ORIGINAL RESEARCH

Assessment of Roughness of Fiber-reinforced Polymer Composite Wires and Other Coated Esthetic Archwires

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Abstract

Aim and objective: The objective of this study was to assess the roughness of three coated archwires and fiber-reinforced polymer composite wires "as received" and post-deflection.

Materials and methods: The sample comprises 40 esthetic archwire segments ($n = 10$) with 0.018″ size of epoxy-coated NiTi wire (G&H), optiflex (Ormco), rhodium-coated NiTi wires (American Orthodontics), and fiber-reinforced polymer composite wires (Biomers) were analyzed. The specimen was evaluated for roughness "as received" and each wire was deflected up to at a crosshead speed of 2.5 mm per minute in a universal test machine (Instron, model 4501). The evaluation of final roughness was done after a deflection on a similar aspect of wire. The comparison of roughness among the different wire brands before and after deflection was evaluated using a one-way ANOVA test. The statistically significant difference in roughness among the two groups was analyzed by Tukey's honestly significant difference test (HSD).

Results: Fiber-reinforced polymer composite wires showed mild roughness than epoxy-coated NiTi wire which showed increased roughness. ANOVA shows statistical significance among wire "as received" and post-deflection. Epoxy-coated NiTi exhibited significantly increased roughness among other groups "as-received" and after deflection ($p = 0.011$).

Conclusion: The coating of the esthetic wire estimates the roughness of orthodontic wires, but it is determined by the coating method. The roughness is increased after a deflection in wires. Epoxy-coated wires showed significantly increased roughness in comparison with other esthetic archwires.

Clinical significance: The roughness of the surface influences friction, color stability, and deterioration properties. It stipulates the stability of color in archwires, effectiveness of guided tooth movement over the archwire, and biocompatibility.

Keywords: Coated archwires, Esthetic archwires, Fiber-reinforced polymer composite wires, Roughness.

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Introduction

The visage of the appliance in orthodontics has become a major esthetic concern for the patients seeking orthodontic treatment. The esthetic quality of archwires is improved by a coating of polytetrafluoroethylene (PTFE), epoxy resin, and rhodium over the metallic archwire.[1] Epoxy resin exhibits excellent adhesion, dimensional stability, and resistance to chemical agents.[2] Optiflex wires are nonmetallic composed of clear optical fiber with a central core of silicon dioxide, cladding of silicon resin for moisture protection and a coating of nylon provides resistance to strain and increases strength.[3]

However, the durability of the esthetic coatings is not clinically evident as they tear over a period of time.[2,4] To overcome the drawbacks of coated archwires, through composite technology of continuous fibers and polymer matrix by tube shrinkage technique, fiber-reinforced polymer composite archwires (FRPC) were introduced.[5,6] The esthetic property is enhanced by the translucent nature of the polymer matrix and material flexibility.[7–9]

In orthodontic treatment, both fixed and removable appliances can cause periodontal problems and demineralization of enamel due to plaque accumulation.[10] Accumulation of plaque is determined by the roughness of the surface of the archwire. Hence, the surface roughness has a major effect.[11]

The roughness of the surface influences friction, color stability, and deterioration properties.[12,13] It stipulates the stability of color in archwires, effectiveness of guided tooth movement over the archwire, and biocompatibility.[13–16]

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Researchers have elicited a direct relationship between the corrosion of archwires causing a release of ions in the oral environment and surface roughness. An increase in surface roughness increases the frictional force, as there are raised contact between archwire and bracket interface.[15,17] The objective of this study was to assess the roughness of three coated archwires and fiber-reinforced polymer composite wires "as received" and post-deflection.

Materials and Methods

The study was conducted in CIPET: School for Advanced Research in Polymers (SARP)–ARSTPS, Guindy, Chennai, Tamil Nadu, India. The sample comprises 40 esthetic archwire segments ($n = 10$) with 0.018″ size of epoxy-coated NiTi wire (G&H), optiflex (Ormco), rhodium-coated NiTi wires (American Orthodontics), and fiber-reinforced polymer composite wires (Biomers) were analyzed. Each sample wire was cut into 20 mm length with an orthodontic wire cutter and washed in distilled water to remove the surface impurities and blot dried.

Each archwire of two straightened sections of 20 mm in length was positioned in a metal block with maxillary central incisor metal brackets (3m Unitek Gemini Metal Twin Brackets) stabilized with cyanoacrylate adhesive (Quickfix), with a distance between the two brackets of 15 mm. The brackets were secured with the wire by elastomeric modules (Ormco). The archwire was oriented at a constant speed of 0.5 mm/second to the surface rugosimeter stylus needle measuring 5-µm in diameter. The average of three readings for each orthodontic treatment was recorded for the surface roughness. The specimen was evaluated for roughness "as received" and each wire was deflected up to at a crosshead speed of 2.5 mm per minute in a universal test machine (Instron, model 4501). The evaluation of final roughness was done after a deflection on a similar aspect of wire.

The data obtained were entered into the computer database. The response of frequencies was calculated and examined in the statistical Software Package of Social Sciences (SPSS) version 22.0 version. The comparison of roughness among the different wire brands before and after deflection was evaluated using a one-way ANOVA test. A statistically significant difference in roughness among the two groups was analyzed by Tukey's honestly significant difference test (HSD). The significance levels used were as follow: highly significant $p \leq 0.01$, non-significant $p > 0.05$, and significant $0.05 \geq p > 0.01$.

