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Original research

Study on the Friction Generated by Aesthetic Arches Covered with Rhodium.

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ABSTRACT

Introduction: Aesthetic metal archwires are more discreet than conventional metal archwires. One of the most commonly used aesthetic metal archwires in orthodontics consists of a rhodium-coated Nickel Titanium (NiTi) alloy core. Rhodium is an extremely hard metal and has a high reflectance, making the NITi metal archwire with rhodium coating an aesthetic solution for orthodontic treatment. **Objective:** To present the evaluation of the friction generated on three types of arches. **Materials and Methods:** An experimental design was performed using 30 archwires of 0.016” x 0.022” of three different characteristics: NiTi without esthetic coating, NiTi with rhodium coating, and NiTi with Teflon coating. These archwires were placed in 20 experimental models made of acrylic to which 40 brackets In-Ovation R ® (Dentsply Sirona) slot 0.018x 0.025” were placed. To simulate oral conditions the archwires were pulled at different distances: 3mm, 6mm, 7mm, and 8mm at a speed of 10 mm/min in the deflection testing machine using artificial saliva at 25°C as lubricant and the friction generated was measured. **Results:** The results showed statistically significant differences in the friction generated by uncoated NiTi archwires when compared to NiTi with rhodium and Teflon coating ($p > 0.0001$) **Conclusions:** Orthodontic archwires with rhodium coating are more aesthetic and do not alter the original dimensions or properties of the wires. Rhodium coating generates less friction in orthodontic tooth movement.

Keywords: aesthetic arches, friction, rhodium.

INTRODUCTION

One of the most desired characteristics by adult patients during orthodontic treatment is that the appliances should be as discreet as possible, and this aspect has to do with their esthetic appearance. Among the most common materials used for metal archwires are stainless steel, Cobalt-Chromium, Nickel-Titanium, and Beta-Titanium[1]. Aesthetic metal archwires are more discreet than conventional metal archwires (Figure 1. A-B). The first aesthetic archwire in orthodontics was a non-metallic wire containing a silica core, a silicone resin layer, and a stain-resistant nylon outer layer and was marketed as Optiflex (Ormco® Co., Glendora, CA)[2,3]. Fallis and Kusy devised an esthetic archwire containing glass fibers (Owens Corning®, Toledo, Ohio) embedded in a polymer matrix composed of bisphenol A-diglycidylether methacrylate and triethylene dimethacrylate glycol[4]. Imai *et al*. devised a fiber-reinforced polymer archwire consisting of polymethylmethacrylate (PMMA) and $CaO-P_2O_5-SiO_2-Al_2O_3$ (CPSA) glass fibers to further improve the aesthetic appearance and with mechanical properties similar to those of metallic archwires[5].

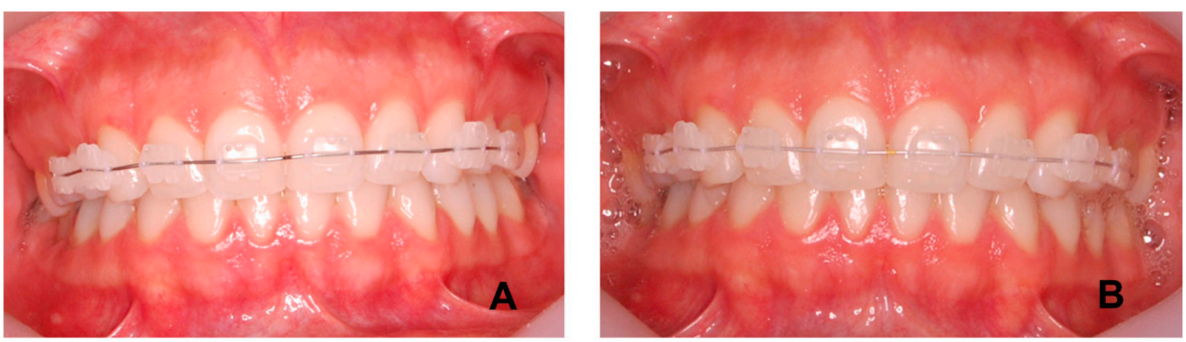

Figure 1. Intraoral photographs that show the comparison of a conventional metal archwire with an esthetic metal archwire. A. Stainless steel archwire with Mystique porcelain bracket. B. Rhodium-coated NiTi archwire with Mystique porcelain bracket.

