Original Article

In Vitro Effect Of Fluoride Prophylactic Agents On Titanium Molybdenum Alloy And Stainless Steel Orthodontic Wires – Scanning Electron Microscope Study

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Abstract:

Background: TMA (Titanium-molybdenum) and SS (Stainless steel) wires are most commonly availed for orthodontic treatment. Meanwhile, patients are encouraged to employ mouthwashes containing fluoride to maintain their oral hygiene. Objective: To assess the effect of different fluoride prophylactic agents on TMA and SS wires for specific time periods namely 10 minutes, 1 hour, 24 hours. **Material and Methods:** The sample comprised TMA and SS wires immersed in agents such as Artificial saliva (pH = 6.8), Acidulated phosphate fluoride gel 1.23% and Stannous fluoride 0.4% to evaluate surface changes incorporated. 180 cut wires were used in this study; out of which half were SS and the other half were TMA wires. These wires were immersed for 10 minutes, 1 hour and 24 hours in each agent. Scanning electron microscope was also utilized to analyze the surface alterations. **Results:** The roughness of these wires increased after immersing in prophylactic agents. An increase in the surface roughness was found with SS wires in stannous fluoridesolution and APF gel on immersion at 10 minutes, 1 hour, and 24 hours’ time intervals with p-value being significant at 24 hour time in stannous fluoride. **Conclusion:** Orthodontists must avoid the contact of orthodontic wires containing titanium protective coating with prophylactic agents.

Keywords: Fluoride, Orthodontic wires, Saliva, Friction

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Introduction:

In the course of an orthodontic treatment, the wires and brackets are bonded to the teeth for tooth movement. Brackets with wires are difficult to clean by the patients. To achieve a healthy and efficient oral hygiene, mouthwashes containing fluoride prophylactic agents are advised to patients along with mechanical cleaning aids. Although these mouthwashes have irrefutable benefits, they have the potential of causing friction, micro-hardness and loss of tensile strength by creating surface alterations a

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changing the mechanical properties of the brackets, arch wires and other restorations present, by deteriorating the corrosion resistance. [1-4] Different wires are availed for the orthodontic therapy. Austenitic stainless steel (SS) was established as orthodontic wires in 1929, owing to their high modulus of elasticity, moderate costs, superior strength, excellent biocompatibility, significant formability and good corrosion resistance. [5] Furthermore, corrosion of orthodontic wires sets in due to the release of various elements from the metal or its alloys. In order to resist this, the SS and TMA wires rely on the phenomenon of passivation (formation of an oxide layer). Despite the presence of these protective oxide layers, the metal surface is capable of releasing metals ions.[6] In case of titanium and its alloys a stable thin oxide layer (TiO_2) is formed, a passive film that easily prevents its breakdown under physiologic conditions. Similarly, oxide films on SS are mainly composed of chromium oxide which resists its corrosion. This surface film avoids further diffusion of oxygen, leading to substantial corrosion resistance. [7] This metal oxide layer is vulnerable to mechanical as well as chemical disruptions and is able to dissolve the metal when in contact to oxygen from the surrounding medium. Environment with a lower pH and fluoride consisting solutions can promote these disruptive processes.[8] The SS and TMA wires are frequently employed at the Phase 2 (anterior and posterior correction and space closure) and Phase 3 (finishing and detailing) of the orthodontic treatment which allows them to remain unprotected to the oral habitat for much prolonged duration.[9] Previous study conducted by Huang at al. [10] assayed that pH had an immense effect on the corrosiveness of the stressed SS wires. Even though pH alone appears to be detrimental to the SS wires, fluoride concentrations and pH both have a negative impact on the TMA wires. The hydrogen embrittlement in solution of fluoride being the main reason for degradation of surface characteristics of TMA wires.[11] Consequently, prophylactic solutions containing fluoride ions have been reported to induce discoloration and corrosion in the titanium metal appliances.[7] We discovered that there was dearth of knowledge available regarding the influence of different types of prophylactic agents containing fluoride on TMA and SS wires for specific time periods. Thus, the present study was carried out to examine the impact of fluoride prophylactic agents on TMA and SS orthodontic wires.

