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The Effects of 0.2% Sodium Fluoride and Persica Mouthwashes on Flexural Strength of Nickel-Titanium Orthodontic Wires

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ABSTRACT

Introduction: This study aimed to evaluate the effects of 0.2% sodium fluoride and Persica mouthwashes on the flexural strength and surface characteristics of nickel-titanium (NiTi) orthodontic wires through an in vitro investigation.

Materials and Methods: Twenty-seven 0.016-inch NiTi wire samples (3cm long) were divided into three groups (n=9/group): distilled water (control), Persica, and 0.2% NaF mouthwash. Wires were immersed for 90 minutes (simulating 3 months of daily use) and subjected to a three-point bending test (0.5mm/min deflection). Surface changes were analyzed via scanning electron microscopy (SEM). Data were compared using ANOVA and Bonferroni tests.

Results: Unloading-phase forces, yield strength, and elastic modulus significantly decreased in NaF and Persica groups versus control ($p<0.05$), with no differences in loading-phase ($p>0.05$). SEM revealed the highest corrosion in NaF and the lowest in control. No significant differences were observed between NaF and Persica ($p>0.05$).

Conclusion: Exposure to 0.2% sodium fluoride and Persica mouthwashes adversely affects the mechanical properties and surface integrity of NiTi orthodontic wires. Clinicians should consider the potential implications of prolonged mouthwash use during orthodontic treatment.

Keywords: Mouthwash; Orthodontic wire; Mechanical properties; Corrosion; Nickel-titanium.

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Introduction

In recent years, orthodontic treatment has become popular as a result of increased patients' awareness of the impact of tooth appearance on their quality of life [1]. Orthodontic wires are important in the mechanics of the treatment [2]. Ideal wires for tooth alignment should be able to move the teeth with light forces over long periods of time [3]. Various alloys are used to make orthodontic wires, including stainless steel, beta titanium, cobalt chromium, fiber-reinforced composite, and nickel titanium alloys. Superelastic nickel-titanium wires provide a nearly constant force over a wide range, which offers many clinical advantages [4]; therefore, especially in the initial stage of treatment for aligning and leveling, the use of nickel-titanium wires has become very common these days [5].

The three-point bending test evaluates the load-deflection characteristic, which is considered the most important parameter determining the biology of tooth movement [6] and provides information on the behavior of wires when deflected in horizontal and vertical directions [7]. The advantages of this test include its simulation of clinical application and its ability to distinguish wires with superelastic properties [6]. Fixed orthodontic appliances make oral hygiene difficult and increase the accumulation of microbial plaque. This facilitates demineralization and induces periodontal problems by disrupting the ecological balance of the oral flora [8-11].

Orthodontists recommend that their patients use fluoride-containing products to prevent tooth decay and accumulation of bacterial plaque [2,10,12,13]. The use of mouthwashes during orthodontic treatment continuously exposes orthodontic wires, which can make wires more vulnerable to corrosion and alter their mechanical properties [14]. It has been shown that the mechanical properties and surface characteristics of orthodontic wires change during short-term immersion (1.5 h) in a fluoride agent [8,9,15]. One of the most widely used mouthwashes in the Middle East is Persica mouthwash [16]. Several studies have reported that Persica reduces microorganisms around brackets in patients receiving fixed orthodontic treatment and has antiplaque effects comparable to mouthwashes containing chlorhexidine and sodium fluoride. It also improves periodontal health, reducing plaque accumulation and gingivitis, as well as bleeding during brushing [17,18]. Due to a lack of studies on the effect of Persica mouthwash on orthodontic wires, the purpose of this in vitro study was to investigate and compare the effects of Persica and sodium fluoride mouthwashes on the flexural strength of Ni-Ti wires.

Materials and Methods

A metal jig with a 15.5mm-wide cavity was used to simulate the interbracket distance between adult incisors and canines (according to Wilkinson's study [19]). Two premolar brackets (Hangzhou Sino Ortho Technology Co., Ltd., China) were attached to the jig, and 27 pieces of 0.016-inch Ni-Ti wire (American Orthodontic, Wisconsin, USA) samples, with 3cm long, were divided into three groups:

Group A (Control): Distilled water.

Group B: Persica mouthwash (Poorsina Pharmaceutical Company, Tehran-Karaj Road, Tehran, Iran).

