An Evaluation of Corrosion Pits in Esthetic Coated Stainless Steel Orthodontic Archwires in Dry and Wet Environment at Different Intervals (*An In Vitro Study*)

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ABSTRACT

Background: The demand for esthetic orthodontic appliances is increasing; so the esthetic orthodontic archwires were introduced. Among them, Teflon and Epoxy coated stainless steel archwires. The amount of force available from the archwire depends on the structural properties and susceptibility to corrosion. All metallic alloys are changed during immersion in artificial saliva, chlorhexidine mouthwash andtoothpaste, but their behaviors differ from one type to another. They corrode at different rates, which lead to decrease the amount of force applied to the teeth. This *in vitro* study was designed to evaluate the corrosion pits in stainless steel archwires coated with Teflon and with Epoxy in dry and after immersion in artificial saliva, chlorhexidine(0.2%) (Parodontax) and toothpaste media (Sensodyne) for (1, 7 and 28) days intervals. Moreover, this study is intended to compare the corrosion pits for each type of archwires at these different media among all intervals.

Materials and Methods: In this study, two hundred forty pieces of orthodontic wires of Teflon (Hubit) coated Stainless steel (120 pieces) and epoxy (Orthotechnology) coated Stainless steel (120 pieces), rectangular in cross section, size (0.019 x 0.025) inch and 15mm in length divided into four groups according to immersion media: (dry environment group, artificial saliva group, chlorhexidine group and toothpaste group). The atomic force microscope was used to measure the corrosion pits for all samples at dry and wet conditions and after different immersion periods.

Results: Statistical analysis showed that there was a highly significant increase in the corrosion pits of Teflon coated stainless steel archwires ($P \leq 0.05$) in wet environment at 28 days immersion period.The highest corrosion pits were found in the toothpaste medium for the two archwire types at 28 days immersion period.

Conclusion: We can conclude that Epoxy coatedstainless steel archwires are indicated to be used above Teflon coated stainless steel archwires in terms of corrosion resistance. IfTeflon coated stainless steel archwires should to be used, they should be change in shorter periods than Epoxy coated stainless steel archwires type

Key words: Esthetic coated archwire, corrosion, Teflon, Epoxy, wet environment, AFM. (J Bagh Coll Dentistry 2016; 28(1):153-157).

INTRODUCTION

Appearance is one of patients' main concerns during orthodontic treatment so there is a growing demand for esthetic appliances [(1,2)] but most fixed orthodontic appliance components are metallic and silver in color [(3)]. This demand has led to the development of orthodontic appliances with acceptable esthetics both for patients and for clinicians [(4)]. This problem has been partially solved by the introduction of esthetic brackets made of ceramic or composite [(5,6)]. However, most archwires are still made of metal such as stainless steel and nickel-titanium, a number of alternatives have been explored to create an esthetic arch wire [(7,8)]. Among these alternatives, coated wires with polymeric materials have been developed [(9,10)]. Materials used in the coating process are Teflon or epoxy resin. The coating manufactured with a process, which plates the base wire [(11)].

The conditions in the mouth are very suitable for the occurrence of corrosion because the oralcavity is warm and wet. The oral environment is particularly ideal for the biodegradation of metal because of its thermal, microbiologic and enzymatic properties [(12)]. These environmental conditions of the oral cavity might alter the morphological characteristics of archwires [(13)].

The ideal archwire is the wire that can withstand the extreme conditions of the mouth [(14)].

Orthodontic alloys must have excellent resistance to corrosion especially in the oral environment. This corrosion resistance is very important for two reasons first is biocompatibility and second is orthodontic appliance durability [(15)]

Understanding the basic material characteristics becomes essential for selecting wires for use in the treatment. Materials used in dentistry must have specific characteristics such as biological safety, adequate tissue response, and resistance to corrosion because they remain in the oral cavity and subjected to the oral environment's physical properties (chemical and microbiological properties), that stimulate the dissolution of metals [(16)].

Therefore, the objectives of this study were three. First, to evaluate and compare the effect of Teflon and Epoxy coating material in the corrosion pits of Stainless Steel, second, to evaluate and compare the effect of dry and wet environment, and third, to evaluate the effect of immersion time.

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MATERIALS AND METHODS

Total number of (240) pieces of upper-coated stainless steel orthodontic archwires, (120) selected from Ortho Technology Company, (Brazil) and (120) selected from Hubit Company, (Korea) were tested for corrosion. The specimens used in the present study having a rectangular (0.019 × 0.025 inch) cross section and cut in to pieces of (15 mm) length. These pieces of wires divided in to four groups according to the media they immersed in them.

They subdivided into three groups according to the period of immersion. Thirty pieces of each wire's type were left in dry environment for 1, 7 and 28 days intervals. Another thirty pieces of each wire's type were immersed in Artificial saliva (pH = 6.75 ± 0.15) (400 mg/LNaCl, 400 mg/L KCl, 795 mg/L$CaCl_2.2H_2O$, 690 mg/L$NaH_2PO4.H_2O$, 5 mg/L $Na_2S.9H_2O$, 1000 mg/L Urea, 500 ml Deionized water, 500ml Distilled water)[17,18,19], Chlorhexidine mouthwash (GSK, Germany, Exp: 06 /2015) and Toothpaste (GSK, UK, Exp: 06 /2015). These wire's pieces were incubated in covered glass containers at 37C˚ for the entire testing period [20].

