ORIGINAL RESEARCH

Assessment of Impact of Fluoride on Mechanical Properties of NiTi and CuNiTi Orthodontic Archwires: An *In Vitro* Study

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Abstract

Aim: The current study was carried out to assess the impact on the mechanical properties of orthodontic wires such as the nickel–titanium (NiTi) and copper-nickel–titanium (CuNiTi) wires by fluoride available in various prophylactic products.

Materials and methods: Fifty-six wire specimens were randomly divided into two groups—control group in which deionized water was used as a medium and study group in which Phos-Flur gel was used. Both study group and control group were divided into two subgroups—NiTi wire group: 0.019 × 0.025 inch NiTi archwires (14 specimens) and CuNiTi wire group: 0.019 × 0.025 inch CuNiTi archwires (14 specimens). Testing of all the wires was done under a universal force testing machine.

Results: Mean loading force among NiTi wire group and CuNiTi wire group specimens with deionized water as a medium was 682.6 and 397.4 MPa, respectively, while the mean loading force among NiTi wire group and CuNiTi wire group specimens with Phos-Flur gel as a medium was 596.1 and 368.4 MPa, respectively. While comparing between study group and control group among NiTi wires, significant results were obtained. Also, while comparing between study group and control group among CuNiTi wires, significant results were obtained.

Conclusion: Following exposure to fluoride agents, NiTi wires and CuNiTi wires are significantly associated with reduced mechanical properties.

Clinical significance: Although fluoride acts as a vital adjunct in maintaining oral hygiene, particularly among patients undergoing fixed orthodontic treatment, its influence on the mechanical properties of the wires is an area to be explored further; thereby, its use is to be monitored.

Keywords: CuNiTi, Fluoride, NiTi archwires.

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Introduction

Orthodontic treatment has become one of the routine dental procedures among teenagers and adolescents these days. At the same time, there has been a simultaneous increase in the demand for better esthetics as well as the quality of orthodontic components.[1]

Key to successful orthodontic treatment lies on two major parameters—oral hygiene and subsequent caries control. In patients with compromised oral hygiene status, there can be demineralization of the tooth enamel and eventual tooth decay. The orthodontists must regularly prescribe differential topical fluoride formulations to maintain oral hygiene, e.g., fluoride-containing toothpastes and mouthwashes. Fluoride-containing mouthwashes are available for daily as well as weekly use with concentrations of 0.05% and 0.2%, respectively.[2,3]

Thus, the orthodontic components such as the wires are exposed to the action of fluoride continuously. There seems to be a strong correlation between the corrosion of orthodontic components and the overall acidic concentration of the environment around the buccal cavity and the usage of products containing fluorides such as mouthwashes and toothpastes.[4–6] Nickel–titanium wires have the property of upholding the persistent load along with having the capacity of shape memory. Copper-nickel–titanium exhibits superior transition temperatures because of enhanced copper content, which enables more homogeneous loadings along with enhanced tooth movement. By the action of oral bacteria inside the oral cavity, an acidic environment could be generated upon metabolizing fermentable carbohydrates. Among these, acetic acid encourages hydrofluoric acid (HF) by interaction with even a minute quantity of fluoride. Protective oxide layer which is present on the surface of orthodontic archwires is dissolved by HF.[5–8] Therefore, this current study was carried out to assess the impact on the mechanical properties (yield strength) of NiTi wires and CuNiTi wires by fluoride available in gel form.

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Materials and Methods

The study was carried out in Dr BR Ambedkar Institute of Dental Sciences and Hospital, Patna, Bihar, India, from January 2022 to March

2022. A total of 56 wire specimens comprised of 28 orthodontic wires, each of 0.019 × 0.025 inch NiTi archwires (Medsan Surgiment, Koden, Karnataka, India) and CuNiTi archwires (Medsan Surgiment, Koden, Karnataka, India) were considered in the study. The immersion medium considered deionized water which acted as the control group and Phos-Flur gel (1.1 percent sodium fluoride; Colgate Oral Pharmaceuticals, New York, USA) was the study group. Therefore, 14 specimens of each type of the orthodontic wires were immersed in the respective solutions such that the control group was comprised of 14 specimens each of NiTi wires and CuNiTi wires, and similarly, the study group was comprised of 14 specimens each of NiTi wires and CuNiTi wires (Table 1). All the wire specimens were cut of size 0.019 × 0.025 inch and were stored in polypropylene test tubes as shown in Figures 1 and 2. Incubation of control group specimens was done in deionized water at 37°C in a plastic vial individually for time period of 120 minutes while study group specimens were immersed in fluoride-containing agent in a plastic vial, respectively. This was followed by washing-off of the solution and cleaning. Further, all the wires were tested under a universal force testing machine wherein loading of each wire done until a deflection of 3 mm was produced (at a speed 1 mm/minute). For each wire specimen, using engineering beam theory, modulus of elasticity (E) and yield strength (YS) were calculated by formulae described previously in the literature.[9]

Table 1: Distribution of specimens according to specific groups

Groups	*Subgroups*	*Number of specimens*
Control group (deionized water)	NiTi wire group	14
	CuNiTi wire group	14
Study group (Phos-Flur gel)	NiTi wire group	14
	CuNiTi wire group	14

The yield strength (YS) was also calculated as follows:

$YS = 3PL/2bd^2$ (MPa)
P = Load at the apparent yield point (N)
L = Support span (mm)
b = Width of specimen (mm)
d = Depth of specimen (mm).