Group C: 0.2% sodium fluoride mouthwash (Behsa company, Arak, Iran).

The wires were immersed in 10mL of each solution at 37°C for 90 minutes (simulating three months of daily use). After rinsing, a three-point bending test was conducted using a Zwick/Roell universal testing machine (Zwick GmbH & Co. KG., Ulm, Germany). A wedge-shaped rod applied force at 0.5 mm/min, deflecting the wire 3mm before returning it to its original position (Figure 1). Load-deflection data were recorded and Results were analyzed by testXpert® software (Zwick GmbH & Co. KG). Modulus of elasticity (E) and yield strength (YS) were calculated using established formulas. To compare loading and unloading forces, yield strength and modulus of elasticity between different groups, ANOVA statistical analysis was used, as well as Bonferroni paired comparison for pairwise comparisons of groups. To examine surface properties of the wires, one wire was randomly selected from each group. It was then examined using a scanning electron microscope (SEM) (Hitachi S4160, cold field Emission, Japan).

Results

The force applied by each wire at different bends in the loading and unloading phases was calculated by the UTM device, and a force-deflection diagram was drawn for each sample and the diagrams of the samples of each group were displayed in one figure (Figure 2). The force applied by wires in different bends up to a bending of 3mm was calculated. Then, loading and unloading forces were extracted at intervals of 0.5, 1, 1.5, 2 and 2.5mm, and the average forces generated by wires of each group at these intervals were calculated.

Also, modulus of elasticity and yield strength of wires of each group in loading and unloading phases were calculated. Table 1 shows the mean and standard deviation of forces generated by wires of each group at half-millimeter bends intervals during the loading and unloading phases. In the loading phase, the highest mean force was recorded in the distilled water group at 2.5mm bend, while the lowest was in the persica group at 0.5mm. No significant differences were found between groups ($p>0.05$). In the unloading phase, the distilled water group again exhibited the highest force at 2.5mm, whereas the fluoride group had the lowest at 0.5mm. Notably, unloading forces at bends≥1mm were significantly reduced ($p<0.05$) for mouthwash-treated wires compared to distilled water, but no difference was observed between fluoride and persica ($p>0.05$). Table 2 shows the mean and standard deviation of elastic modulus and yield strength of the wires of each group in loading and unloading phases. Elastic modulus and yield strength were highest in the distilled water group and lowest in the persica group. Significant differences ($p<0.05$) were found in the unloading phase between:

Distilled water vs. persica.

Distilled water vs. fluoride.

The smallest difference was between persica and fluoride in unloading, suggesting similar mechanical degradation. Examination of the images of the samples by SEM electron microscopy showed that the highest corrosion rate was in the wire placed in fluoride mouthwash, and the lowest corrosion belonged to the distilled water group (Figure 3).

Table 1. Mean and standard deviation of forces generated by wires of each group at specified bends in the loading and unloading phases.

Phase	*Bending distances (mm)*	*Descriptive statistics*					
		Distilled water		*Persica*		*Fluoride*	
		Mean force (N)	*Standard deviation*	*Mean force (N)*	*Standard deviation*	*Mean force (N)*	*Standard deviation*
Unloading	*2.5*	*0.993*	*0.075*	*0.798*	*0.0687*	*0.831*	*0.087*
	2	*0.69*	*0.036*	*0.496*	*0.0791*	*0.517*	*0.066*
	1.5	*0.55*	*0.032*	*0.37*	*0.0673*	*0.367*	*0.057*
	1	*0.528*	*0.02*	*0.348*	*0.0478*	*0.345*	*0.042*
	0.5	*0.466*	*0.096*	*0.369*	*0.1*	*0.322*	*0.0672*
loading	*2.5*	*2.8*	*0.015*	*2.796*	*0.105*	*2.746*	*0.154*
	2	*2.593*	*0.028*	*2.57*	*0.843*	*2.527*	*0.122*
	1.5	*2.348*	*0.053*	*2.296*	*0.871*	*2.299*	*0.114*
	1	*2.018*	*0.102*	*1.928*	*0.121*	*1.953*	*0.136*
	0.5	*1.086*	*0.155*	*0.978*	*0.178*	*1.119*	*0.352*

Table 2. Average and standard deviation of elastic modulus and yield strength of wires of each group in loading and unloading phases.

