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Evaluation of Corrosion of Rhodium Coated and Uncoated Nickel Titanium Archwires after Immersion in Different Mouthwashes

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ABSTRACT

Introduction: Nickel titanium orthodontic archwires are widely used due to their favourable characteristics mainly in levelling and alignment stage. Gingivitis and enamel demineralization are commonly encountered side effects of fixed orthodontic treatment. Mouthwashes are prescribed as adjunct aids for good oral hygiene but their prolonged use may result in corrosion of orthodontic appliances.

Aim: The current study was designed to evaluate corrosion of Rhodium coated and conventional nickel titanium orthodontic archwires in different commercially available mouth washes.

Materials and methods: Samples of rhodium coated and un-coated nickel titanium wire were immersed in four media (Listerine cool mint, Listerine total care zero, silca and distilled water as a control group) for two months. The atomic force microscopy AFM was used for evaluation of wires. Analysis of variance test (ANOVA) and independent t-test was used to compare the means and Turkey's (HSD) test used when there was significant difference.

Results: Significant differences were found among different immersion media for both types of archwires and the highest Ra values were recorded after immersion in Listerine cool mint then in total care zero. Independent t-test revealed significant differences between tested archwires in Listerine cool mint and total care zero. No significant difference was found in as received, distilled water and silca.

Conclusion: Acidic media increase corrosion tendency in comparison to neutral one as the Ra values increased with decreasing pH. Rhodium coated have higher corrosion tendency compared to conventional in acidic mouthwashes and should be used with caution with them.

Key words: Rhodium coated, NiTi, AFM, Corrosion

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INTRODUCTION

Recently there is increased demand for aesthetic in the appearance of orthodontic appliances. Therefore, companies have introduced new appliances with favourable aesthetic and clinical characteristics [1]. In orthodontics, archwires considered as the basic force system. Clinically, archwires should provide appropriate, predictable and repeatable forces throughout treatment [2].

Aesthetic archwires divided into composite archwires and coated metal archwires [3]. The material of archwire coating should be biocompatible, aesthetic, has reduced frictional resistance and can be added in thin layers [4].

Archwire coated with gold/rhodium is known as the white metals, they have the advantages of enhanced esthetics and shine, reduced porosity and surface roughness [5]. During the last years, rhodium-coated archwires have been getting a reputation in orthodontic practice due to favorable corrosion resistance and aesthetic characteristics that can withstand in the oral cavity media [6].

The orthodontic wires are prone to corrosion in the oral cavity as they are in contact with saliva as an electrochemical process during orthodontic treatment, which not only reduce the treatment effectiveness, but may also result in release of toxic and allergic components [7].

Oral hygiene is highly compromised with placement of fixed orthodontic appliance that result in plaque retention, gingivitis and enamel decalcification [8]. Therefore, mouthwashes are usually prescribed, but the long term use of these mouthwashes can increase the possibility of orthodontic wires corrosion [9]. Hence, the present study

was conducted to evaluate the corrosion properties of Rhodium coated and uncoated nickel titanium orthodontic archwires in different mouth washes.

MATERIALS AND METHODS

The sample

The Archwires used in the study were Rhodium coated Nickel Titanium orthodontic archwire from IOS (International Orthodontic Services, Stafford, USA) and Nickel Titanium orthodontic archwire from Orthometric co. (Brazil). All these wires were upper archwires, rectangular (0.018 × 0.025 inch) in cross section and cut into pieces of 15 mm in length. For each wire type, 32 pieces were divided into four subgroups (8 pieces for each sub groups) and out of the sixty four archwire pieces, randomly (8 pieces) for each wire type (as received) were taken for corrosion evaluation by AFM before starting the experiment.

The medium

The following materials were used as media in which the archwires were immersed:

- Distilled water as a control media (pH 7.25 / Iraq).
- Listerine (Total Care Zero) mouth wash (pH 4.3) contains sodium fluoride 220 ppm.
- Listerine (Cool mint) mouth wash (pH 4.11) contains alcohol 21.6%.
- Silca herb mouth wash (pH 8) contains proven natural herbal extracts (Germany).

