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ORIGINAL RESEARCH

Effect of Fluoride Prophylactic Agents on the Surface Topography of NiTi and CuNiTi Wires

Pratap N Mane, Renuka Pawar, Chanamallappa Ganiger, Sandesh Phaphe

ABSTRACT

Aim: The aim of this study was to see the effect of topical fluoride on surface texture on nickel-titanium and copper-nickel-titanium orthodontic archwires.

Materials and methods: Preformed rectangular NiTi and CuNiTi wires were immersed in in fluoride solution and artificial saliva (control) for 90 minutes at 37°C. after immersion optical microscope was used to see the fluoride effect on the wire topography.

Results: The acidulated fluoride agents appeared to cause greater corrosive effects as compared to the neutral fluoride agents.

Conclusion: The result suggest that using topical fluoride agents leads to corrosion of surface topography indirectly affecting the mechanical properties of the wire that will lead to prolonged orthodontic treatment.

Clinical significance: The use of topical fluoride agents has to be limited in patients with prolonged orthodontic treatment as it causes the corrosion of the NiTi and CuNiTi wires.

Keywords: NiTi, CuNiTi, Fluoride agents, Optical microscope.

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INTRODUCTION

Orthodontic mechanotherapy encompasses the use of several archwires during specific stages of treatment. Nickel-titanium (NiTi), thermally activated copper-nickel-titanium (CuNiTi), wires are the ones predominantly in use.

The efficiency of sliding mechanics depends upon minimizing friction at the bracket archwire interface. Friction may be influenced by several factors such as the force with which the archwire contacts the brackets, the contact angle between the archwire and bracket as well as the surface characteristics of the brackets and archwires. Alteration of the surface characteristics of archwires by way of pitting and corrosion of the surface would add to the coefficient of friction in the mechanics, thereby compromising the sliding of brackets along archwires. It has been suggested in 2003 by Watanabe et al[1] that the surface roughness of titanium-based archwires, namely, NiTi, CuNiTi, β-titanium and titanium-niobium is increased following exposure to fluoride contain prophylactic agents. Mary P. Walker and Richard White[2] in 2005 have shown that titanium-based archwires particularly NiTi and CuNiTi show occurrence of corrosion, pitting and inclusion bodies on the surface upon exposure to neutral and acidulated fluoride prophylactic agents. The titanium-based archwires are known to have high corrosion resistance attributable to the formation of a stable oxide layer because of passivation.

MATERIALS AND METHODS

The study was carried out at the metallurgy laboratory of the 'PRAJ Metallurgical Laboratory, Pune and the Department of Orthodontics and Dentofacial Orthopedics, School of Dental Sciences, KIMSDU, Karad, Maharashtra, India.

The material used for the study included two different types of preformed archwires namely NiTi, CuNiTi and two fluoride containing prophylactic agents and a control solution (artificial saliva). Each of the two groups of wires consisted of 20 wire specimens. The two groups of wires selected were:

- Group I: 0.017″ × 0.25″ NiTi archwires (LIBRAL, Okhla Industrial Area, New Delhi, India)
- Group II: 0.017″ × 0.25″ CuNiTi archwires (LIBRAL, Okhla Industrial Area, New Delhi, India).

The fluoride agents selected were as follows:

1. Phos-flur gel (1.1% sodium fluoride acidulated phosphate, APF, 0.5% w/v Fluoride, Colgate Oral Pharmaceuticals, Canton, MA).
2. Prevident 5000 (1.1% sodium fluoride neutral agents 0.5% w/v fluoride pH = 7; Colgate Oral Pharmaceuticals, New York, USA).

These agents were selected since their pH values were significantly different from each other. The control solution used was artificial saliva containing methylcellulose 0.5% w/v and glycerin 30% w/v per 5 ml of solution with pH of 7 (ICPA Health Products Ltd). Each wire specimen was 0.42 × 0.62 × 25 mm in dimension, cut from the straight portion of the preformed archwires.

