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Influence of aesthetic coating on the load-deflection ratio of nickel–titanium archwires

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Abstract

Aim: To assess the influence of aesthetic surface coating on load-deflection ratios in nickel-titanium (NiTi) orthodontic wires compared with uncoated wires.
Methods: NiTi wires (0.016") from four different manufacturers (Morelli, Sorocaba, SP, Brazil; TP, La Porte, IN, USA; Eurodonto, Curitiba, PR, Brazil; Ortho Organizers, San Marcos, CA, USA) were divided into eight groups, according to presence or absence of coating: group 1, Morelli coated wire; group 2, Morelli uncoated; group 3, TP coated; group 4, TP uncoated; group 5, Eurodonto coated; group 6, Eurodonto uncoated; group 7, Ortho Organizers coated; group 8, Ortho Organizers uncoated. To determine the load-deflection ratio, a three-point bending test was performed in a AGS-X 250 KN (Shimadzu) universal testing machine.
Results: The results showed that aesthetic coatings did not influence load-deflection ratio in NiTi orthodontic wires at 1-mm and 2-mm activation. However, comparison across the four tested brands revealed that Eurodonto coated wires exhibited the greatest force levels at 1-mm, 2-mm, and 3-mm deflection. At 3-mm deflection, Ortho Organizers coated wires exhibited lower force levels than all other tested brands, except for TP wires.
Conclusions: We conclude that the load-deflection ratio of NiTi wires was not influenced significantly by aesthetic coatings, especially at lower activations.

Keywords: Orthodontic wires. Aesthetics. Alloys.

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Introduction

Individual variations considered, orthodontic treatment usually extends over months or years. Therefore, the appearance of orthodontic appliances has become a significant factor in orthodontic treatment decisions, particularly due to increasing demands from adult patients[1-3]. These demands mean that aesthetic considerations now extend beyond ceramic or composite brackets and ligatures and are now a concern for archwires as well, which has led to the advent of aesthetic orthodontic wires[4,5].

Aesthetic orthodontic wires may be divided into three categories: a) stainless-steel or nickel-titanium (NiTi) wires coated with epoxy resin, which are manufactured by depositing or embedding an approximately 0.002"-thick layer of epoxy resin onto the wire; b) stainless-steel or NiTi wires coated with Teflon (polytetrafluoroethylene, PTFE), which mimics tooth color. PTFE coatings are applied by an atomic process that yields a mean layer thickness of 20-25 µm; and c) fiber-reinforced composite resin wires[6,7].

Unsolved questions remain as to whether the mechanical properties of metal archwires, such as the load-deflection ratio, could be affected by such coatings and by modifications in wire dimension made to compensate for the added thickness of the coating layer[8]. The load-deflection ratio has been used as a marker of how much force is released with each millimeter of wire activation, as well as to determine the elastic limit of the wire[9].

Several advantages of aesthetically coated NiTi archwires in their original, as-received condition have been described, including reduced surface roughness, increased corrosion resistance, and reduced friction[10-15].

However, some disadvantages of PTFE and epoxy coatings have been reported, including poor durability of the coating, discoloration, cracking and pitting, increased surface roughness, and predisposition to a buildup of amorphous organic matter, both through the mechanical action of masticatory forces and tooth brushing and due to the effects of oral enzymes. These changes or losses of coating material have been observed after clinical use and even after exposure to simulated oral environments[2,11,16-23].

Within this context, given the limited scientific evidence regarding the potential benefits of aesthetically coated NiTi archwires in orthodontic practice, the present investigation sought to assess the influence of aesthetic coatings on the load-deflection ratio of NiTi wires.

Methods

Sample size calculation was based on an alpha level significance of 1% ($\alpha = 0.01$) and a beta level of 20% ($\beta = 0.20$), with a power of 80% to detect a mean difference between the four groups of 125.04 g/mm, with a standard error deviation of 5.58, which is in agreement with the study of Silva et al.[20]. Therefore, a sample size of 6 wire segments per group was required.

Aesthetically coated NiTi orthodontic wires from four different brands and their respective control (uncoated) wires were evaluated in this study (Table 1). To assess the influence of aesthetic coating on load-deflection ratio, the sample was divided into eight groups: group 1, Morelli coated wire; group 2, Morelli uncoated; group 3, TP coated; group 4, TP uncoated; group 5, Eurodonto coated; group 6, Eurodonto uncoated; group 7, Ortho Organizers coated; group 8, Ortho Organizers uncoated. All wires in each group were obtained from the same batch. These brands were selected because we aimed to test different coatings types (epoxy resin or Teflon), coated surfaces (buccal or total surface), and wires from different origins (nationally manufactured or imported).

