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An *In-vitro* Study of the Load Deflection Characteristics of the Thermal Wires Immersed in Different Fluoride Prophylactic Agents

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ABSTRACT

Background: *Fluoridated prophylactic agents have been reported to cause corrosion and discoloration of titanium alloys. Degradation in the mechanical properties lead to a decrease in a suitable orthodontic force, thereby causing delayed leveling of crooked teeth. This study was designed to evaluate the load deflection characteristics of thermal nickel titanium arch wires during unloading phase after ninety minutes immersion in three different fluoride agents.* ***Material and methods:*** *Forty specimens of thermal wires were obtained from Ortho Technology Company, which had 0.019” × 0.025” rectangular in cross section. Ten specimens from the wire size were immersed in one of the tested fluoride prophylactic agents (neutral sodium fluoride gel, stannous fluoride gel or Phos-Flur® mouth rinse) or in the controlled medium of normal saline and incubated at 37°C for ninety minutes. A Wp 300 universal material testing machine was modified and used to perform a three-point bending test in a water path at 37 ± 1°C. The statistical difference between the different agents was analyzed using ANOVA and least significant difference tests.* ***Results:*** *The unloading forces at 0.5 mm, 1.0 mm, and 1.5 mm where significantly reduced especially in acidulated phosphate fluoride treated specimens followed by neutral fluoride treated specimens.* ***Conclusion:*** *Based on the results found in this study it can be preferred to use fluoride prophylactic agents with the least acidity and fluoride ions concentration.*

Keywords: Fluorides, Load-deflection, Thermal wires

INTRODUCTION

Thermal nickel titanium wires have been gaining acceptance in the orthodontic practice during the last years because of their unique properties of super elasticity and shape memory property which is the capability of Ni-Ti wires to be plastically deformed in their martensitic phase, in addition to the low stiffness, high spring back and super elasticity [1-3]. Fluoride prophylactic agents have been widely used to inhibit demineralization or do re- mineralization of white spot lesions around orthodontic brackets and bands; however, the fluoride ions in the prophylactic agents have been reported to cause corrosion and discoloration of titanium and its alloys [4]. Degradation in the mechanical properties lead to a reduction in appropriate orthodontic force, thereby causing delayed alignment of irregular teeth [5]. This is an *in vitro* study is to evaluate the effect of three different fluoride prophylactic agents on the load deflection of the thermal orthodontic arch wires.

MATERIALS AND METHODS

The samples included forty pieces of 4 cm length obtained by cutting the straight, posterior portion of preformed upper thermal arch wire using a cutter. The pieces were 0.019” × 0.025” (Ortho Technology Co., CA, USA). These samples were divided into four groups; each group contains 10 pieces of 0.019” × 0.025”) according to immersion medium:

1) Control medium (normal saline (NaCl) 0.9% w/v pH=7).
2) Stannous fluoride (SnF_2) gel 0.4% (Dental Technologies alpha-dent, Lincolnwood, Illinois, USA with pH=3.3).
3) Phos-Flur® mouth rinse 0.044% w/v (Colgate Oral Pharmaceutical, New York, USA with pH=4.2) Active Ingredients: Sodium fluoride 0.044% (w/v).

4) Neutral sodium fluoride (NaF) gel 1.1% (DentMat Holdings, Lompoc, California, USA with pH=7).

All samples were incubated at 37°C in inert plastic tubes of 10 ml capacity for ninety minutes (90 minutes=1 minutes per day topical fluoride application for three months). Then the samples were removed from their respective test media washed with normal saline and placed in a new, clean, and individually labeled plastic tubes before mechanical testing. The three-point bending test was carried out to test the load deflection characteristics of the selected arch wires. The samples were mounted into a three point bending test fixture (stainless steel jig with two barreled rods set 15 mm apart) the mid portion of the wire were loaded to 2 mm deflection by rotating the hand wheel of WP300 universal testing machine (G.U.N.T. Gerätebau GmbH, Hamburg, Germany) in clockwise direction then very gently unwind the hand wheel in counter clock direction to unload to zero deflection. For statistical analysis the unloading forces at 1.5 mm, 1 mm, 0.5 mm were used since unloading phase of the wire represent the necessary forces to achieve tooth movement. To simulate aqueous oral environment, the test was carried out in a water bath at 37 ± 1°C the temperature was controlled by using a digital thermometer. One-way analysis of variance (ANOVA) was used to examine whether any significant difference at $p<0.05$ exist between the four tested groups. Further, least significant difference (LSD) was used to compare among tested groups.