All the results were recorded in a Microsoft Excel sheet and were analyzed by SPSS software. Student's *t* test was used for evaluation of level of significance.

Results

The mean loading force among NiTi wire group and CuNiTi wire group specimens with deionized water as a medium was 682.6 and 397.4 MPa, respectively, as shown in Table 2. The mean loading force among NiTi wire group and CuNiTi wire group specimens with Phos-Flur gel as a medium was 596.1 and 368.4 MPa, respectively, as shown in Table 2. While comparing between study group and control group among NiTi wires, significant results were obtained. Also while comparing between study group and control group among CuNiTi wires, significant results were obtained as shown in Table 3. Hence, it can be inferred that application of fluoride deteriorates the mechanical properties of NiTi and CuNiTi wires.

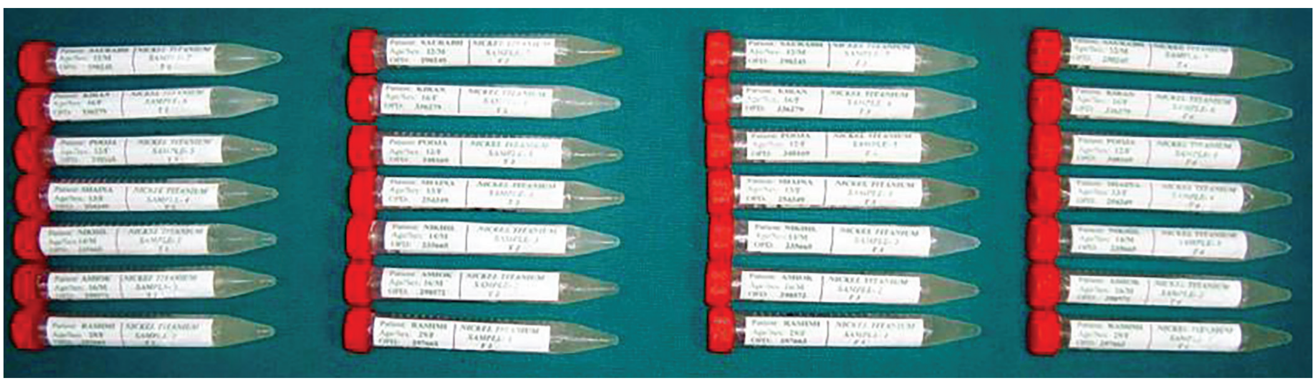

Fig. 1: Polypropylene test tubes containing CuNiTi wire samples

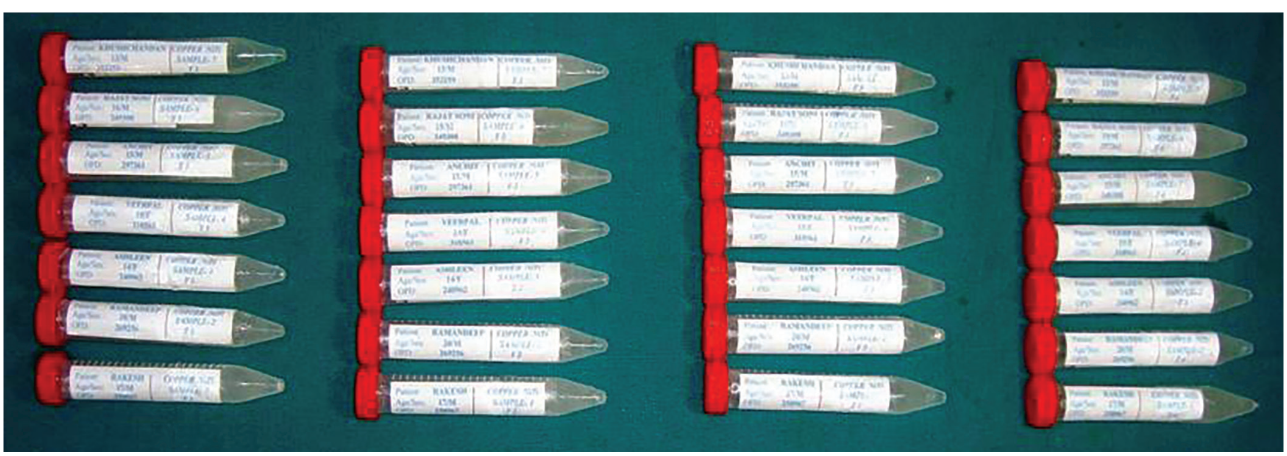

Fig. 2: Polypropylene test tubes containing NiTi wire samples

Table 2: Loading forces as tested by a universal force testing machine

Groups	*Subgroups*	*Mean loading force (MPa)*	*SD*
Control group (deionized water)	NiTi wire group	682.6	46.8
	CuNiTi wire group	397.4	21.8
Study group (Phos-Flur gel)	NiTi wire group	596.1	53.9
	CuNiTi wire group	368.4	29.4