Immersion procedure

In distilled water: The wire pieces were immersed completely in perfectly covered glass container in distilled water, kept in the incubator at 37°C which is the temperature of the human body. The distilled water was replaced daily for two months.

In listerine (cool mint) and in listerine (total care zero) mouthwash: The wire pieces were immersed completely in perfectly covered glass container in Listerine mouthwash for one minute daily, according to the manufacturer's instructions. During immersion, the samples were incubated at 37°C which is the temperature of the human body. For the rest of the day they were stored at the same temperature in distilled water in the incubator, this procedure was repeated daily for two months.

In silca herb mouthwash: The wire pieces were immersed completely in perfectly covered glass container in diluted Silca herb mouthwash for one minute daily, according to the manufacturer's instructions. During immersion, the samples were incubated at 37°C which is the temperature of the human body. For the rest of the day they were stored at the same temperature in distilled water in the incubator, this procedure was repeated daily for two months. After this time, all the specimens were removed from the solutions and rinsed with distilled water, dried by tissue paper and kept in Petri dishes to be ready for the analysis [10].

Testing the samples

The Atomic Force Microscope (AFM) in tapping mode was used to perform surface analysis of the archwire samples after the completion of the experiment. Measurements were performed at room temperature.

For each specimen, the surface scanning area taken at the centre of the wire with 20 × 20 µm. The specimen fixed to a piezo scanner with three translatory degrees of freedom.

Subsequently, the three-dimensional AFM view of archwires shown on the monitor of the attached computer. This image representing the surface of the specimen. The AFM software used to process the images [11].

Statistical analyses

Data were collected and analysed using SPSS (statistical package of social science) software version 25 (Chicago, USA). The statistical analyses included descriptive statistics mean, Standard Deviation (SD) and Inferential statistics. Shapiro-Wilks was used for testing the data normality. It has been found that Roughness Average (Ra) values were normally distributed. Analysis of variance tests (ANOVA) and independent t-test were used to compare the means and Turkey's (HSD) test used when there was significant difference. Statistical significance was considered for a p-value <0.05.

RESULTS

The Average Roughness (Ra) values obtained from the AFM measurements had been used for the evaluation of corrosion of the studied archwires in different tested media.

The effect of the different media on average Roughness (Ra). Table 1 shows the mean, standard deviations, minimum and maximum values of Ra (µm) for each type of archwires in different media. The Ra values of the studied NiTi orthodontic archwires were affected by the type of media as shown in Figure 1. For both types of wires, the highest Ra values were found after immersion in Listerine (Cool mint) mouth wash then in Listerine (Total care zero) mouth wash.

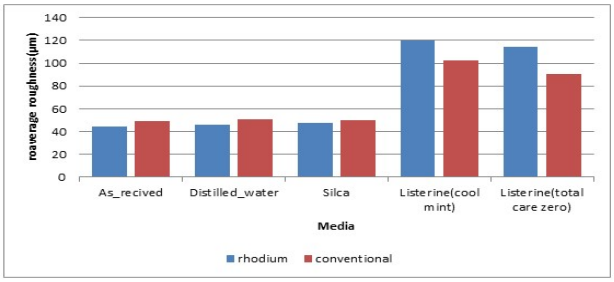

Figure 1: Histogram representation of average roughness (µm) for each type of archwires and the effect of different media.

A statistical analysis had been done by using one-way ANOVA to compare among the Ra values and the result revealed significant differences among different immersion media for each type of archwires (p-value <0.05) as seen in Table 1.

Table 1: Descriptive statistics of average roughness (µm) for each type of archwires and the effect of different media.

Wire types	Media	Descriptive statistics				ANOVA Test	
		Mean	S.D.	Min.	Max.	F-test	P-value
Rhodium coated	As received	44.21	5.76	36.24	52.52	192.733	0
	Distilled water	46.05	5.57	39.23	55.09		
	Silca	48.02	6.18	39.83	57.08		
	Listerine (cool mint)	120.15	10.36	108.96	136.2		
	Listerine (total care zero)	114.1	10.29	100.42	127.23		
Conventional	As received	49.28	8.49	36.34	59.62	81.139	0
	Distilled water	51.01	8.13	40.4	61.28		
	Silca	50.2	9.57	39.46	64.02		
	Listerine (cool mint)	102.59	8.82	92.94	114.84		
	Listerine (total care zero)	90.23	4.29	84.53	95.74		

Since the difference was highly significant among media, a statistical comparison had been done by using Tukey's HSD test between each two type of media as shown in Table 2.