Material and Methods:

This vitro experimental study was conducted and designed with the aim of assessing the surface alterations incorporated by prophylactic agents containing fluoride on TMA and SS orthodontic wires. The sample comprised two types of wires which were most commonly used in orthodontic practice i.e. stainless steel containing 73% iron, 18% chromium and 9%, nickel and TMA containing 79% titanium, 11% molybdenum, 6% zinc and 4% tin. Agents utilized were artificial saliva (pH = 6.8), Acidulated phosphate fluoride (APF) gel 1.23% and Stannous fluoride 0.4%. The fluoride prophylactic agents utilized were undiluted. Total 180 cut wires were used in this study; out of which 90 were SS and 90 were TMA with the dimensions 0.48 x 0.64 x 10. These wires were categorized into three groups of 60 each. First group was immersed in neutral agent that is artificial saliva which was control group. The second and third groups were immersed in APF gel and stannous fluoride gel for 10 minutes, one hour and twenty four hours. After withdrawing from the solution, wires were washed with distilled water, and the average surface roughness of each wire was accessed on the flat surface using profilometer. These wires were also observed under a scanning electron microscope (SEM) under the magnification of 500. The color changes were observed and categorized in four different groups on discoloration scale. A comparison of the average surface roughness and color changes of these wires were carried out after immersing in fluoride prophylactic agents, at different time intervals by using a SEM.

The study duration was 6 months. This study was approved by Institutional Ethics Committee. The data procured was analyzed by Statistical Package for Social Sciences (SPSS) version 20 software. Shapiro-Wilk’s test/Kolmogorov-Smirnov test was used to check normality prior to analysis. Descriptive analysis through frequency distribution was calculated. A p-value of less than 0.05 was considered significant.

Results:

Roughness of these wires increased after immersing in prophylactic agents. SS as well as TMA wires showed slight amount of increase in the surface roughness after immersing in prophylactic agents for 5 minutes. But these changes are minimal and are not statistically significant. Least amount of change in roughness was observed with stainless steel wires in artificial saliva for 10 minutes (mean ± SD; 0.079 ± 0.006), 1 hour (mean ± SD; 0.77 ± 0.007) and 24 hours (mean ± SD; 0.87±0.004) (Table 1).

Scanning electron microscopic pictures of these wires also showed the similar results (Figure 1, Figure 2). An increase in the surface roughness was found with SS orthodontic wires in stannous fluoride solution and APF gel on immersion at 10 minutes, 1 hour, and 24hours’ time intervals (Figure 3). However, the p-value for Stannous fluoride (10 minutes, 1 hour, 24 hour; 0.38, 0.08, 0.05) was not statistically significant. Similarly, the p-value for APF gel (10 minutes, 1 hour, 24 hours; 0.11, 0.05, 0.11) was not significant. SEM pictures also showed no change in surface morphology of these wires in different agents with increase in time (Figure 1, Figure 2).

It is observed that there is no color change in SS wires when immersed in artificial saliva, stannous fluoride and APF gel for 10 minutes and 1 hour. Very mild color changes were seen with these wires in stannous fluoride and APF for 24 hours but these were not significant (Table 2). Moreover, the scanning electron microscopic picture also showed a drastic change in surface morphology of TMA wires after 24 hours immersion in APF gel. Similarly, a high increase in surface roughness was also observed with TMA wires after 1 hour of immersion in stannous fluoride solution (Figure 4).

Discussion:

Topically used fluorides reported to initiate and enhance corrosion of titanium based orthodontic wires. [9,12,13] Our study evaluated the effects of various fluoride agents on two types of orthodontic wires viz SS and TMA wires. The prophylactic agents used in this study were stannous fluoride and APF gel while artificial saliva was the control. A similar in vitro study was conducted by Wantanabe et al [7] where four titanium based (2 nickel titanium alloys, 2 beta titanium alloys) orthodontic wires were immersed in 5 different fluoride solutions (2 APF agents, 1 neutral agent and 2 stannous fluoride agents) at time interval of 10 minutes, 1 hour and 24 hour. These wires were assessed for surface roughness and discoloration while also monitoring under SEM.