Solution type	*Loading elastic modulus (Gpa)*		*Loading yield strength (Mpa)*		*Unloading elastic modulus (Gpa)*		*Unloading yield strength (Mpa)*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*
Distilled water	*124.98*	*9.56*	*997.7*	*79.39*	*108.74*	*7.83*	*664.87*	*45.4*
Fluoride	*117.2*	*12.23*	*937.7*	*99.86*	*83.76*	*11.32*	*582.35*	*63.42*
Persica	*114.95*	*11.55*	*917.17*	*90.85*	*81.12*	*15.82*	*586.79*	*75.92*

Figure 1. A three-point bending test was conducted using a Zwick/Roell universal testing machine (Zwick GmbH & Co. KG, Ulm, Germany).

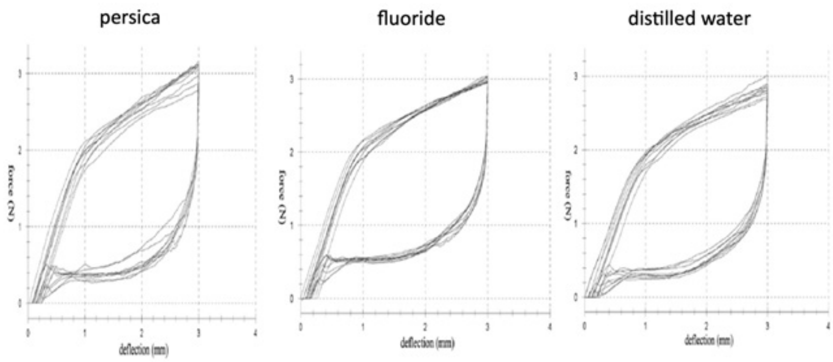

Figure 2. Force-deflection diagrams of each group.

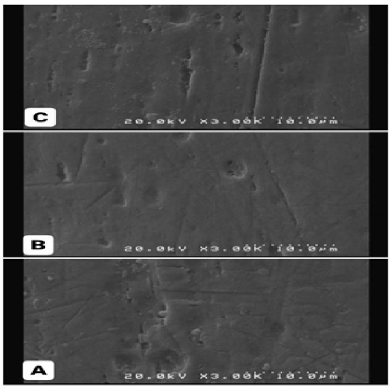

Figure 3. Examination of the samples' images by SEM electron microscopy revealed that the highest corrosion rate occurred in the wire placed in fluoride mouthwash (C), while the lowest corrosion rate was observed in the distilled water group (A).

Discussion

Orthodontic wires are an important tool for transmitting force to the teeth in orthodontic treatment but they can cause the accumulation of microbial plaque; therefore, orthodontists recommend that their patients use mouthwash regularly during treatment to prevent tooth decay. Wires undergo changes and corrosion after exposure to oral conditions or the use of mouthwashes [10]. Nowadays, studies are looking for mouthwashes with less effect on orthodontic wires during orthodontic treatment. Therefore, the present study was conducted to determine the effect of common mouthwashes, sodium fluoride and persica, on the mechanical properties and flexural strength of nickel-titanium wires. In the present study, three-point bending test was used to investigate the effects of mouthwashes on the flexural strength of wires, which is a highly repeatable test that allows comparison with other studies. After placing the wires in fluoride and persica mouthwashes, we put them inside the machine for tests and the forces, the yield strength and elastic modulus were measured. Finally, the wires were evaluated under a scanning electron microscope (SEM) to examine changes in surface and corrosion. For the three-point bending test, the wires were fixed by orthodontic brackets and O-rings. To simulate the distance between the brackets to the distance between the teeth, 10 to 16mm length have been used in studies [8,14,19-23], but in this study, similar to the study of Aghili et al. and Wilkinson et al., a distance of 15.5mm (equivalent to the distance from the central incisor to the canine) was chosen [8,19]. The time the wires were exposed to mouthwashes in the previous studies was 60 or 90 minutes; In the present study, similar to most studies, 90 minutes was chosen to simulate the condition of the wires after 3 months of exposure to the oral environment [3,8,13,14,21,23-26].