Regarding aesthetic metal archwires, the most commonly used in orthodontics consist of a nickel-titanium (NiTi) alloy core coated with plastic resin materials such as synthetic resin or fluoride, epoxy resin composed mainly of polytetrafluoroethylene or Teflon® and hydrogenated carbon or zirconium dioxide resins[6]. Later on, other types of coatings such as aluminum and titanium nitride, and tungsten carbide/carbon were introduced to protect the alloy from the corrosive effects of fluoride gel-based mouthwashes and toothpastes commonly recommended to the orthodontic patient for oral care at home[7].

Another way of making orthodontic archwires more aesthetic emerged in 2008 with the application of rhodium on the surface of the archwires, initially under the commercial name of *High Esthetic* and later changed to *White Wire* (Bioforce Sentalloy® and White wire Tomy Inc., Futaba, Japan)[8]. This process was created to minimize the metallic appearance of the archwires while maintaining the superelastic properties of NiTi archwires[9].

Rhodium (Rh) is a chemical element of atomic number 45 found in the periodic table of the elements in group nine, ductile, not very abundant, of the platinum group, silver-white in color, has a higher melting point and a lower density than platinum[10]. It is a hard metal resistant to chemicals. The Rh coating obtained by evaporation or electroplating is extremely hard and has a high reflectance. Reflectance is an extremely useful feature to provide a more aesthetic appearance. Rh is used in the manufacture of optical instruments, as well as in jewelry, providing high-quality finishes utilizing an immersion electrolysis technique. This process consists of immersing a piece of gold or silver jewelry in a chemical solution containing minute quantities of the metal. These solutions contain several diluted grams of Rh, and through an electrolytic process, a layer of several microns of Rh adheres to the surface of the piece that has been immersed. At the end of the process, the result is a jewel that is covered by this thin layer of Rh, which is a totally innocuous material for people. For this reason, this study aimed to assess the friction generated by Rh-coated NiTi archwires measuring frictional forces with self-ligating brackets using the deflection machine.

MATERIALS AND METHODS

An experimental design was performed at the Laboratory of Dental Materials of the Universidad Nacional Autónoma de México. Thirty 0.016 "x0.022" wire archwires of three different characteristics, NiTi without esthetic coating, with Rh coating, and with Teflon coating, were used. These archwires were placed in 20 experimental models made of acrylic to which 40 In Ovation R® (Dentsply Sirona) 0.018 "x0.025" slot brackets were placed. Used arches were excluded. A pilot test was previously performed using five archwires from each group.

Group 1: 10 NiTi archwires without esthetic coating (Bioforce Sentalloy®, Tomy Inc., Futaba, Japan).
Group 2: 10 NiTi archwires with Rh coating (Bioforce Sentalloy® and White wire Tomy Inc., Futaba, Japan).
Group 3: 10 NiTi archwires with Teflon coating on the labial surface of the arch (TP Orthodontics Inc.).

To carry out the deflection test, a device fabricated to simulate the buccal surface of the tooth on which the brackets were cemented was used. This device was made of acrylic to the exact size to be placed in the Universal Instron machine. Two brackets were placed on each device at different heights from each other to simulate the inter bracket distance and the crowding of the patient and thus generate a significant friction result. Once the machine was programmed, the friction produced at different distances was measured: 3mm, 6mm, 7mm, and 8mm at a speed of 10 mm/min. The arches were placed in the brackets and two measurements per arch were taken. Since saliva is always present while the brackets are working, the operator poured artificial saliva into the bracket at a temperature of 25°C without touching the archwire during arch traction to simulate an intraoral clinical situation.

Each archwire was measured twice and the friction of each group was compared. For the statistical analysis, an analysis of variance (ANOVA) was performed to identify if there were statistically significant differences between the three groups at the four different distances.