The control group and experimental groups were established as follows:

- Control group: Ten wire samples from each wire group were immersed in artificial saliva.
- Experimental groups:
  - Group 1: A total of ten wire samples consisting of five samples from each wire group, which were immersed, in the APF gel.
  - Group 2: A total of ten wire samples consisting of five samples from each wire group were immersed in the phos-flur fluoride rinse.

Five specimens from each wire group were immersed in 10 ml artificial saliva and two fluoride containing agents (10 ml/each agent) and incubated in individual plastic containers at 37ºC for 90 minutes. The exposure time of 90 minutes would be equivalent to 3 months of 1-minute daily topical fluoride application or fluoride rinse as stated by Mary Walker and Richard White.[1]

All the specimens were undertaken for microscopic analysis to qualitatively characterize the topography of the wire surface. The specimens were mounted directly on the metals stubs and observed using an optical microscope at 1000× magnification, (Reichert, Austria). The surface topography for each of the wires was observed.

RESULTS

All the experimental group wires specimens exhibited corrosive alterations on their surface topography upon immersion in fluoride agents. The acidulated fluoride agents appeared to cause greater corrosive effects as compared to the neutral fluoride agents. Corrosive changes in surface topography were observed for both wires. The control group wire surfaces exposed to artificial saliva show some dark areas without evidence of corrosion, which may be by-products of the manufacturing process. Figures 1 to 4 show the corrosive action of topical fluorides on the NiTi and CuNiTi wires.

DISCUSSION

The CuNiTi wire specimens exposed to fluoride agents exhibited pitting and corrosion of the wire surfaces as suggested by the optical microscope photomicrographs. In a clinical setting, corrosion of the CuNiTi wire surfaces