RESULTS

Table 1 showed the means and standard deviations of forces at intervals of 0.5 mm deflection during unloading for 0.019” × 0.025” thermal nickel titanium arch wire. F-test by ANOVA table showed that there was statistically a highly significant difference in the load defection of 0.019” × 0.025” thermal arch wires immersed in different fluoride agents during unloading at 1.5 mm, 1.0 mm, 0.5 mm, $p<0.001$. Table 2 showed the results of LSD after ANOVA for 0.019” × 0.025” thermal nickel titanium arch wires. The load deflection graphs for the thermal wires after being immersed in tested agents in comparison with the control group are presented in Figure 1.

Table 1 Descriptive statistics of load (gm) during unloading phase and groups’ difference for 0.019” × 0.025” thermal wires

		Descriptive statistics								Media difference	
unloading phase	Deflection (mm)	NaCl		SnF_2		Phos-Flur®		NaF			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	F-test	p-value
	1.5	179.35	3.06	168.9	7.37	155.05	6.53	158	2.05	44.461	0.00***
	1	115.3	6	110.5	10.08	93.6	6.38	99.1	2.38	21.78	0.00***
	0.5	113.65	2.42	112	6.77	79.3	6.1	97.6	4.09	96.319	0.00***
*** Highly significant											

Table 2 Least significant difference after ANOVA for 0.019” × 0.025” thermal wires

Phase	Deflection (mm)	Groups		Mean Difference	p- value
Unloading	1.5	NaCl	SnF_2	10.45	0.000 ***
			Phos-Flur®	24.3	0.000 ***
			NaF	21.35	0.000 ***
		SnF_2	Phos-Flur®	13.85	0.000 ***
			NaF	10.9	0.000 ***
		Phos-Flur®	NaF	-2.95	0.218 #
	1	NaCl	SnF_2	4.8	0.122 #
			Phos-Flur®	21.7	0.000 ***
			NaF	16.2	0.000 ***
		SnF_2	APF	16.9	0.000 ***
			NaF	11.4	0.001 ***
		Phos-Flur®	NaF	-5.5	0.078 #
	0.5	NaCl	SnF_2	1.65	0.477 #
			Phos-Flur®	34.35	0.000 ***
			NaF	16.05	0.000 ***
		SnF_2	Phos-Flur®	32.7	0.000 ***
			NaF	14.4	0.000 ***
		Phos-Flur®	NaF	-18.3	0.000 ***
#: P>0.05 (Not significant); *: p<0.05 (Significant); ***: p<0.001 (Highly significant)					

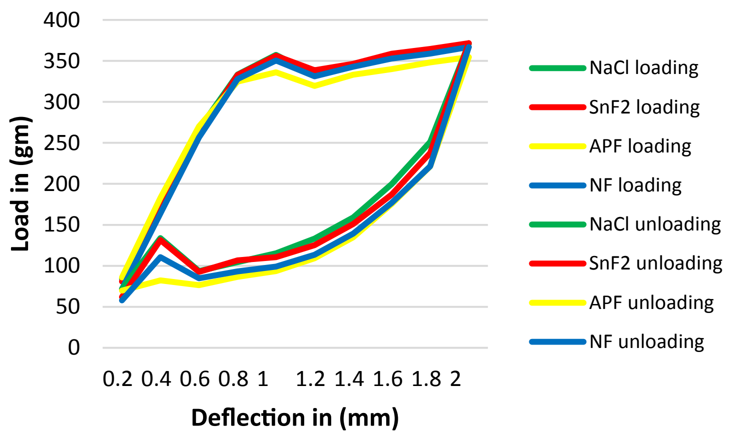

Figure 1 Load deflection curve for 0.019" × 0.025" thermal wires (APF: Phos-Flur®; NF: NaF)