RESULTS

Group 1: NiTi without esthetic coating showed the highest mean values in all distances (1.33, 2.52, 3.79, and 3.91N respectively), while Group 2: NiTi with Rh coating obtained the lowest average (0.64,1.64,2.68 and 2.73 N respectively). These differences were statistically significant (p=0.001). The rest of the results are shown in Table 1.

Table 1.
Mean friction at displacement

	Mean friction at displacement			
Displacement (N)	**3mm**	**5mm**	**7mm**	**8mm**
Group 1: NiTi without esthetic coating	1.33 ± 1.09	2.52 ± 1.18	3.79 ± 1.24	3.91 ±1.28
Group 2: NiTi archwires with Rh coating	0.64 ± 0.41	1.64 ± 1.18	2.68 ±1.27	2.73 ± 1.27
Group 3: NiTi archwires with Teflon coating	0.29 ± 0.07	0.41 ± 0.18	0.75 ± 0.43	0.74 ± 0.43
F	12.43	23.66	42.29	44.38

ANOVA (p= 0.0001) ±: standard deviation, N: newton

DISCUSSION

In this study, it was found that there is greater friction in NiTi archwires without aesthetic coating, which is similar to what was found in the study by Muguruma *et al.*[11], where the influence of the aesthetic coating of orthodontic archwires on the deformation and friction of the archwires was analyzed, and they found that orthodontic archwires with aesthetic coating can produce less friction than expected. They remark that the friction generated by the coated wires was influenced by the overall transverse and inner core dimensions, inner core nanohardness, and inner core elastic modulus, but not by surface roughness.

Another study by Elayyan *et al.*[3] analyzed the mechanical properties of superelastic archwires with an esthetic coating on conventional ligature brackets and self-ligating brackets. The results showed that both superelastic archwires with an esthetic coating and self-ligating brackets produce less loading and unloading forces, less friction, and less deflection compared to conventional ligation in conjunction with this type of esthetic archwires; however, these variables were not examined in this study.

The study conducted by Da Silva and collaborators[12] in which the mechanical properties of archwires with esthetic coating were analyzed showed results similar to ours, adding that the groups with an esthetic coating layer on their entire surface show a greater reduction in the internal dimensions of their core, thus generating a lower loading and unloading force, lower modulus of elasticity, lower resilience and higher deflection force values.

In this study, a three-point test was used to compare the mechanical behavior of various esthetic arches, controlling the temperature at 37°C. A 3mm activation can be observed as a

0.016" round arch when placing the esthetic coating on some arches, the loading and unloading force should be considered from the mechanical point of view as a 0.014" arch and not that of a 0.016" arch. It has been demonstrated in the deflection test that some polymer aesthetic archwires do not generate continuous forces for long periods since these archwires do not exhibit superelasticity or shape memory properties (Figure 2. A). As can be seen in Figure 2. B, the stress-strain curve graph of the Sentalloy archwires (Bioforce Sentalloy® Tomy Inc., Futaba, Japan) shows the typical behavior of a superelastic archwire without altering its dimensions. On the other hand, we should consider that the Bioforce archwire is a multi-strength archwire where the anterior part generates a light force, medium force in the premolar area, and a heavy force in the molar area[13], therefore, the behavior may be slightly different from the NiTi with Teflon coating since the latter is not a multi-strength archwire. Another factor to consider in the case of Teflon-coated archwires is that only the buccal side of the archwire is coated. We may assume that the results might be different if all sides of the archwire were coated.