Table 1 - Characteristics of the nickel–titanium aesthetic archwires and respective control wires.

Manufacturer	Dimension	Coating type	Coated surface
TP Orthodontics, La Porte, IN, USA	0.016"	Teflon	Buccal
Ortho Organizers, San Marcos, CA, USA	0.016"	Teflon	Total
Eurodonto, Curitiba, PR, Brazil	0.016"	Teflon	Total
Morelli, Sorocaba, SP, Brazil	0.016"	Epoxy resin	Total

The three-point bending (flexural) test was used to assess load-deflection ratio, as it is regarded as the assay that best simulates the conditions of real-life orthodontic practice[24,25].

All assays were performed in accordance with the ISO 15841:2006 standard (Figure 1). As suggested in the ISO standard, the wire span between supports was 10 mm, the crosshead rate was set at 6.0 mm/min, and the radius of both fulcrum and indenter was 0.1 mm. Assays were carried out in a Servo Elétrica AGS-X 250 KN (Shimadzu) universal testing machine coupled to a workstation running Trapezium X software (Shimadzu). The span between support and fulcrum was 5 mm, and deflection was carried out with a centrally placed indenter. Specimens measured 30 mm and were obtained from the straightest section of each archwire with distal end cutters. Each of the eight groups comprised six specimens. Thus, a total of 48 specimens were tested at a temperature of 37 °C, obtained by using heating lamps in a thermal chamber coupled to the universal testing machine (Figure 1). All wires were isolated from the outside environment to ensure temperature stability during testing.

Deflection was quantified with the AGS-X 250 KN electronic deflectometer (Shimadzu), with the universal testing machine programmed to impart a maximum deflection of 3.0 mm. These assays yielded force (gf) vs. deflection (mm) curves, which were analyzed and compared.

Data were described as means and standard deviations and entered into tables. The Shapiro-Wilk test was applied to evaluate the normality of data distribution. For the 1-mm and 3-mm activations, values fell outside the normal distribution curve ($p = 0.009$ and $p = 0.029$ respectively), and thus required nonparametric tests for comparison. For the 2-mm activation, all values fell within the normal distribution curve ($p = 0.331$), and groups were thus compared by parametric tests.

To assess the null hypothesis that the eight tested groups of independent samples would be homogeneous in terms of load-deflection ratio distribution, the Kruskal-Wallis test was applied to 1-mm and 3-mm activation values. When the null hypothesis was rejected, Dunn's multiple comparisons test was used to ascertain which groups differed. For the 2-mm activation, analysis of variance (ANOVA) was used to test the null hypothesis of absence of difference across groups, with Tukey's multiple comparisons used to ascertain which groups differed. The level of significance was set at 5% ($p < 0.05$) for all tests. All statistical procedures were performed in the Statistical Package for the Social Sciences (SPSS) 22.0 software environment.

Fig. 1 - Specimen positioned for three-point bending test at 37 °C.

Results

Table 2 lists the means and standard deviations obtained in each group after bending tests, as well as the differences across groups, as determined by Dunn's test (1-mm and 3-mm activations) and Tukey's test (2-mm activation). At 1 mm and 2 mm of activation, aesthetic coating did not have a significant influence on the load-deflection ratio when comparing coated and uncoated wires from the same brand. At the 3-mm activation, load/deflection ratios were significantly increased in Eurodonto coated wires and were reduced in Ortho Organizers wires.

Comparison between different brands revealed that, at 1 mm, 2 mm and 3 mm of activation, most groups were not significantly different, except for the Eurodonto coated wires, which exhibited the highest load/deflection levels. At 3-mm activation, it was also observed that Ortho Organizers coated wires had lower load/deflection levels than those of Morelli and Eurodonto coated wires.

Discussion

In the present study, the load-deflection ratio of orthodontic archwires made of nickel-titanium—the alloy of choice for the initial leveling and aligning phases of orthodontic treatment—was tested by means of a three-point bending test. As recommended in the literature, tests were performed without brackets, and ambient temperature was kept at 37 °C throughout the experiment[21,24-27].

