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The Effect of Different Methods of Fluoride Administration at Different Concentrations on the Load-Deflection Properties of Rhodium-Coated Niti Archwires

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ABSTRACT

Background and Objective: Fluoride compounds are widely used for the control of dental plaque. Considering the effect of different fluoride compounds on the mechanical properties of orthodontic wires, this study was conducted to analyze the effect of different methods of fluoride administration at different concentrations on the load-deflection properties of rhodium-coated NiTi orthodontic archwires.

Methods: This clinical trial was conducted on 30 patients aged between 15 and 25 years referring to Babol University of Medical Sciences due to dental crowding and didn't have vertical skeletal defects. 0.016-inch Rhodium-Coated A-NiTi wire was placed on patients' maxillary brackets. Patients were randomly divided into three groups of ten: The control group used only fluoride toothpaste, the second group used fluoride toothpaste with sodium fluoride mouthwash (0.05%) and the third group used fluoride toothpaste with Acidulated Phosphate Fluoride gel (1.23% APF). After six weeks, the values of unloading force (N), yield strength (N/m2) and stiffness (N/m) of the wires were obtained using a three-point bending test.

Findings: The mean unloading force and stiffness of the second group wires were higher than that of the other groups and in the first group, they were higher than the control group in all values, but no significant differences were found between the groups. There was a significant difference between the yield strengths of different groups (p=0.038). The mean yield strength in the second group was higher than the other groups (0.94±0.16 N/m2) and was significantly different from the control group (0.75±0.19 N/m2) (p=0.030).

Conclusion: According to this study, method of fluoride administration does not affect the unloading force and stiffness but the yield strength of rhodium-coated NiTi archwires increases with an increase in the fluoride concentration.

Keywords: *Orthodontic Wires, Mechanical Tests, Sodium Fluoride.*

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Introduction

The technological advances in recent decades have led to the development of orthodontic materials. As a result, different types of orthodontic wires with various properties are currently available (1, 2). Orthodontic wires are typically made of nickel-titanium (Ni-Ti), stainless steel (SS), cobalt-chromium-nickel (Co-Cr-Ni), and beta-titanium (β-Ti). The main advantage of these wires is the superiority of their mechanical properties to other materials such as polymers and ceramics. However, one of their major disadvantages is the silver color of the metal, which makes it difficult to use them in adults due to their unpleasant appearance (3). Aesthetic wires were introduced to overcome this problem. These wires are generally manufactured using two methods, namely the ion implantation and the coating methods. In wires produced with the coating method, the metal alloy is coated with polymers such as epoxy resins, polytetrafluoroethylene, or rhodium. Currently, these types of wires have the highest rate of clinical use among the aesthetic wires (4-6). However, among the studies conducted on the properties of the coated wires, there are studies that indicate the mechanical properties of the coated wires are impressed by the effect of enzymes and masticatory forces (4). Other studies also revealed the vulnerability of these wires to the mechanical and thermal cycles (4-6).

Due to their retentive nature, the use of these wires and other orthodontic appliances results in trapping of dental plaque and formation of a bacterial biofilm made of acidogenic bacteria including streptococcus mutans and different types of lactobacilli. There is subsequently a decrease in the acceptable oral health level. This biofilm is capable of causing gingivitis and caries (7-9). One of the ways for plaque control and caries risk reduction involves the use of fluoride compounds (3, 10, 11). Patients with fixed appliances need prophylactic fluoride due to the protective effect of fluoride on the tooth surface (12-14). Studies indicate that the mechanical properties and surface characterization of the orthodontic wires are compromised by the use of topical fluoride (11). According to the study by Alavi et al., a 0.05% sodium fluoride mouthwash with pH=4 harms the unloading force of NiTi wires (4). In another study, in the presence of APF, a significant decrease in the loading force of NiTi and stainless-steel wires was observed. but there were no notable changes in the loading forces of Rhodium-coated NiTi wires due to their protective layer (15). Mane et al. showed a significant reduction in unloading yield strength of NiTi and Cu-NiTi wires after exposure to APF fluoride gel (16). Aghili et al.'s study demonstrated that fluoride mouthwash reduces the stiffness of NiTi wires while increasing the stiffness of coated wires (17).

Despite the presence of in vitro studies, the lack of sufficient clinical research encourages researchers to clinically analyze the effect of topical fluoride on the mechanical properties of orthodontic wires (4, 18-20). It seems necessary to design a clinical trial study and analyze the effect of fluoride under oral conditions to consider the impact of factors such as saliva, food, chewing force, and thermal changes on the wire. Our reviews on the results of previous studies show that no clinical studies were conducted on the effect of fluoride treatment on the mechanical properties of coated wires in the patient's mouth. Therefore, this study was conducted to investigate the effect of different methods of fluoride administration at different concentrations on the load-deflection properties of rhodium-coated NiTi Archwires clinically.

