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A comparative study of the effect of fluoride on titanium and stainless steel brackets

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ABSTRACT
Objectives:to asses the effects of fluoride on the corrosion of orthodontic metals. The present study is a comparative study of the effect of fluoride on titanium and stainless-steel brackets
Material and methods:
Results: Fluoride (5.1) showed a higher Average Rough than Listerine (4.4) than Fluoride (3.5) and Titanium 2 showed a higher Average Rough than Titanium 1 than Stainless steel. Fluoride (5.1) showed a higher RMS than Listerine (4.4) than Fluoride (3.5) and Titanium 2 showed a higher RMS than Titanium 1 than Stainless steel. Fluoride (5.1) showed a higher mean height (ht) than Listerine (4.4) than Fluoride (3.5) and Titanium 2 showed a higher mean height (ht) than Stainless steel than Titanium 1.
Conclusion: In conclusion, our investigation demonstrated the potential use of an flouride for the study of surface properties of orthodontic materials. This study showed great variability in the surface roughness of brackets, with Stainless Steel turning out to be the least rough. The quantitative surface roughness was higher in the fluoride in titanium group compared to the Stainless-Steel group.
keywords:brackets, fluoride, titanium, stainless steel.

INTRODUCTION

Orthodontic brackets and arch wires are commonly made of metal alloys, and are maintained in the oral cavity for several years, thus, their corrosion must be considered. Moreover, there are many factors in the oral environment that promote orthodontic metal appliance corrosion, such as temperature, saliva pH, fluoride, bacterial flora, enzyme activity, and proteins [1]. Corrosion compromises the mechanical properties of metal alloys by increasing surface roughness and decreasing mechanical strength [2,3].

The cytotoxicity of a corroded metal orthodontic appliance is an important issue. Corrosion releases metal ions into the oral cavity that are ingested into the gastrointestinal system. A previous cell culture study found that stainless steel brackets incubated in cell culture medium for 30 days released high concentrations of metal ions, such as titanium, chromium, manganese, nickel, and molybdenum. Metal ion release can cause both local and systemic adverse biological effects on patients' health. [4 5].

Fluoride products have been widely recommended for dental caries control, and fluoride toothpaste is almost universally recommended for tooth brushing. Additionally, fluoride gel is commonly used, especially in high-risk caries patients, such as those undergoing orthodontic treatment. However, sodium fluoride from fluoride-containing products reacts with hydrogen ions from bacterial products, resulting in the formation of hydrofluoric acid (HF). This acid dissolves the protective oxide layer on the surface of metal orthodontic components, resulting in bracket and archwire corrosion [6-8].

A previous study reported that stainless steel and nickel-titanium wires used with stainless steel brackets corroded when immersed in 1.23% acidulated phosphate fluoride (APF). This corrosion resulted in surface roughness and friction between the brackets and archwires, affecting the efficiency of orthodontic treatment [2,9]. Moreover, surface roughness is a predisposing factor for caries and gingivitis because it induces plaque accumulation on the appliances and adjacent tooth surfaces [10]. Few studies have evaluated the effects of fluoride on the corrosion of orthodontic metals [2, 11]. The present study is a comparative study of the effect of fluoride on titanium and stainless-steel brackets

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MATERIAL AND METHOD:

1-Brackets: A total 240 brackets with 0.022- in slot will be used in current study.The brackets were included two types of titanium brackets and one type of stainless steel brackets.

Types of brackes:

- Titanium 1: Aria bracket , Ortho Organizer , USA.
- Titanium 2: Integra bracket, Rocky Mountain Orthodontics, USA.
- Stainless steal: Discovery, Dentaurum , Germany.

2-Oral Solutions:

Three commercially oral rinses containing Fluoride in different concentration and with different PH as testing solution, and Artificial Saliva:

A. Sultan Fluoride gel containing 1.23% acidulated phosphate fluoride atPH 3.5,USA.
B. Aqua fresh mouth wash containing 0.05% Sodium fluoride at PH of5.1, Untited Kingdom.
C. Listerine Teeth &Gum Defense mouth wash containing F ionconcentration 178 mg/ dl at PH 4.41, USA.
D. Artificial saliva were used to assess the metal ionic release.

The study included 4 groups according to types of solution:

Testing groups:

Group 1,2,3, (rinses contain Fluoride):contain three set of 20 brackets of each group(titanium 1, titanium 2,stainless steel).

The test samples will be immersed for 1 minutes three time aday, then will be kept in a closed container with 50 ml of artificial saliva C, for 2 months. The artificial saliva will be replenished every day.