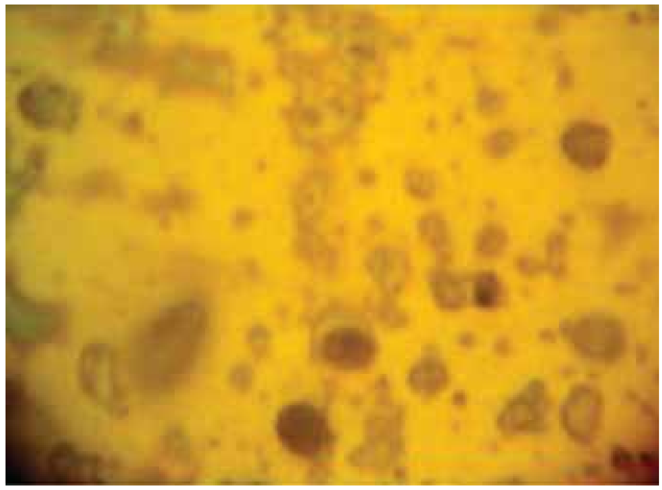

Fig. 1: Effect of phos-flur on CuNiTi, seen at magnification: 1000×

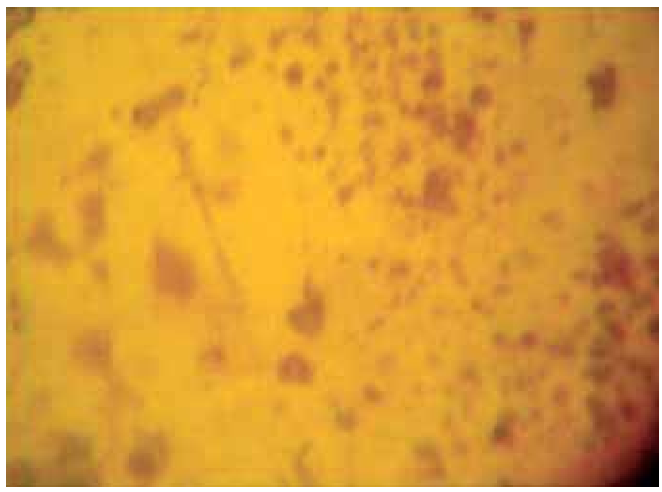

Fig. 2: Effect of phos-flur on NiTi, seen at magnification: 100×

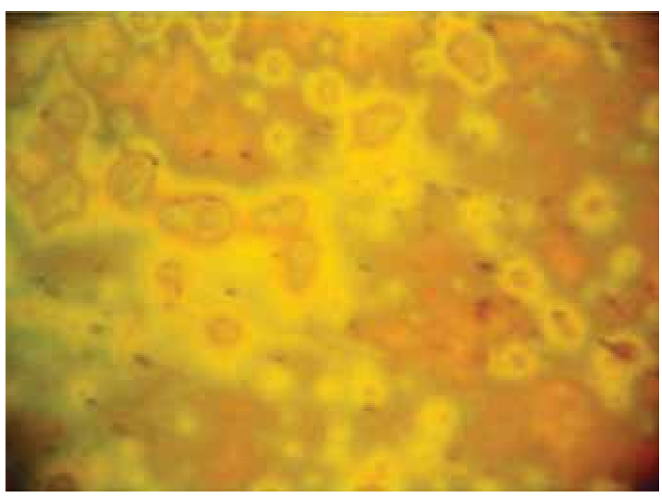

Fig. 3: Effect of prevident gel on NiTi, seen at magnification: 1000×

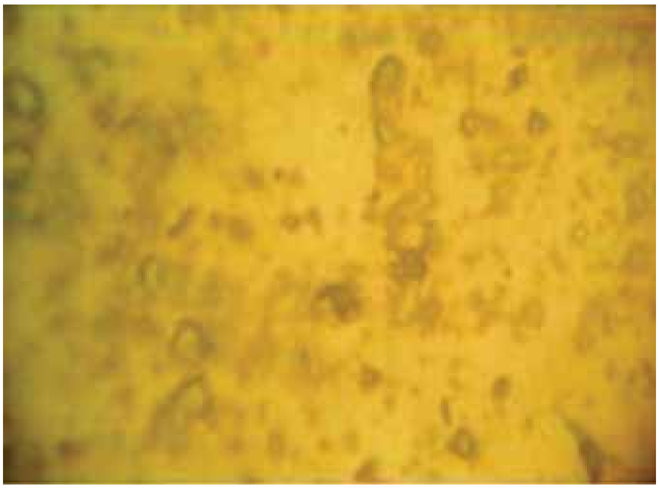

Fig. 4: Effect of prevident gel on CuNiTi, seen at magnification: 1000×

may add to the coefficient of kinetic friction at the bracket-wire interface, thereby interfering with effective tooth movement.

Topical fluorides have been reported to cause corrosion of titanium-based archwires[1-7] this suggests that fluoride might also adversely affect titanium-based alloy mechanical properties.

Also the corrosion of wire surface may have an adverse effect on the mechanical properties of the archwire mainly because of phenomenon of hydrogen embrittlement. Hydrogen embrittlement and increased fracture susceptibility of titanium-based orthodontic wires in fluoride solution have been studied by Toumelin-Chamela and F-Rouelle.[4]

However, ionizable fluoride compounds, such as sodium fluorides and hydrogen fluoride activate the surface and can cause rapid corrosion.[9] Hydrogen absorption and embrittlement of titanium-based alloys after fluoride exposure have been explained by the fact that, surface oxides of titanium are known to be highly effective in reducing hydrogen penetration.[9]

When titanium-based orthodontic wires are exposed to acidulated an neutral topical fluoride agents, it is suggested that, hydrofluoric acid (HF) is produced according to equation:[1]

$$H_3PO_4 + 3\ NAF \rightarrow NA_3PO_4 + 3\ HF$$

The hydrofluoric acid dissolves the protective oxide layer on the surface of titanium and its alloys according to the following equations:

$$TI_2O_3 + 6\ HF \rightarrow 2TIF_3 + 3H_2O$$

$$TIO_2 + 4\ HF \rightarrow TIF_4 + 2H_2O$$

$$TIO_2 + 2\ HF \rightarrow TIF_2 + H_2O$$

The degradation and loss of the oxide film exposes the underlying alloy, leading to corrosion and the absorption of hydrogen ions from the fluoride solutions because of the high affinity of titanium with hydrogen.[8]