Methods

This clinical trial was approved by the ethics committee of Babol University of Medical Sciences with the code IR.MUBABOL.REC.1395.262 and registered in the clinical trial system with the code IRCT20180220038804N1 and was conducted on 30 patients aged 15 to 25 years referred to Babol Dental School who were able to observe hygiene and did not use special mouthwash, cigarettes, alcohol, drugs that

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affect saliva flow. In order to match the forces on the wire, patients with vertical skeletal dysplasia and posterior crowding and unusual eating habits were excluded from the study. After obtaining informed consent from patients, they were taught how to observe hygienic principles. Patients were divided into three equal groups based on a table of random digits:

Control group: The patients were advised to use neutral sodium fluoride toothpaste (Oral-B, USA) at a concentration of 315 ppm twice a day (once before and once after bedtime).

Second group: Using toothpaste (same method advised in the control group) along with daily sodium fluoride mouthwash (0.05%) (Oral-B, USA) at a concentration of 226 ppm (once a day at a rate of 15 ml after brushing and for 30 seconds) was advised to patients.

Third group: Using toothpaste (same method advised in the control group) along with 1.23% APF gel (Sultan, USA) at a concentration of 12300 ppm was advised (According to the company's instructions, they put the gel once for 60 seconds in their mouth using a tray and then avoided eating and drinking for 30 minutes after use to increase fluoride absorption).

American Orthodontics brackets with 0.028×0.022 slots (MBT system) were bonded to the patients' teeth. Rhodium-coated A-NiTi (GAC, International, Bohemia, NY) 0.016-inch wires were placed through maxillary brackets with elastic O-ring (Orthotechnology, Lutz, Florida, USA). After 6 weeks, the wires were removed from the patients' mouths. A three-point bending test was conducted to study the mechanical properties of the wires after their placement in the mouth. In addition, three wire samples were tested prior to the treatment to study the load-deflection properties and obtain the stiffness and load-deflection diagrams. To conduct this test, 20mm of the wire's flat segment was cut in accordance with the American Dental Association Specification No.32 (from the front of the bracket attached to the first premolars to the back). The test was conducted in the research center of the Metallurgy Faculty of Tehran University using a Universal Testing Machine (STM-20, Karaj, Iran) with a 14-mm deflection span at 37±2 ˚C and 1 mm/min speed. To conduct the test, the isolated wire segment was placed on two sides of the device and a force was applied to the wire until a 3.5-mm deflection was achieved (Figure 1). Thereafter, the loading force was suddenly lifted from the wire and the unloading force, yield strength, and stiffness values were calculated for the 0.5, 1, 2, and 3-mm deflections. Finally, the load-deflection diagram was obtained using the mentioned device. It is worth stating that the device load cell was 2000 N.

Figure 1. Three-point bending test device

Sample size calculation was done using the data from mechanical testing by Walker et al. (11). A sample size of 10 wires per group was required to detect a 10 % difference between groups with a power of 0.80. Data analysis was done in SPSS (Statistical Package for the Social Sciences) version 22. The unloading, yield strength, and stiffness values of the three groups were assessed by one-way ANOVA test and each

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pair of groups was also compared using Tukey's test. Repeated measurement ANOVA (RM ANOVA) was performed on all dependent variables for different times. This analysis explored within-subject differences over time and between groups. In all cases, Mauchly’s test of the assumption of sphericity was breached for each test, and Greenhouse-Geisser estimate sphericity was used to correct degrees of freedom, with statistics listed. Since there were many pairwise comparisons, the adjusted Bonferroni comparisons were statistically determined for discussion and p<0.05 was considered significant.

Results

According to data, although the mean unloading force for the third group was higher than the other groups and the mean unloading force for the second group was higher than the control group for all deflections, there was no significant difference between the groups with regard to the unloading force values corresponding to the 0.5, 1, 2, and 3 deflections based on the RMANOVA statistical test (F=0.232, df=3.37, p=0.893). As expected, the unloading force increased significantly in the groups with an increase in the deflection. (Table 1).

According to the ANOVA test, there was a significant difference between the yield strengths of the study groups (p=0.038). Based on the Tukey’s test, this difference was significant between the third group and the control group (p=0.030). However, the difference between the second group and the other groups was not statistically significant. The ANOVA statistical test showed no significant difference in the stiffness in the 3 study groups at 0.5, 1, 2, and 3-mm deflections (Table 2).

Table 1. Comparing the mean unloading forces of the three study groups for the 0.5, 1, 2, and 3-mm deflections

Group / Deflection	Unloading force (N)			p-value
	Fluoride tooth paste Mean±SD	Fluoride tooth paste+fluoride mouth rinse Mean±SD	Fluoride tooth paste+fluoride gel Mean±SD	
0.5	0.61±0.23[a**]	0.62±0.17[a]	0.68±0.25[a]	0.75
1	0.77±0.20[b]	0.82±0.18[b]	0.89±0.16[b]	0.24
2	0.86±0.20[c]	0.92±0.09[c]	0.97±0.19[c]	0.37
3	1.74±0.20[d]	1.75±0.12[d]	1.81±0.19[d]	0.63
p-value[£]	<0.001	<0.001	<0.001	0.89[ʃ]

[**]Different English letters in each column show a significant difference at (α=0.05) level between each two deflections in each group with the adjusted Bonferroni test. [£]The p-value represented in the table above was obtained from the RMANOVA statistical test. [*]The p-value represented was obtained from the ANOVA statistical test. [ʃ]interaction effect of the deflection and groups on the unloading force using RMANOVA tests.