The corrosion pits measurements made at the following time intervals: 1day, 7 days and 28 days. Corrosion pits measurements were obtained by Atomic Force Microscope (AFM; JPK Nanowizard, Nr: H-01-0086, and JPK Image Processing software, version 3.0; JPK Instruments AG, Berlin, Germany) with a non-contact tip coated with silicon (NCLR-20; NanoWorld, Neuchatel, Switzerland), with a constant force of 48 N/mm and resonance frequency of 190 kHz (figure 1).

After preparation, the samples were washed withdistilled water and immersed in 70% ethanol for 4-5 seconds and thenimmersed in acetone (act as a volatile organic solvent) for 8-10 seconds and dried by dryair for one minute. This method of cleaning used to remove all contaminated layerformed on the alloy during storage [21].

The artificial saliva was replaced every 7 days with a fresh solution to avoid its saturation with the corrosion products [22,23].

The chlorhexidine solution was used according to the manufacturer instruction and the samples were immersed completely in the solution in the test tubes and covered perfectly by theirs covers, shake by the shaker for 1 minute, then they were removed and washed with distilled water, dried by dry air and re-put in the artificial saliva**,** then incubated at 37^0C. This procedure would be repeated 2 times daily for (1day, 7 days, and 28 days) intervals [20].

The samples of the Toothpaste groups were immersed completely in the paste on a slap for 2minutesAfter the 2 minutes were completed successfully the wires were removed and washed with distilled water, dried by dry air water and re-put in the artificial saliva**,** then incubated at 37 ^{0}C. This procedure would be repeated 3 times daily for (1day, 7 days, and 28 days) intervals [20].

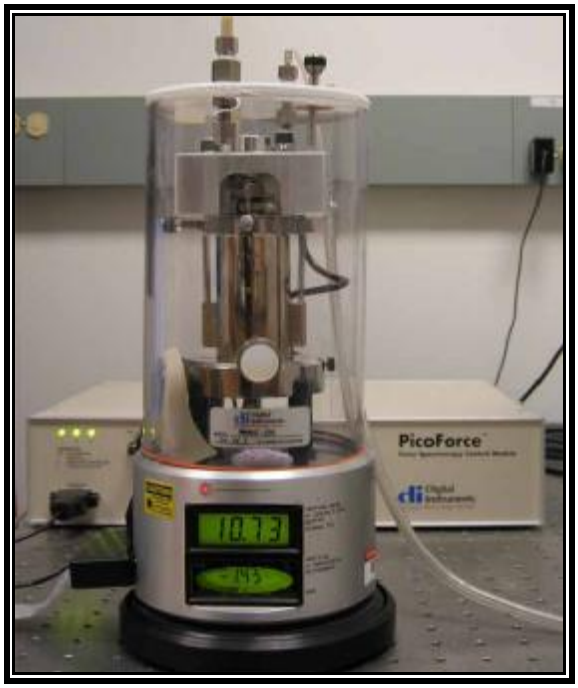

Figure 1: Atomic Force Microscope (AFM).

Statistical Analysis

Data collected analyzed by using relevant software Statistical Package of Social Science (SPSS, Chicago, 21). These data of the corrosion pits for all specimens averaged, and the results analyzed with the following statistics:

1. Descriptive statistics :(mean of corrosion pits and its standard deviation).
2. Inferential statistics: {Independent sample t-test, One Way Analysis of Variance (ANOVA) and Least Significant Difference (LSD)}.

RESULTS

The Effect of Coating Material:

Dependent sample of t-test showed non-significant coating type difference in the corrosion pits in dry environment at different intervals and when the wires were immersed in Chlorhexidine for 1 day and in the Toothpaste for 1 day and 7 days. On the other hand, there was highly significant difference when the wires immersed in the remaining media at different intervals (table 1).

The Effect of the Immersion Media:

Analysis of variance difference (ANOVA) has demonstrated a non-significant difference among the media at the first day of immersion of the two wire's type but showed a highly significant difference at 28 days. On the other hand, it revealed a highly significant media effect difference of Hubit and a non-significant difference of Orthotechnology at 7 days immersion period (table 2).

The Effect of the Time Intervals:

The time interval has non-significant effect on the corrosion pits at dry environment. Analysis of variance difference (ANOVA) has demonstrated highly significant differences among the different intervals in wet environment except that for Epoxy coated stainless steel at Chlorhexidine (table 3).

Table 1: The Effect of Coating Material Difference for Each Wire Immersed in Specific Media for Different Intervals.