Results

ANOVA is used to find significance between wires before and after a deflection. Less than 0.05 *p* value is observed as significant. Table 1 shows esthetic wire roughness before and after a deflection. Fiber-reinforced composite wires show 1.93 roughness before deflection and 3.92 after deflection, as the same optiflex shows 1.65 before and 5.01 after deflection. All wires show some degree of roughness after deflection, epoxy-coated NiTi wire shows 3.24 before and 6.57 mean roughness after deflection, rhodium-coated NiTi wires shows 2.01 mean roughness before and 4.83 after a deflection. Fiber-reinforced composite wires showed mild roughness than epoxy-coated NiTi wire which showed increased roughness. ANOVA shows statistical significance among wire "as received" and post-deflection. Epoxy-coated NiTi exhibited significantly increased roughness among other groups "as-received" and after deflection ($p = 0.011$).

Tukey's honestly significant difference test (HSD) (roughness differentiation among "as-received" and after deflection) showed a significantly increased roughness for epoxy-coated NiTi wire after a deflection.

Discussion

In orthodontics, the use of esthetic appliances has been increased. The mechanotherapy of tooth movement is dependent on various factors such as plaque accumulation, friction, and corrosion characters. These factors are determined by the characteristics of surface roughness. Deflection is the total energy acquired per distortion in millimeters. In this study, the roughness of esthetic archwires was evaluated before and after load deflection by rugosimeter. Rugosimeter is an instrument used for measuring the surface roughness of the wire.[18]

The roughness depends on the force of two surfaces which determines the quality of tooth movement during orthodontic treatment.[19] In clinical use of the coated esthetic wires, the loss of coating has been observed over a period of time, hence to observe these changes, a clinical simulation was performed by deflection test.[2,20] The stage of alignment and leveling during orthodontic treatment undergoes large deflection, therefore, a 0.018″ wire was chosen in this study.

Epoxy resin-coated wires are a combination of epoxide and synthetic resin, achieved by electrostatic coating. The wire surface is air sprayed with epoxy particles as atomized liquid along with the application of high voltage. This enhances the adhesion, dimensional stability, electrical insulation, and chemical resistance, but the mechanical properties are altered by an increase in the thickness of the epoxy coating.[21]

Optiflex is a modified optical fiber made up of silicon dioxide, silicon resin, and stain-resistant nylon. The mechanical advantage of the optiplex is the flexural modulus, but the fracturing of the core in optiflex on the application of metal ligatures and a sharp instrument is a limitation.[22]

A rhodium-coated archwire is made up of ion implantation of rhodium over sentalloy wire. This increases the shimmering and

Table 1: Esthetic archwire roughness before and after the deflection

		Roughness						
		As received			*After deflection*			
S. no.	*Esthetic coating wire*	*Mean*	*SD*	*Intergroup comparison*	*Mean*	*SD*	*Intergroup comparison*	*p value*
1	Fiber-reinforced composite wires	1.93	12.39[a]	A	3.92	24.38[b]	A	0.002
2	Optiflex wires	1.65	31.05[b]	B	5.01	36.19[c]	A	0.231
3	Epoxy-coated NiTi wires	3.24	11.46[a]	C	6.57	22.36[b]	C	0.011
4	Rhodium-coated NiTi wires	2.01	53.84[a]	D	4.83	14.39[b]	D	0.042

A statistically significant difference ($p = 0.05$) between different time periods in each group is indicated by different letters a, b, c in the same line
A statistically significant difference ($p = 0.05$) between different time periods in each group is indicated by different letters A, B, C, D in the same column

surface finish of the metals. The disadvantage of this wire is surface corrosion elicited in stress deflection.[23]

The coatings on the orthodontic wire reduce the surface irregularity and act as a lubricant facilitating the sliding of wire over the bracket.[24] In earlier research, it has been stated that the roughness is increased on esthetic coatings.[25] This was verified in this study, that the roughness of epoxy-coated archwires, was significantly higher initially than the other groups. Epoxy-coated archwires showed the highest roughness value post-deflection. The porosity is greater in the epoxy-coated archwires, hence there is increased roughness of the wire, this has also been stated by Kim et al.[26] The stress concentration locations may function as porosity, leading to the fracture of the coatings under deflection. Moreover, future clinical research is required to understand the outcome of orthodontic treatment requiring longer treatment time, considering the biologic complexity exerted in the movement of the tooth.

The rhodium-coated archwires are called white metals, were shown to be rougher when compared with the parylene polymer-coated archwires, and sentalloy non-coated wires, this has been stated by Iijima et al.[27] D'Anto et al. evaluated orthodontic wires microscopically without and with esthetic coating on b-titanium (b-Ti), nickel–titanium (NiTi), and stainless-steel (SS) alloys, and found that implantation of rhodium ions increases sliding and roughness of esthetic wires.[25] In artificial saliva, deterioration of NiTi to deflection stress has been proved in areas under tension.[23] After deflection, the roughness of the wire increases due to corrosion of the surface of the wires. The reduction of flexibility, improving the surface characteristics and increasing hardness is enhanced by the implantation of ions.[28] However, periodic ion implantation must be done to reduce maximum friction.[29]

Fiber-reinforced polymer composite archwire showed decreased roughness when compared with other esthetic archwires. This is congruent with the previous study conducted by Inami et al.[16] The disproportion in roughness is associated with the manufacturer, technique of manufacturing, and the surface of the material.[14,15,30,31]

A limitation of the study was the difficulty in extrapolating the values for roughness determined *in vitro* to an *in vivo* situation. This was due to the difficulty of reproducing oral conditions such as muscular and occlusal forces, and tooth movement through bone which may affect the binding of the archwire to the bracket.

Conclusion

The method of coating the wires influences the orthodontic wire roughness. The roughness increases on esthetic wire under deflection. Epoxy-coated wires showed significantly increased roughness in comparison with other esthetic archwires. Future studies are necessary to evaluate other considerations that convict the loss of the coatings over the archwires. Flaying of esthetic coating must be elucidated in clinical use with advanced research in the future.

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