Table 2. Comparing the mean yield strength and stiffness values at 0.5, 1, 2, and 3-mm deflections

Group / Variables	Fluoride tooth paste Mean±SD	Fluoride tooth paste+fluoride mouth rinse Mean±SD	Fluoride tooth paste+fluoride gel Mean±SD	p-value
Yeiled Strength	0.75±19[a**]	0.83±0.93[ab]	0.94±0.16[b]	0.038
Stiffness	2.85±0.20	2.88±0.18	2.94±0.23	0.56

[**]Similar English letters show lack of a significant difference at (α=0.05) level. The data in the table above was obtained from the ANOVA statistical test.

Discussion

The results of the present study demonstrated that different methods of fluoride administration do not significantly affect the unloading force and stiffness of rhodium-coated NiTi orthodontic wires. Furthermore, as the fluoride concentration increases, the stiffness of the wire increases but not in a significant way. In the study by Sander, the effect of different fluoride compounds on the rhodium-coated NiTi and polymer-coated wires was studied. Although they observed the effects of corrosion on the coating layers of the rhodium-coated NiTi wires, which were exposed to APF gel, they concluded that there was not a significant difference between the effects of different methods of fluoride administration on the unloading force in rhodium-coated NiTi wires (21). The findings of the present study indicated that with lower concentrations of fluoride, the decrease in the unloading force increases at different deflections. The study conducted by Katic et al. revealed that in rhodium-coated NiTi wires, the highest daily release of Ni^{2+} ions in the first three weeks occurs in prophylactic materials with the lowest fluoride concentration. However, following the submersion of this wire in prophylactic materials with high concentrations of fluoride, the rate of ion release at different periods was very low. This could be the reason for the reinforced mechanical properties of the rhodium-coated NiTi wires in the groups with higher fluoride concentrations in the present clinical study, which led to the preservation of wire for a short time in the mouth environment (22). In this study, the increase in the concentration of fluoride led to an increase in stiffness but was not significant. Aghili et al. conducted a study to analyze the effects of the 0.05% fluoride mouth rinse on three types of wire, including stainless steel, NiTi, and rhodium-coated NiTi wires. They reported that the use of the fluoride mouth rinse resulted in a significant increase in the stiffness of the rhodium-coated NiTi wires. This difference could be attributed to the inadequate sample size (5 samples per study group) in the study by Aghili as compared to the larger sample size in the present study (17).

Hammad et al. also conducted a study to analyze the effect of fluoride on the mechanical and surface properties of wires coated with the translucent composite. They concluded that the administration of fluoride considerably reduces the stiffness of wires as compared to the control group (i.e., wires submerged in distilled water) (23). The difference between the results of this study and the present study could be attributed to the difference in the type of wire coating. Fluoride could have harmed the surface layer of the wire used by Hammad, which was a polymer matrix composite with glass fillers. Katić et al. examined the effect of different methods of fluoride administration on the surface and the mechanical properties of different NiTi wires. They indicated that the pH and fluoride concentration did not affect the mechanical and surface characteristics of the wires alone. However, the fluoride form has a significant effect on the properties of wires. They also realized that the mechanical properties of the rhodium-coated NiTi wires in the unloading phase decrease in the presence of the MI paste gel (at a fluoride concentration of 900ppm) while these properties are improved in the presence of Mirafuor (at a fluoride concentration of 6150ppm). In addition, it was reported that the type of wire coating could result in changes in the response of wires to different types of fluoride, which could be the reason for the different responses of the rhodium-coated NiTi wires to higher concentrations of fluoride as compared to the uncoated wires (24).

According to the study by Mane et al., when NiTi wire is exposed to fluoride, the formation of a titanium hybrid due to hydrogen failure in the NiTi network results in a change in the network's ability to convert from martensite to austenitic form, resulting in reduced wire strength. The reduction of this mechanical property of the wire causes an unfavorable change in the springiness of NiTi wire. Therefore, when using NiTi wire, high concentrations of fluoride in gel form should be used with more caution (16). However, in our study, the average yield strength in the fluoride gel group was significantly higher than other groups. This difference is due to the presence of a rhodium coating layer. Obviously, in this circumstance, the springiness of the wire is positively affected, and as opposed to NiTi wires, we don't have the limitation of

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using fluoride. Therefore, we can use this wire in some cases that the risk of caries is higher and the need for higher concentrations of fluoride as a gel is needed. However, we need more clinical studies with a larger sample size to give clinical advice.

The present study indicate that the method of fluoride administration does not affect the unloading force and stiffness of the rhodium-coated NiTi orthodontic wires. However, the yield strength of these wires increases with an increase in the fluoride concentration.

Conflict of interest: there is no conflict of interest in this study.

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