Media	Intervals	Descriptive Statistics				Company Difference (d.f.=18)		
		Hubit		Orthotechnology				
		Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Difference	t-test	p-value
Dry	1 day	0.000375	0.000196	0.00039	0.000229	-0.000015	-0.158	0.876
	7 days	0.000401	0.000201	0.000351	0.000175	0.000050	0.594	0.560
	28 days	0.000355	0.000166	0.000364	0.000228	-0.000009	-0.101	0.921
Artificial Saliva	1 day	0.000403	0.000096	0.000289	0.000071	0.000114	3.029	*0.007
	7 days	0.000560	0.000045	0.000297	0.000069	0.000263	10.068	*0.000
	28 days	0.001020	0.000239	0.000535	0.000114	0.000485	5.789	*0.000
CHX	1 day	0.000326	0.000171	0.000320	0.000067	0.000006	0.103	0.919
	7 days	0.000226	0.000043	0.000321	0.000058	-0.000095	-4.143	*0.001
	28 days	0.001285	0.000149	0.000298	0.000105	0.000987	17.129	*0.000
Tooth paste	1 day	0.000379	0.000110	0.000396	0.000159	-0.000017	-0.279	0.784
	7 days	0.000267	0.000082	0.000292	0.000027	-0.000025	-0.922	0.369
	28 days	0.001290	0.000039	0.000743	0.000126	0.000547	13.096	*0.000

(*) mean highly significant

Table 2: The Effect of Different Media on the Corrosion Pits of Different Wires and Intervals.

Company	Intervals	Descriptive Statistics								Media difference (d.f.=39)	
		Dry		Artificial saliva		Chlorhexidine		Tooth paste			
		Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	F-test	p-value
Hubit	1 day	0.000375	0.000196	0.000403	0.000096	0.000326	0.000171	0.000379	0.000110	0.471	0.705
	7 days	0.000401	0.000201	0.000560	0.000045	0.000226	0.000043	0.000267	0.000082	17.858	*0.000
	28 days	0.000355	0.000166	0.001020	0.000239	0.001285	0.000149	0.001290	0.000039	71.677	*0.000
Ortho technology	1 day	0.000390	0.000229	0.000289	0.000071	0.000320	0.000067	0.000396	0.000159	1.277	0.297
	7 days	0.000351	0.000175	0.000297	0.000069	0.000321	0.000058	0.000292	0.000027	0.739	0.536
	28 days	0.000364	0.000228	0.000535	0.000114	0.000298	0.000105	0.000743	0.000126	17.210	*0.000

(*) mean highly significant

Table 3: The Effect of Time of Immersion in Each Media for Each Wire.

Media	Company	Descriptive Statistics						Intervals Difference (d.f.=29)	
		1 day		7 days		28 days			
		Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	F-test	p-value
Dry	Hubit	0.000375	0.000196	0.000401	0.000201	0.000355	0.000166	0.150	0.861
	OrthoTechnology	0.00039	0.000229	0.000351	0.000175	0.000364	0.000228	0.088	0.916
Artificial Saliva	Hubit	0.000403	0.000096	0.000560	0.000045	0.001020	0.000239	45.200	*0.000
	OrthoTechnology	0.000289	0.000071	0.000297	0.000069	0.000535	0.000114	25.564	*0.000
CHX	Hubit	0.000326	0.00017	0.000226	0.000043	0.001285	0.000149	193.129	*0.000
	OrthoTechnology	0.000320	0.000067	0.000321	0.000058	0.000298	0.000105	0.266	0.768
Tooth Paste	Hubit	0.000379	0.000110	0.000267	0.000082	0.001290	0.000039	467.830	*0.000
	OrthoTechnology	0.000396	0.000159	0.000292	0.000027	0.000743	0.000126	39.962	*0.000

(*) mean highly significant

DISCUSSION

The Effect of Coating Material

The non-significant coating type difference in the corrosion pits in dry environment, in Chlorhexidine for 1 day and in the Toothpaste for 1 day and 7 days may be due to the presence of the protective oxide layer.

On the other hand, the highly significant difference when the wires were immersed in the artificial saliva media at different intervals may be attributed to the fact the Teflon coating layer adds a minimal thickness to the archwires while Epoxy coating dose add a more significant thickness. This result agreed with *da Silvaa et al.* [24] and *Khamees* [25].

The Effect of the Immersion Media

The highly significant difference among the media at 28 days of immersion of the two types of wiremay related to some factor or factors that are able to modify the properties of the wires, such as the pH level, wet condition, thickness of coating, the composition of coating and the temperature.

On the other hand, the result revealed a highly significant media effect difference of Hubit and a non-significant difference of Orthotechnology at 7 days immersion period.The finding of this study disagreed with *Neumann et al.* [26] study in which they found Teflon coating (Hubit) prevented the corrosion of the wire completely.

The Effect of the Time Intervals

The time interval has no effect on the corrosion pits at dry environment. This may related to the constant factors of the environment at this study.

Thehighly significant differences among the different intervals at wet environment for the Teflon coated stainless steel wires (Hubit) may be due to rapture of the protective layer. This result agree with *Al-Najafy* [27] who found that the surface roughness of Teflon coated stainless increased with increased immersion time.The finding of this study disagree with *Neumann et al.*[26] study.

This study also showed non-significant effect of the immersion time for Epoxy coated stainless steel at Chlorhexidine. This may be due to the type, nature and thickness of coating material, which need more time to corrode.

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