Table 2: Comparison between each two type of media for each type of wire by using Tukey's HSD test.

Wire types	Media		Mean Difference (in µm)	p-value
Rhodium_coated_NiTi	As received	Distilled water	-1.84	0.99
		Silca	-3.8	0.872
		Listerine (cool mint)	-75.93	0
		Listerine (total care zero)	-69.88	0
	Distilled water	Silca	-1.96	0.987
		Listerine (cool mint)	-74.09	0
		Listerine (total care zero)	-68.04	0
	Silca	Listerine (cool mint)	-72.13	0
		Listerine (total care zero)	-66.08	0
	Listerine (cool mint)	Listerine (total care zero)	6.05	0.555
Conventional NiTi	As received	Distilled water	-1.73	0.993
		Silca	-0.91	0.999
		Listerine (cool mint)	-53.31	0
		Listerine (total care zero)	-40.94	0
	Distilled water	Silca	0.81	1
		Listerine (cool mint)	-51.58	0
		Listerine (total care zero)	-39.21	0
	Silca	Listerine (cool mint)	-52.39	0
		Listerine (total care zero)	-40.03	0
	Listerine (cool mint)	Listerine (total care zero)	12.36	0.032

For Rhodium archwires, the difference was non-significant (P>0.05) between as received group and the distilled water and Silca groups, between the Distilled water and Silca groups and between the two Listerine mouthwashes groups. While, significant differences were found between all other groups (P ≤ 0.05).

For conventional NiTi wires, the difference was non-significant (P>0.05) between as received group and the distilled water and Silca groups, and between the Distilled water and Silca groups. Significant difference was found between all other groups (P ≤ 0.05). the effect of different archwire types on their Average Roughness (Ra).

Table 3 shows that Ra values of the studied NiTi orthodontic archwires were affected by the type of these wires. In as received state, distilled water and silica media, the highest Ra values were demonstrated by conventional NiTi wires. On the other hand, Rhodium coated showed a higher increase in Ra values compared to conventional in Listerine (cool mint) and (total care zero) mouthwashes. Independent t–test used to compare the means and revealed significant differences between tested archwires in Listerine cool mint and total care zero (P ≤ 0.05). No significant difference were found in as received, distilled water and silca (P>0.05).

Table 3: comparison between rhodium coated and uncoated wires in different media using independent t–test.

Media	mean in (in µm)		comparison	
	Rhodium	conventional	t-test	p-value
As_recived	44.21	49.28	-1.399	0.184
Distilled_water	46.05	51.01	-1.424	0.176
Silca	48.02	50.2	-0.542	0.596
Listerine(cool mint)	120.15	102.59	3.649	0.003
Listerine(total care zero)	114.1	90.23	6.057	0

DISCUSSION

Maintaining a good oral hygiene is very necessary during orthodontic treatment. As orthodontic patients are more susceptible to have plaque accumulation, dental caries and gingivitis, therefore mouthwashes may be prescribed for its preventive and antiseptic effect [12]. This study chose three types of mouth washes (Listerine with alcohol, Listerine with fluoride and Slica herb mouthwash) as they are commercially available. The distilled water used in the study as a control media because it is not acidic and not corrosive as it has a pH of 7.25 [13].

The immersion period was one minute daily, according to the manufacturer's instructions considering that mouth wash is usually used for 30 seconds in the morning and night while the incubation period was two months, as archwires clinically used within this time range or less than this period [14].

After the experiment was completed and the samples were cleaned and dried, the Atomic Force Microscope was used to perform surface analysis of the archwire samples [15]. It has been reported that the AFM can provide three dimensional image and reaslistic representation of the surface characteristics [16,17].