DISCUSSION

Fluorides have been reported to cause corrosion and degradation in the mechanical properties of commonly used arch wires by forming hydrofluoric acid (HF acid), which causing disruption of protective oxide layer [6-8]. It should be understood that the fluoride associated effect depends on concentration of fluoride ions in the agent being used, the pH level of the agent, the time interval of immersion, and the wires manufacturing characteristics) [9]. In the present study, the three-point bending test is conducted. It is a consistent testing method useful for purely theoretical estimations offers a high level of reproducibility and allows comparison with other studies [10-12]. The beam tests were carried out using a jig machined from stainless steel with two barreled rods that set 15 mm apart to mimic a typical inter-bracket span [13]. In the present study, a commercially available thermal arch wires were tested with cross sections 0.019" × 0.025" selected because of their clinical popularity to generate low force levels due to material properties. Wire deflections of 2 mm and then the unloading forces at 0.5 mm interval were selected because of its probable occurrence under clinical circumstances [3]. In the present study, the fluoride agents that were used differ in their fluoride ion concentration and pH value and according to manufacturer directives they used for one minute per day topical application. The NaCl were used as a control medium because Ni-Ti based arch wires has high corrosion resistance in NaCl solution [14]. NaCl has taken on as a control medium by preceding studies [15-17]. The results of the present study are in agreement with other findings [18-20].

Hashim and Al-Joubori [17] found significant reduction in the unloading forces of heat activated nickel titanium arch wires after only sixty-minute soaking in the fluoride agents, and the amount of reduction was greatest in the NaF treated samples which has the highest concentration. Sabane, et al. [18] and Koushik, et al. [19] found significant decrease in unloading mechanical properties of Ni-Ti and Cu Ni-Ti following soaking in fluoride agents for ninety minutes time. Ahrari, et al. [20] found significant decrease in the unloading forces at lower deflection following soaking of Ni-Ti and Cu Ni-Ti in 0.2% sodium fluoride solution for 24 hours.

In the present study, the amount of reduction was greatest in the Phos-Flur® treated sample followed by NaF treated samples. It seems that increasing immersion time in acidic fluoride media has more effect in degradation of unloading forces than immersion in NaF agent which has a balanced pH value. Lee, et al. [21] reported an increased amount of corrosion with higher fluoride concentration, longer immersion time and most importantly a lower pH, this is in consistence to the findings in the present study. Furthermore, corrosion resistance was lost in solutions which contain fluoride with varying pH value [4]. The results of the present study are disagreeing to the finding by others [5,22-24].

Walker, et al. [5] stated that the application of acidic and neutral fluoride treatments has no significant effect on Cu Ni-Ti (copper Ni-Ti that show a thermal properties) mechanical properties compared with distilled-water control treatment, but a reduction in the unloading mechanical properties of Ni-Ti wires was observed. It was assumed that the copper component in the Cu Ni-Ti arch wires partially inhibit the activity of hydrofluoric acid; therefore, prevent fluoride related degradation in the mechanical properties of Cu Ni-Ti wires. But Walker and his colleagues have noticed surface corrosion in Ni-Ti and Cu Ni-Ti arch wires in their study.

Schiff, et al. [22,23] (indicated that Ni-Ti wires were more susceptible to corrosion than Cu Ni-Ti wires. Ramalingam, et al. [24] found that the mechanical properties of Cu Ni-Ti arch wires retrieved from patients who used a fluoride gel and Phos-Flur® rinse for 30 days were not affected by fluoride agents but Ni-Ti wires had a reduction in the unloading force especially in gel group.

Huang [25] reported that fluoride concentration as the only parameter that affected the degree of corrosion, while the pH of incubation (from 6.3 to 3.4) was not relevant, which is in contrast to the finding in the present study. However, all the fluoride agents used in Huang's study were diluted up to 10 folds in artificial saliva, making the final fluoride concentration and pH different to those of the original formulations.

CONCLUSION

From the present study it can be concluded that the synergistic action of fluoride ion concentration and low pH are more important than each of the single treatment alone, since there is statistically significant reduction in the unloading forces among the tested groups when compared with the sample immersed in the control group the margin of difference in the unloading forces was in between (22 g to 34 g), While the margin of difference between Phos-Flur® and NaF treated sample was ranged from (3 g to 18 g) which has no significant difference. From the present study, the problem of corrosion and subsequent degradation in unloading forces might not be clinically significant as long as the prophylaxis agents used during orthodontic treatment include mouth gels or mouth rinse with least fluoride concentration at higher pH value.

From the present study, it can be concluded that the stannous fluoride agent may prove to be the safest prophylactic agent that can be prescribed to the patient under orthodontic treatment.

DECLARATIONS

Conflict of Interest

The authors and planners have disclosed no potential conflicts of interest, financial or otherwise.

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