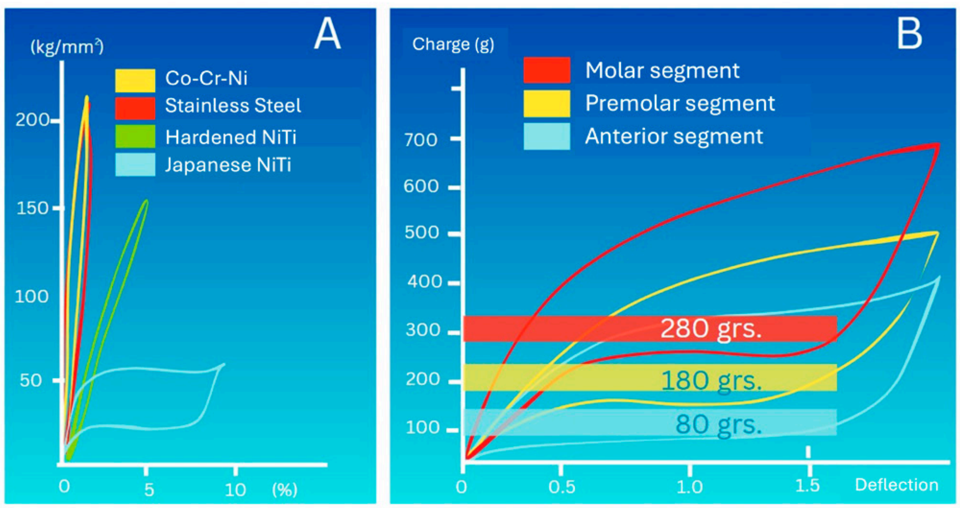

Figure 2. NiTi stress-strain curve. A. Comparison of deflection loads of four different wires: Co-Cr-Ni (yellow), Stainless Steel (red), hardened NiTi (green), and Sentalloy (blue). B. Bioforce is a multiforce archwire where the anterior part generates a light force of 80 g (blue), medium force in the premolar area of 180 g (yellow), and heavy force in the molar area of 280 g (red) (8).

Kusy and Whitley,[14] simulating the sliding mechanics of ceramic and stainless steel brackets in their active and passive configuration, obtained the same results of our study in finding that polyphenylene coatings on orthodontic archwires are equally effective, with a stiffness similar to those usually used at the beginning and in the intermediate stages of orthodontic treatment.

The advantage of Rh-coated NiTi is that these coatings do not delaminate when used in the mouth and do not tear off as Teflon coatings do, thus losing their esthetic appearance (Figure 3. A-B). The limitations of our study are that the saliva is artificial and, therefore, the oral conditions were not the same. Factors such as temperature can also affect archwire performance, especially NiTi archwires. Another important limitation is that the study was performed on 0.016" x 0.022" archwires, and it is possible that the results may vary in the finishing stage of treatment.

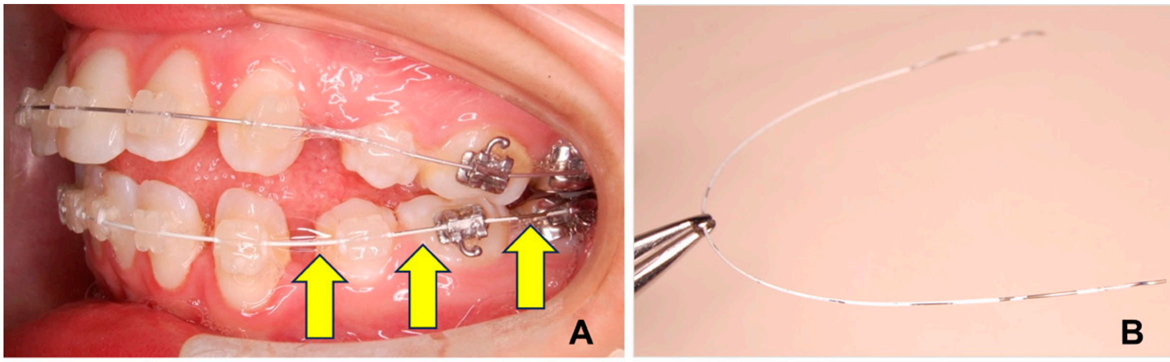

Figure 3. Esthetic NiTi archwire with delaminated Teflon coating when used in the leveling stage. A. Esthetic archwire NiTi with Teflon coating in the mouth. B. Esthetic NiTi archwire with Teflon coating outside the mouth.

CONCLUSION

As a coating in orthodontic archwires, Rhodium fulfills the purpose of generating a more esthetic appearance, not altering the original dimensions of the archwires. This study demonstrated that the archwires submitted to Rh coating can be used for esthetic orthodontic treatments and expect better results since they generate less traction friction.

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