micron; ** Different letters mean significant difference at P≤0.05.

DISCUSSION

The results of the present study showed a significant difference of surface roughness among the three materials used in dry condition, where SS gave rise to a significant decrease of surface roughness in comparison with TMA and this is in agreement with Bourauel *et al.*, [9] who found in their studies that SS was the smoother when compared with TMA.

The CC, on the other hand, showed a significant increase in the surface roughness when compared with the remaining materials, and this may be attributed to both manufacturing process and the type of surface coating that play a role in the differences in roughness, also the quality and grain size of the abrasives used for Composite materials in artificial saliva, polishing influence the smoothness of wire surface as reported by Wichelhaus *et al.*, [12].

The present study showed that the immersion of SS, TMA and CC in artificial saliva for one day gave rise to a significant difference among them, whereas SS showed a significant decrease in surface roughness when compared with TMA and CC. This may be due to the metal ion release from these materials or corrosion process, and this is in accordance with Hwang *et al* [13].

When CC was immersed in artificial saliva for one day, it showed a significant increase of surface roughness when compared with SS and TMA. This may be attributed to the dislodgement of fillers from and this is in agreement with Ferracane and Condon [14].

When SS and TMA were immersed in artificial saliva for 14 and 28 days, it appeared that the significant level of difference remained the same between them, and this is in agreement with other researchers [15,16] who mentioned that the corrosion of the appliances reaches a plateau after 6 days and does not increase appreciably after that.

The present study shows that the immersion of CC for 14 and 28 day in artificial saliva gave rise to a significant difference between these periods, whereas the immersion of CC for 28 day gave rise to a significant increase of surface roughness when compared with 14 day, and this is in agreement with Yip and To [17] who stated that when the duration of immersion of composite in artificial saliva increase, all of composite materials showed a trend of increasing surface roughness such increase is significant before and after two weeks.

CONCLUSIONS

It was concluded that the surface roughness of SS and TMA wires increased during the first day of immersion in artificial saliva, such increase is not significant after that, while in case of CC as the immersion period increase the surface roughness significantly increased.

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