This study found no significant change in surface roughness, color and surface morphology of both SS and TMA wires after immersing in artificial saliva for all the three time frames (Table 1, Figure 3,Figure 4)). The obtained results of this current experiment revealed that TMA wires showed a mild increase in surface roughness when placed in APF agent and artificial saliva for 10 minutes as compared to the SS which showed a moderate increase in the same condition. TMA wires immersed in Stannous fluoride gel at 10 minutes (0.34 ±0.007), 1 hour (0.33±0.008), 24 hour (0.35 ± 0.009) indicated moderate rise. However, this increase was not statistically significant (Table 1). This might be due to its inherent property of high strength and excellent corrosion resistance.[5] Furthermore, there was no much surface discoloration of stannous fluoride on SS and TMA wires except at 24 hours. At 24 hours, there was noticeable pitting corrosion observed, both of which were not significant (Figure 1,Figure 2) In the previous experiment when TMA wires were immersed in Florentine II (stannous fluoride agent) for specific time intervals (10 minutes, 1 hour and 24 hours) it demonstrated no change in the surface coloration (Table 2).

In addition, APF gel showed negligible effect on SS wires whereas a good amount of surface changes were observed with respect to TMA. A greater change in the surface roughness of these wires was found after 1 hour and 24 hours of immersion in APF gel. Statistical analysis of both these values showed that there is significant increase in the roughness of these wires with a p-value of <0.001 at 1 hour and 24 hours respectively. These findings are in great similarity with the prior studies that affirmed surface changes of TMA wires in APF agents for 24 hours. [7]

The SnF_2 agent, caused a mild increase in the surface roughness on the SS wires as well as TMA wires but these changes were insignificant. This was in accordance to the previous study which illustrated that SnF_2 was unable to induce any surface changes to the titanium wires.[7] Supposedly, believed to be due to the amount of fluoride ions that were greater in the

APF gel than the SnF_2 solution. Titanium and its alloys have the ability of dissolving hydrofluoric acid and producing a complex compound:

$$TiO_2 + 4HF \Downarrow\Diamond TiF_4 + 2H_2O$$ [14]

$$Ti_2O_3 + 6HF \Downarrow\Diamond 2\, TiF_3 + 3H_2O.$$ [15]

The alternative cause for obtaining these results were decreased pH levels.[14,15,16] Generally, composition of APF agents are such that they have a pH levels that is around 3.4-3.6 compared with that artificial saliva (pH 6.8). Irrespective of levels of reduced pH present in the SnF_2 solutions there was no change in the tarnish parameters and surface morphology of the titanium wires. This non reactivity might be attributed to the less fluoride levels in the SnF_2 than APF gel. Consequently, the low pH of fluoride is thought to be a crucial element in the degradation of the surface titanium oxide film ensuing both hydrogen embrittlement of titanium with its alloys and fluoride related corrosion.[17] Besides, with the exposure to neutral sodium fluoride solutions (fluoride concentration 0.5% or greater), the corrosion resistance of titanium alloy also decreases.[18] Thereupon, the preceding study deduced that the fluoride associated alloy effects usually rely on the fluoride concentration as well as the pH of the prophylactic agent. [17] Most of the mechanical property degradation was caused by the acidulated fluoride agent than the natural agents. This is in accordance to our study.

Our study found appreciable discoloration with respective to the TMA wires when submerged in APF gel for 1 hour while there was no color change in SS wires placed in the same medium and at the same time interval (Table 2). The study conducted by further supported our finding that appreciable color alterations were seen in TMA wires when placed in APF solution for 1 hour and severe discoloration after 24 hours was summarized.[7] This result was in great similarity with the preceding study conducted by Watanabe et al where titanium wires showed appreciable changes in color when placed in Nupro APF agent for 1 hour along with severe discoloration when immersed for 24 hours. Additionally, TMA wires as well as SS wires revealed no color change while kept in artificial saliva.

Clinically, the application of fluoride agents persists for several minutes and is present in the oral cavity for at least 30 minutes prior to rinsing. The application period of these agents when compared to the immersion time utilized in this experiment revealed that a onetime application of these fluoride agents for one or two months might not alter the surface morphology of the SS wires. However, the APF agents have the potential of inducing changes in color and surface morphology.

Conclusion:

The present study showed that Titanium-based orthodontic wires changed color and surface morphology after immersion in APF agents for 1 hour and 24 hours. Its surface roughness was also significantly increased whereas stainless steel wires showed least amount of surface changes in various prophylactic agents at different time periods. The present result suggests that orthodontist should avoid placing wires coated with titanium protective film in contact with fluoride containing prophylactic agents, tooth pastes or dental rinses.

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