The results of the present study showed that unloading forces were reduced by placing the wires in Persica and fluoride mouthwashes, which represented significant changes compared to the control group except for the 0.5mm bend ($p<0.05$). Unloading forces are the forces that the wire releases after bending and pressure is removed and cause tooth movement. A decrease in this force can negatively affect the duration of orthodontic treatment. Aljabour et al. [27] also obtained similar results in a study on the effect of neutral sodium fluoride gel, stannous fluoride gel, and Phosflur mouthwash on the mechanical properties of heat-activated Ni-Ti wires, which showed a significant decrease in the unloading forces of nickel-titanium wires after being placed in neutral sodium fluoride gel for 60 minutes at 37°C. They concluded that these fluoride-containing agents can be effective during orthodontic treatment. Mlinaric et al. [28], Koushik et al. [14], Alavi et al. [5], and Sukumar et al. [29], in accordance with the present study, concluded that exposure to fluoride agents reduces unloading forces. Hashim [13] also obtained similar results in a study on the effect of neutral sodium fluoride gel and stannous fluoride gel on nickel-titanium wires after 60 minutes of immersion in these agents. There are various reasons for the decrease in mechanical properties of nickel-titanium wires when fluoride agents are used; for example, various studies have suggested that fluorides, by forming hydrofluoric acid, cause corrosion and disruption of the protective oxide layer on the wires, which ultimately reduces the mechanical properties of nickel-titanium wires, and unloading forces can be affected by these factors. As Nsaif et al. [30] also obtained similar results in a study on the effect of acid phosphate fluoride (APF) on the mechanical properties of rhodium-coated nickel-titanium wires and stainless steel wires. Their results also showed a significant decrease in the flexural strength of stainless steel and nickel-titanium wires after being placed in an acidic fluoride solution for 60 minutes; but no decrease in the properties of rhodium-coated nickel-titanium wires was observed. However, in a study conducted by Aghili et al. [8], the results were in contrast with the present study. Their results showed an increase in unloading forces after 90 minutes of exposure of nickel titanium and stainless-steel wires to 0.05% sodium fluoride mouthwash, Zataria extract, and chlorhexidine. This different result could be due to the epoxy resin coating of the wires or the different concentration of fluoride mouthwash used. Also, in a study conducted by Sander et al. [21], the results obtained were different.

Their results showed no difference in unloading forces after placing esthetically coated wires in neutral sodium fluoride gel, neutral sodium fluoride mouthwash, or acid phosphate fluoride (APF) gel. This different result could be due to the polymer and rhodium coating of the wires they used. In the study conducted by Srivastava et al. [26], unlike the present study, the results obtained did not show a significant change in unloading forces after placing Ni-Ti, Cu Ni-Ti, SS, and β-Ti wires in neutral fluoride (Phos-Flur) and NaF mouthwashes, which could be because of the fact that in their study, the force was applied at a non-perpendicular angle to the wire. Loading force, as the force that must be applied to the wire to engage the bracket, was investigated in the present study. Our results showed that loading forces decreased when the wires were placed in Persica and fluoride mouthwashes, but these changes were not significant ($p>0.05$).

In the present study, in agreement with the studies of Alavi et al. [5] and Mlinaric et al. [28], no significant difference in loading forces was shown after the wires were immersed in fluoride agents. Also, Koushik et al. [14] did not show a significant change in the loading characteristics of Ni-Ti and Cu-Ni-Ti wires following immersion in fluoride agents for 90 minutes. By contrast, Aghili et al.` study [8] on the mechanical properties and surface morphology of Ni-Ti coated Ni-Ti, and stainless steel wires found that the loading forces of nickel titanium and stainless steel wires after 90 minutes of exposure to fluoride agents significantly decreased; which could be due to the different concentrations of mouthwash or epoxy resin coating used in their study. Also, Katic et al. [22], unlike the present study, showed a significant decrease in loading forces after placing nickel-titanium wires in Miraflow and MIPaste fluoride agents, which could be due to the concentration and type of fluoride agent used in that study. Additionally, Sukumar et al. [29] concluded that fluoride mouthwash can decrease loading forces of copper Ni-Ti wires which is in contrast with our study and could be because of different wire materials used in studies. Also, A study by Kaur et al. reported that exposure of Ni-Ti and copper Ni-Ti wires to phos-fluor gel, compared to deionized water, significantly reduced the loading force, which is not consistent with the current study. The use of the gel form instead of mouthwash can be considered as a possible reason for this difference [31]. The modulus of elasticity is expressed as the change in stress relative to the change in strain and indicates the relative stiffness of the wire in the elastic range. Its importance in orthodontics is that a wire with a high modulus has a small deflection range for engaging a misaligned tooth, which leads to plastic deformation of the wire or applying too much force to the tooth. The results of the present study also showed that the modulus of elasticity in the unloading phase decreased with the placement of the wires in persica and fluoride mouthwashes, which showed significant changes compared to the control group ($p<0.05$), but the decrease in the modulus of elasticity after the wires were placed in mouthwashes during the loading phase did not show significant changes ($p>0.05$).