Group 4 : contains three set of 20 brackets (titanium 1, titanium 2 , stainless steel), which corresponds to a typical clinical case, were immersed in sterile plastic tubes containing 50 ml of artificial saliva soluton and maintained at 37 c temperature for 2 months. During the immersion period, the solutions were agitated twice daily. At the end of the immersion period 40 ml from each solution was removed using a syringe with a plastic tip.

3- Surface characteristics

-Analyze the slot surface characteristics before the experimental laboratory study, and after the end of study.

- Atomic force microscope test (AFM):The bracket slot floor will be analyzed and photographed before and after the experiment to characterize the surface morphology.
- Metal ion released test:The ionic release of the bracket components in the artificial saliva will be studied by Inductively Coupled Plasma Atomic Emission Spectroscopy.

Statistical analysis of the data: Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp).The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level. The used tests were F-test (ANOVA) and Post Hoc test (Tukey), Kruskal Wallis test and Post Hoc (Dunn's multiple comparisons test).

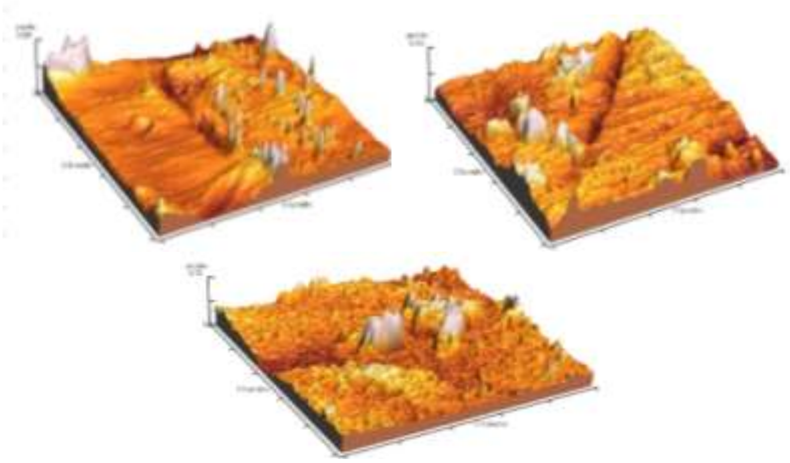

Figure 1. Representative three-dimensional AFM topography images (2.0 µm x2.0 µm) of three samples of orthodontic brackets: Stainless steel, Titanium 1, Titanium 2.

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RESULTS

Table (1): Comparison between the three studied concentrations according to Average Rough (Ra) in each material. Regarding stainless steel, Titanium 1 and Titanium 2, there was a statistically significant difference between concentrations (p=<0.001*), Fluoride (5.1) showed a higher Average Rough than Listerine (4.4) than Fluoride (3.5). Table (2): Comparison between the three studied materials according to Average Rough (Ra) in each concentration. Regarding Fluoride (3.5), Fluoride (5.1), and Listerine (4.4), there was a statistically significant difference between materials (p=<0.001*), Titanium 2 showed a higher Average Rough than Titanium 1 than Stainless steel.

Table (3): Comparison between the three studied concentrations according to RMS in each material. Regarding stainless steel, Titanium 1 and Titanium 2, there was a statistically significant difference between concentrations (p=<0.001*), Fluoride (5.1) showed a higher RMS than Listerine (4.4) than Fluoride (3.5). Table (4): Comparison between the three studied materials according to RMS in each concentration. Regarding Fluoride (3.5), Fluoride (5.1), and Listerine (4.4), there was a statistically significant difference between materials (p=<0.001*), Titanium 2 showed a higher RMS than Titanium 1 than Stainless steel.

Table (5): Comparison between the three studied concentrations according to mean height (ht) in each material. Regarding stainless steel, Titanium 1 and Titanium 2, there was a statistically significant difference between concentrations (p=<0.001*), Fluoride (5.1) showed a higher mean height (ht) than Listerine (4.4) than Fluoride (3.5).Table (6): Comparison between the three studied materials according to mean height (ht) in each concentration. Regarding Fluoride (3.5), Fluoride (5.1), and Listerine (4.4), there was a statistically significant difference between materials (p=<0.001*). In Fluoride (3.5) and Fluoride (5.1), Titanium 2 showed a higher mean height (ht) than Stainless steel than Titanium 1. In Listerine (4.4), Titanium 2 showed a higher mean height (ht) than Titanium 1 than Stainless steel.