The acidic pH of the fluoride agents can be considered to be an important factor in the breakdown of the protective titanium oxide layer leading to both, fluoride related corrosion and hydrogen embitterment of titanium-based alloys.[4,8]

The addition of copper to NiTi alloy not only enhances the thermal reactive properties of the metal, but has also been reported to act as a relative inhibitor of reducing acids, such as HF.[9] HF, which has been reported to be generated in the presence of sodium fluoride, can then dissolve the titanium-based oxide layers. However, the reduction inhibition properties of the copper component of the CuNiTi wire and the reported increase in the concentration of copper at the alloy/oxide interface[10] might protect the alloy from subsequent hydrogen penetration.

In addition, an archwire may be used for prolonged periods of time; thereby increasing the overall fluoride exposure time.

A qualitative optical microscope analysis of the wire surface topography was included to study the possible corrosion of the orthodontic wire surfaces following exposure to fluoride agents as this reduces tooth movement. The effect on titanium-based wires included pitting and corrosion of the wire surfaces and appearance of inclusion bodies along the entire length of the wire surfaces. The two fluoride agents produced surface corrosive topographical effects on NiTi, CuNiTi wires; these events may eventually result in the deterioration of the mechanical properties in the archwires.

There was variation amongst specimens in the severity of pitting and inclusion bodies which may be attributable to the agent having a lower pH and higher fluoride concentration the acidulated fluoride agents had a greater corrosive and pitting effect than the neutral fluoride agent, with greater distortion of the metal surface.

Topical fluoride agents with NiTi wire could decrease the functional unloading mechanical properties of the wire and contribute to prolonged orthodontic treatment.[2]

The reactivity in laboratory experiments is dramatically increased relative to the actual clinical conditions, which exaggerates the effects noted. The effects shown have not been validated *in vivo*, since the only available evidence on intraorally fractured nickel-titanium archwires did not support the implication of hydrogen embrittlement as a failure mechanism.[11]

Hence, a possible link between surface corrosion and mechanical property deterioration could exist for NiTi, CuNiTi archwires exposed to fluoride containing agents.

CONCLUSION

All the tested wire specimens exhibited corrosive alterations in their surface topography upon immersion in fluoride agents. The acidulated fluoride agents appeared to cause greater corrosive effects and degradation of mechanical properties of the wire specimens as compared to the neutral fluoride agents. The corrosive effects observed on the wire specimen surfaces may have the clinical implication of increased coefficient of friction of the bracket wire interfaces in clinical settings. Additionally, the increased friction may also delay the desired tooth movement; therefore, in patients who are using topical gels with high concentration of fluoride in association with NiTi orthodontic wires, the fluoride-related degradation of unloading mechanical properties could contribute to prolonged orthodontic treatment.

The duration for the present study was only 90 minutes, which is very less when compared to actual duration of wire in patient this could lead to more corrosion of wire. In the present study only surface topography was considered, the mechanical properties of the wires needs to be considered in further studies.

CLINICAL SIGNIFICANCE

The use of topical fluoride agents has to be limited in patients with prolonged orthodontic treatment as it causes the corrosion of the NiTi and CuNiTi wires.

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ABOUT THE AUTHORS

Pratap N Mane (Corresponding Author)

Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics, KIMSDU, School of Dental Sciences, Karad-415110 Maharashtra, India, Phone: 02164-243334, 09823133822 e-mail: drpratapmane31@gmail.com

Renuka Pawar

Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, KIMSDU, School of Dental Sciences, Karad Maharashtra, India

Chanamallappa Ganiger

Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, KIMSDU, School of Dental Sciences, Karad Maharashtra, India

Sandesh Phaphe

Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, KIMSDU, School of Dental Sciences, Karad Maharashtra, India