Table 3: Intergroup comparison

Group comparison	*t-statistics*	*p value*
Control group (NiTi wire) vs study group (NiTi wire)	−1.225	0.001 (significant)
Control group (CuNiTi wire) vs study group (CuNiTi wire)	−1.996	0.002 (significant)

Discussion

Orthodontic treatment uses a variety of archwires specified for use at varying stages during the treatment. The ones most commonly used are NiTi and CuNiTi wires. The less the friction at the interface between the brackets and the archwires, the more will be the proficiency of the sliding mechanism. A variety of factors may affect friction. Some of them include the force of contact between the archwires and the brackets, the contact angle between the two and not to forget the surface properties between the brackets and the archwires. Any change in the surface properties owing to corrosion would eventually lead to an increase in the frictional component, thereby reducing the sliding efficiency of archwires on the brackets. A very important role to prevent dental caries has been attributed to fluoride-containing products such as toothpastes. In addition to this, fluoride-containing gels are also commonly prescribed. These products are especially advocated in patients with high caries index and those seeking orthodontic therapy. However, it has been found that HF produced is generated as a by-product of the interaction between fluoride possessing agents and the hydrogen ions released by the bacterial products. This acid eventually leads to corrosion of the metallic components of orthodontic therapy such as archwires and brackets owing to dissolution of the oxide layer.[7–9] Hence, this study was carried out to assess the impact on the mechanical properties of orthodontic wires such as the NiTi and CuNiTi wires by fluoride available in various prophylactic products.

In the present study, among the control group's specimens, the mean loading force among group A and group B specimens was 682.6 and 397.4 MPa, respectively. Among the study group's specimens, the mean loading force among group A and group B specimens was 596.1 and 368.4 MPa, respectively. Our results were in concordance with the results obtained by Mane et al., who also reported similar findings in their study. They assessed the impact on the surface texture of NiTi and CuNiTi wires used in orthodontic therapy by topical fluorides. These preformed wires were kept in an immersed state in fluoride solution and artificially prepared saliva at 37°C for a period of 90 minutes. An optical microscope was thereafter used to assess the effect of these solutions on the surface characteristics of these wires. It was inferred that acidulated preparations containing fluorides were more corrosive than neutral agents. It was thus observed that there needs to be a limitation in the usage of certain fluoride agents during prolonged orthodontic therapy in order to minimize the corrosion of NiTi and CuNiTi wires.[9]

In the present study, while comparing between study group and control group among NiTi wires, significant results were obtained. Also while comparing between study group and control group among CuNiTi wires, significant results were obtained. Similar findings were recorded in the study conducted by Ramalingam et al. In their study, three sample groups with 30 patients each receiving fixed orthodontic treatment were formed. First group did not use any agents containing fluoride, the second group used a fluoride rinse, and the last group used gels containing fluoride. The modulus of elasticity as well as the yield strength of the archwires was assessed after 30 days. The third group showed a significant fall in the modulus of elasticity of the NiTi archwires during unloading. On observing under a scanning electron microscope, it was assessed that maximum pitting was seen in the CuNiTi wires which were exposed to gels. It was inferred that there can be a prolongation of orthodontic therapy owing to the deterioration of mechanical properties of NiTi wires due to fluoride use.[10] Močnik et al. had assessed the role of environmental factors on the properties of NiTi and stainless steel products used in dentistry. Cyclic potentiodynamic technique was used to assess the role of pH as well as fluorides on various electrochemical properties. During the study, it was seen that lower the pH more is the susceptibility toward corrosion among the NiTi alloys. No effect was observed with a minor increase in the fluoride ions' concentrations up to 0.024 M. However at concentrations of 0.076 M, there does seem to be an alteration of the properties. The study observed that after tribocorrosion, there was a thicker layer of an oxide film on the surface of NiTi and other steel alloys in contrast to those which were exposed to saliva only.[11]

An *in situ* experiment was carried out by Abbassy et al. to assess the impact on the frictional resistance by fluoride application between ceramic and titanium wires. No significant changes were observed in the frictional resistance of the above wires. The buffering effect of the saliva to counter the APF solution as well as the dilution effect was proposed as the explanations for the above mechanism. It was also seen that whenever the orthodontic wires interacted with oral cavity environment, there was an organization of a noncellular layer on the surface of the materials as a consequence to spontaneous adsorption of certain macromolecules of extracellular nature, predominantly containing glycoproteins and proteoglycans. Therefore, it was noticed that under *in situ* conditions, the formerly stated reasons lowered the impact of fluoride on NiTi wires.[12–15]

However, our study had fewer limitations. Effect of different fluoride products was not assessed. Also, the effect of time factor and saliva on the mechanical properties was not evaluated.

Conclusion

Following exposure to fluoride agents, NiTi wires and CuNiTi wires are significantly associated with reduced mechanical properties. Hence, routine prophylactic use of fluoride agents should be done with utmost precaution among patients undergoing fixed orthodontic treatment.

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