Table (1): Comparison between the three studied concentrations according to Average Rough (Ra) in each material

Material	Concentrations			p
	Fluoride (3.5) (n = 10)	**Fluoride (5.1) (n = 10)**	**Listerine (4.4) (n = 10)**	
Stainless steel	13.68 ± 3.39	75.02 ± 2.09	44.72 ± 1.94	<0.001*
Titanium 1	22.76 ± 2.27	87.80 ± 5.17	54.24 ± 1.98	<0.001*
Titanium 2	34.87 ± 1.79	111.97 ± 4.04	63.03 ± 0.38	<0.001*

F: **F for ANOVA test**, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
*: Statistically significant at $p \le 0.05$

Table (2): Comparison between the three studied materials according to Average Rough (Ra) in each concentration

Concentrations	Material			p
	Stainless steel (n = 10)	**Titanium 1 (n = 10)**	**Titanium 2 (n = 10)**	
Fluoride (3.5)	13.68 ± 3.39	22.76 ± 2.27	34.87 ± 1.79	<0.001*
Fluoride (5.1)	75.02 ± 2.09	87.80 ± 5.17	111.97 ± 4.04	<0.001*
Listerine (4.4)	44.72 ± 1.94	54.24 ± 1.98	63.03 ± 0.38	<0.001*

F: **F for ANOVA test**, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
p: p value for comparing between the studied material
*: Statistically significant at $p \le 0.05$

Table (3): Comparison between the three studied concentrations according to RMS in each material

Material	Concentrations			p
	Fluoride (3.5) (n = 10)	**Fluoride (5.1) (n = 10)**	**Listerine (4.4) (n = 10)**	
Stainless steel	20.79 ± 4.32	95.05 ± 5.22	68.04 ± 4.45	<0.001*
Titanium 1	35.61 ± 6.47	118.78 ± 11.98	86.95 ± 15.06	<0.001*
Titanium 2	50.22 ± 8.28	94.83 ± 68.0	90.31 ± 6.97	0.035*

F: **F for ANOVA test**, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
*: Statistically significant at $p \le 0.05$

Table (4): Comparison between the three studied materials according to RMS in each concentration

Concentrations	Material			p
	Stainless steel (n = 10)	**Titanium 1 (n = 10)**	**Titanium 2 (n = 10)**	
Fluoride (3.5)	20.79 ± 4.32	35.61 ± 6.47	50.22 ± 8.28	<0.001*
Fluoride (5.1)	95.05 ± 5.22	118.78 ± 11.98	94.83 ± 68.0	0.321
Listerine (4.4)	68.04 ± 4.45	86.95 ± 15.06	90.31 ± 6.97	<0.001*

F: **F for ANOVA test**, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
*: Statistically significant at $p \le 0.05$

Table (5): Comparison between the three studied concentrations according to mean height (ht) in each material

Material	Concentrations			p
	Fluoride (3.5) (n = 10)	**Fluoride (5.1) (n = 10)**	**Listerine (4.4) (n = 10)**	
Stainless steel	221.09 ± 211.65	470.25 ± 21.35	194.90 ± 48.17	<0.001*
Titanium 1	220.72 ± 115.25	352.47 ± 117.37	277.93 ± 96.17	0.041*
Titanium 2	244.85 ± 121.70	517.12 ± 235.78	363.52 ± 59.29	0.007*

H: H for **Kruskal Wallis test,** Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Dunn's for multiple comparisons test)**
*: Statistically significant at $p \le 0.05$

Table (6): Comparison between the three studied materials according to mean height (ht) in each concentration

Concentrations	Material			p
	Stainless steel (n = 10)	**Titanium 1 (n = 10)**	**Titanium 2 (n = 10)**	
Fluoride (3.5)	221.09 ± 211.65	220.72 ± 115.25	244.85 ± 121.70	0.292
Fluoride (5.1)	470.25 ± 21.35	352.47 ± 117.37	517.12 ± 235.78	0.028*
Listerine (4.4)	194.90 ± 48.17	277.93 ± 96.17	363.52 ± 59.29	<0.001*

H: H for **Kruskal Wallis test,** Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Dunn's for multiple comparisons test)**
*: Statistically significant at $p \le 0.05$

Table (7): Mineral analysis: all groups showed minerals below the detection level.