In accordance with our study, Rajendran et al. [32] and Hammed et al. [23] concluded that exposure to fluoride agents causes a decrease in the elastic modulus in the unloading phase. In a study conducted by Mane et al. [24] on the effect of Phos-flur gel and Prevident on the elastic modulus and yield strength in the loading and unloading phases for nickel-titanium and copper-nickel-titanium orthodontic wires, similar results were obtained. Their results also showed a significant decrease in the elastic modulus in the unloading phase, and this change was not significant in the loading phase. Gupta et al. [25] studied the effects of Phos-flur gel and neutral sodium fluoride on the elastic modulus of nickel-titanium wires; their results showed a decrease in the elastic modulus in the unloading phase, unlike the loading phase, after exposure to mouthwashes, which was consistent with the results of the present study. In contrast to the present study, the study by Sander et al. [21] did not show a significant decrease in the elastic modulus of the wires after placing the esthetically coated wires in neutral sodium fluoride gel, neutral sodium fluoride mouthwash, or acid phosphate fluoride (APF) gel. This different result could be due to the polymer and rhodium coating of the wires used. The results were also different in the study by Katic et al. [22]. They showed a significant change in the modulus of elasticity during the loading phase after placing nickel titanium wires with different coatings in MiPaste gel, Elmex toothpaste, and Mirafluor toothpaste, which could be due to the fact that fluoride was used in different forms and concentrations in their study. Yield strength, as the maximum stress that a wire can withstand before plastic deformation, can be important in determining the stress that can be applied to the wires during orthodontic treatment so that the wire can move within its elastic range and return to its original state after the pressure is removed. Therefore, reducing this value can be effective in the process and duration of orthodontic treatment. The results of the present study showed that the yield strength in the unloading phase decreased with the placement of the wires in persica and fluoride mouthwashes, which showed significant changes compared to the control group ($p<0.05$), but the decrease in yield strength after the wires were placed in mouthwashes during the loading phase did not show a significant change ($p>0.05$), which was consistent with the results of the studies of Mane et al. [24], Gupta et al. [25], and Mlinaric et al. [28].

Meanwhile, in the study of Hammad et al. [23], unlike our study, no significant decrease in the yield strength of wires was shown after placing composite-coated wires of nickel titanium and stainless steel wires in acid phosphate fluoride (APF) gel. This different result could be due to the composite coating of the wires used or the different concentration of fluoride agent used. The results of the study by Sander et al. [21] were also different from our study. They did not observe a significant change in the yield strength in the unloading phase, as well as loading after placing the cosmetic-coated wires in different fluoride agents, which could be due to the polymer and rhodium coating of the wires used. When nickel titanium wires are exposed to fluoride, sodium fluoride in the oral environment is converted to hydrofluoric acid, which reacts with the titanium oxide to form titanium fluoride, which causes corrosion of the wire surface [24]. In the present study, the results of SEM electron microscopy images showed the highest corrosion in the wire exposed to fluoride mouthwash, and the lowest corrosion rate belonged to the control group (distilled water); as Aghili et al. [8], Sander et al. [21], Gupta et al. [25] and Koushik et al. [14] observed an increase in corrosion of the wire surface after exposure to fluoride-containing agents under SEM electron microscopy. In contrast with us, Katic et al. [22] did not show a significant difference between the different groups after observing the wires under SEM microscope, which could be due to the shorter exposure to mouthwash. Also, in the study of Sander et al. [21], the results were different. Their results did not show a clear difference in corrosion between the SEM images of the wires exposed to mouthwash and sodium fluoride gel compared to the control group, which could be due to coating of the wires used in their study.

Conclusion

NaF and Persica mouthwashes adversely affect NiTi wire mechanical properties and surface integrity. Clinicians should monitor wire performance in patients using these mouthwashes regularly.

Conflict of Interest

There is no conflict of interest to declare.

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