The results showed that, at 1 and 2 mm of activation, aesthetic coatings did not have a significant influence on the load-deflection ratio of wires from the same brand. This is consistent with the findings of Silva et al.[20], Neves et al.[13], and Washington et al.[3]. At 3-mm activation, however, coating did have an influence on the behavior of wires from two brands. In the present study, Eurodonto coated wires exhibited increased load-deflection ratios compared with their uncoated counterparts. This result is in agreement with that obtained by Bradley et al.[21], who found increased load-deflection ratios in coated wires at greater activations and after clinical use. Conversely, Ortho Organizers coated wires demonstrated decreased load-deflection force levels compared with uncoated wires from the same brand. This finding corroborates those of prior studies by Elayyan et al.[17], Elayyan et al.[23], Alavi and Hosseini[2], Kaphoor and Sundareswaran[28], and Ryu et al.[29], which found a reduction in load-deflection ratio in aesthetically coated wires.

Table 1 - Mean and standard deviation loads (gf) in three-point bending tests, stratified by brand and presence of aesthetic coating.

Groups	1 mm activation			2 mm activation			3 mm activation		
	Mean	SD	sig	Mean	SD	sig	Mean	SD	sig
1	116.22	11.78	a,b,c,d,g,h	192.64	46.35	a,b,c	276.41	65.18	a,b,c,d,f,h
2	131.67	46.76	b,c,d,f,g,h	225.11	46.76	a,b,c	321.57	29.79	b,e,f,h
3	142.94	25.52	c,d,f,g,h	204.21	14.53	a,b,c	219.96	29.81	c,d,g
4	114.78	26.67	d,g	161.56	44.21	a	238.04	11.40	d,g
5	195.38	26.32	e	263.23	76.86	b	373.45	77.99	e
6	165.65	35.13	e,f	251.26	37.64	c	305.70	32.29	f
7	122.71	27.73	f,g,h	175.15	49.46	a,c	204.34	26.47	g
8	148.71	25.01	f,h	233.29	34.23	a,b,c	288.17	41.80	d,e,f,h

Same lowercase letters in the same column denote absence of statistical significance ($p > 0.05$). Different lowercase letters in the same column denote statistically significant differences ($p < 0.05$).

On comparison across the four tested brands, Eurodonto coated wires were found to exhibit the greatest force levels at all activations, whereas Ortho Organizers coated wires exhibited lower force levels than all other tested brands at 3-mm deflection, except for TP wires. Interestingly, while coating tended to increase force levels in Eurodonto, it had the opposite effect (reduction of force levels) in Ortho Organizers wires. Similar results were reported by Silva et al.[20], who found different force levels in coated wires from several brands.

According to previous studies[28,30], this finding may be explained by the fact the archwires of some brands do not undergo a reduction in cross-section to compensate for the thickness of the aesthetic coating. Conversely, Ortho Organizers wires have reduced cross-sections[20,30]. Since the present study compared wires made of the same metallic alloy (NiTi), our results may not be explained by the type of alloy used for manufacturing the wires. Thus, the diameter of the wire, along with the thickness of coating, were found to be the factors that have the greatest influence on load-deflection ratios, which became more evident at the greatest activation (3 mm).

This aspect is relevant when choosing the wire to be used in the initial stages of alignment and leveling, especially in patients with moderate to severe crowding, in which wires with a low load-deflection ratio are needed to reduce the biological burden of orthodontic movement. The cross-sections of Morelli and Eurodonto coated archwires have not been analyzed in other studies.

Thus, by extrapolating the results of the present study to clinical practice, the presence of aesthetic coating on the archwire (in as-received condition) should not have a significant influence on load-deflection ratio, especially at lower activations (1 mm and 2 mm). However, other studies[2,11,16-22] have reported substantial loss of coating in the oral milieu, with consequent increase in wire roughness. In cases of moderate to severe crowding, which require massive deflection, the increased friction caused by loss of the aesthetic coating could hinder achievement of proper alignment and leveling.

Conclusion

In assays performed under the conditions of the present study, aesthetic coatings did not have a significant influence on the load-deflection ratio of NiTi orthodontic wires, especially at lower activations. However, comparison across the four tested brands revealed that Eurodonto coated wires exhibited the greatest force levels at all activations.

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