Cation	Concentration mg/l		
	Stainless steel	**Titanium (1)**	**Titanium (2)**
Iron (Fe)	<0.03	<0.03	<0.03
Copper (Cu)	<0.005	<0.37	<0.005
Nickel Ni	<0.03	<0.04	<0.03
Magnesium Mn	<0.01	<0.01	<0.01
Vanadium V	<0.8	<0.8	<0.8
Chromium Cr	<0.06	<0.06	<0.06
Aluminum Al	<0.65	<0.65	<0.65
Titanium Ti	<1.00	<1.00	<1.00

<: below the detection level

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DISCUSSION

Orthodontic brackets are commonly made of metal alloys, and are maintained in the oral cavity for several years, thus, their corrosion must be considered. Moreover, there are many factors in the oral environment that promote orthodontic metal appliance corrosion, such as temperature, saliva pH, fluoride, bacterial flora, enzyme activity, and proteins [1]. Corrosion compromises the mechanical properties of metal alloys by increasing surface roughness and decreasing mechanical strength [2,3].

Fluoride products have been widely recommended for dental caries control, and fluoride toothpaste is almost universally recommended for tooth brushing. However, sodium fluoride from fluoride-containing products reacts with hydrogen ions from bacterial products, resulting in the formation of hydrofluoric acid (HF). This acid dissolves the protective oxide layer on the surface of metal orthodontic components, resulting in bracket and archwire corrosion [6, 8]. Previous studies have measured the surface roughness of brackets using scanning electron microscopy, and atomic force microscopy (AFM). SEM can visualize two dimensionally the surface morphology, and a quantitative information is not being provided regarding the selected area[12, 13].

The chemical effect of fluoride products on metal orthodontic appliance corrosion has been previously reported. The reaction between the sodium fluoride (NaF) from fluoride products and the hydrogen ions (H^+) from bacterial products and acidic food or drink results in the production of hydrofluoric acid (HF). HF damages the oxidized layers on stainless steel and titanium-based alloys.[14].The acidity of APF gel was found to play a significant role in enhancing metal appliance corrosion [15]. In accordance with the present study, Regarding stainless steel, Titanium 1 and Titanium 2, there was a statistically significant difference between concentrations ($p=<0.001^*$), Fluoride (5.1) showed a higher Average Rough than Listerine (4.4) than Fluoride (3.5).

Huang et al. [16] reported that decreasing the pH in the acidic artificial saliva can increase the corrosion reaction, in terms of the metal ions release, of the commercial Titanium. In this study Regarding Fluoride (3.5), Fluoride (5.1), and Listerine (4.4), Titanium 2 showed a higher Average Rough than Titanium 1 than Stainless steel. metal brackets of stainless steel have a good superficial surface homogeneity and because of which, it has favourable mechanical properties and corrosion resistance. Even though a protective passive layer is present on the SS alloy, the Fe, Cr, or Ni (or all) ions may still be released from the metal surface in the acidic oral environment over the corrosion processes, which increases the risk of tissue damage, aesthetic changes (staining of the tooth by corrosive products) and loss of metal properties [17, 18]. In the present study, all groups showed minerals below the detection level.Compared to stainless steel brackets, titanium brackets have more surface roughness [19, 20].

It was believed that the fluoride concentration in the immersion environments seemed to play a more important role on the surface topography variation than the environment's acidity. Many studies have shown that fluoride ions can destroy the protectiveness of surface TiO_2 passive film on Ti or Ti alloy, leading to an attacked corrosion morphology, a decreased polarization resistance, and an increased anodic current density or metal ions release. Furthermore, the corrosion resistance, in terms of the above mentioned corrosion parameters, of Ti or Ti alloy decreases on increasing the NaF concentration in the artificial saliva [16, 21, 22]. Recently, the detrimental effect of fluoride ions on the corrosion resistance of NiTi archwire was reported [23]. Schiff et al. [24] studied the corrosion resistance of orthodontic wires in three different commercial mouthwashes and found that the NiTi wire is subject to severe corrosion in Na_2FPO_4-containing mouthwash.

Our results showed that the least rough backets was the Stainless Steel backets. It has been demonstrated that Stainless Steel shows the lowest frictional coefficient and because of its combination of low roughness, high hardness, and high strength. (25) These data are consistent with those from the study of Doshi and BhadPatil, (26) which showed higher values of surface roughness for titanium, and with the results of several studies5 in which titanium were considered the roughest.

CONCLUSION

In conclusion, our investigation demonstrated the potential use of an flouride for the study of surface properties of orthodontic materials. This study showed great variability in the surface roughness of brackets, with Stainless Steel turning out to be the least rough. The quantitative surface roughness was higher in the fluoride in titanium group compared to the Stainless-Steel group. Further studies must be undertaken to assess the variation of surface roughness that follows the clinical use.

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