The data obtained from the current study revealed that the Ra values of the studied NiTi orthodontic archwires were affected by the type of media as the highest Ra values were found after immersion in Listerine (Cool mint) mouth wash then in Listerine (Total care zero) mouth wash for both types of wires, while the lowest Ra values for Rhodium archwires were found in as received state followed by distilled water then in silca herb mouthwash. On the other hand, the lowest Ra value for conventional archwires were found in as received state followed by silca and then in distilled water.

This is probably due to the effect of media PH as there was significant increase in roughness in acidic media compared to neutral one. So the Ra values increased with decreasing pH. The low pH value decrease the resistance of alloy to corrosion as it reduce the stability of passive layer (titanium dioxide) with the high concentration of hydrogen ions that pull oxygen from the titanium dioxide layer and expose the underlying NiTi alloy surface. This in accordance with previous studies [18,19] who reported that titanium based alloy has an increased rate of corrosion in acidic environment.

The corrosive nature of Listerine mouthwash, in addition to low pH, may also be attributed to its ingredients. Cool mint mouthwash contains ethanol that might increase its corrosive potential [20]. While total care zero mouthwash contain fluoride. Fluoride ions attack the protective oxide layer of the wires, Titanium-based archwires show signs of pitting corrosion and inclusion

bodies on their surfaces upon exposure to acidulated and neutral fluoride as had been reported by [21,22].

Regarding as received samples, AFM analysis revealed pre exiting surface roughness. These surface defects may be happened during the manufacturing processes. For the two types of wires, the difference was non-significant (P>0.05) between as received group and the distilled water and Silca groups, between the distilled water and Silca groups. This finding may be attributed to pH of distilled water (7.25), which is not acidic and not corrosive. Regarding silca, non-corrosive nature can be explained on the basis of its' ingredients and high pH(8), this result came in accordance with that reported by Brar [23] who found low corrosion rate in organic mouthwash in comparison to Listerine and chlorhexidine mouthwashes.

Regarding the effect of coating on corrosion potential of studied wires, the result showed that the highest Ra values were demonstrated by conventional NiTi wires in as received state, distilled water and Silca media. This result came in agreement to Krishnan [15] who reported that surface modification of NiTi wires proved to be effective in improving surface roughness. However no significant difference were found between rhodium coated and uncoated wires in as received, distilled water and silca groups (P>0.05).

On the other hand, Rhodium coated showed a higher increase in Ra values compared to conventional in Listerine (cool mint) and (total care zero) mouthwashes. Independent t-test used to compare the means and revealed significant differences between tested archwires in Listerine cool mint and total care zero ($P \leq 0.05$). This result comes in agreement with the findings reported by da Silva [24] in a study that assessed the surface characteristics and coating stability of esthetic coated archwires. The results showed that coating had significantly deteriorated and an increased surface roughness compared to uncoated wires. The high corrosion tendency of rhodium coated wires may be attributed to the formation of a galvanic cell between the noble coating and the base alloy of the archwire due to the porosity of coating where the coating becomes a cathode and the base wire becomes an anode [25]. The finding of this study came in accordance with Katic [21] who found that rhodium coated wire had higher surface roughness compared to uncoated wire in fluoride containing agents. Furthermore in agreement with Rincic [20] who found that rhodium coated NiTi wires showed the highest tendency for localized corrosion compared to uncoated and nitride coated NiTi wires in saliva and all used media (Curaspet, Gengigel, and Listerine).

CONCLUSION

The conclusions that can be drawn from this study are:

- Conventional NiTi wires have higher surface roughness compared to rhodium coated NiTi wires in as received form.
- Rhodium coated NiTi wires have higher susceptibility to corrosion in acidic mouthwash compared to uncoated NiTi wires.
- Mouthwashes with low pH increase surface roughness of NiTi orthodontic archwires therefore should be used with caution.

CONFLICTS OF INTEREST

No conflicts of interest.

ETHICAL CLEARANCE

This research has exemption as it a routine treatment (no new materials were used).

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Conflict of Interest the authors declare that there are no potential conflicts of interest related to the study.

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