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Original Research Article

Esthetic nickel titanium wires– Do they deliver the same force?

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ABSTRACT

Objective: To test the difference in loading and unloading forces delivered by six coated nickel-titanium wires and their non-coated equivalents.

Materials and Methods: Commercially available six coated nickel-titanium wires and their non-coated equivalents of sizes 0.016-inch diameter round and 0.016 X 0.022-inch rectangular cross-section were procured. The wires were evaluated using a three-point bending test based on the method in ISO Standard 15841.

Results: No statistically significant differences in force values were found between coated and non-coated wires, listed by deflection in three-point bending, for these specific groups.

Statistical analysis was done using SPSS version 11.5 (Chicago, III). Analysis of variance was performed with Sheffe post hoc for the mean comparison among the measurements of each loading and unloading deflection for coated and non-coated wires. Student's t-tests was performed for the mean comparisons between non coated and coated groups for each deflection.

Conclusion: There is no significant difference in load response between coated and non-coated nickel-titanium wires of the same size when subjected to the same deflection using a standard three-point bend test method.

1. Introduction

With the increase in number of adult patients seeking orthodontic treatment, the demand for esthetic orthodontic appliances has increased dramatically. Appearance is one of patients main concerns during orthodontic treatment. A growing need for demand of esthetics have created a need for the so-called invisible orthodontic appliances like Invisalign and lingual braces.[1] There is a growing demand for esthetic appliances, but most fixed orthodontic appliance components are metallic and silver in color.[2,3] This problem has been partially solved by the introduction of esthetic brackets made of ceramic or composite, which are becoming more popular.[3,4] However, archwires are still made of metals such as stainless steel and nickel titanium (NiTi). Coating metallic archwires with plastic resin materials is currently the only existing solution to this aesthetic problem.[2] Materials used in the coating process are Teflon® or epoxy resin. The process of applying this layer includes using clean compressed air as a transport medium for the atomized Teflon® particles to coat the wire which is further heat treated in a chamber furnace.[2]

Some researchers found that plastic coating decreased friction between archwires and brackets.[5] On the contrary, Proffit (2000) described this coat as undurable.[6] Other authors have experienced some difficulties with these coated archwires, claiming that the colour tends to change with time and that the coating splits during use in the mouth,

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exposing the underlying metal.

2. Aim

To evaluate the mechanical properties of six different commercially available esthetic niti wires & their non-esthetic equivalent using three-point bend testing. These mechanical properties included loading & unloading values measured at specific millimetre extensions.

3. Materials and Methods

1. Photographic Camera – Canon EOS 600 D
2. Digital micrometer (Figure 3)
3. Nickel-Titanium maxillary preformed segments of 0.016 inch round and 0.016 x 0.022 inch cross-section wires procured from 6 commercial companies
4. Universal testing machine (Figures 1 and 2)

Fig. 1: Instron universal testing machine

Sample size: Ethical clearance was obtained from the institutional ethics committee.

10 wire specimens of 0.016″ diameter round and 0.016 x 0.022″ cross section rectangular each of 6 commercial companies were used to get desired result.

The study was carried out having 6 groups with 2 subgroups each totaling to 12 subgroups as explained above.

Fig. 2: Zoomed image

Fig. 3: Digital caliper

Table 1: Comparison of mean force (N) between coated and non coated Nickel – Titanium wires at different Deflections (mm) by Manufacturers.(Round Archwires)

Manufacturer	Variable Deflections	mm	N	Coated Mean±SD,N	Noncoated Mean±SD,N	p value
Forestand	Loading	1	10	2.2 ± 0.11	2.18 ± 0.12	0.7
		2	10	2.21 ± 0.15	2.19 ± 0.13	0.75
		3	10	2.23 ± 0.14	2.2 ± 0.16	0.66
	Unloading	2.5	10	2.26 ± 0.15	2.2 ± 0.14	0.36
		1.5	10	2.3 ± 0.13	2.19± 0.16	0.09
		0.5	10	2.31 ± 0.19	2.17 ± 0.17	0.08
AO	Loading	1	10	2.3 ± 0.25	2.1 ± 0.47	0.23
		2	10	2.32 ± 0.27	2.13 ± 0.49	0.28
		3	10	2.35 ± 0.29	2.14 ± 0.41	0.19
	Unloading	2.5	10	2.4 ± 0.39	2.19 ± 0.43	0.25
		1.5	10	2.41 ± 0.69	1.95 ± 0.45	0.08
		0.5	10	2.45 ± 0.9	1.99 ± 0.49	0.16
TP	Loading	1	10	2.47 ± 0.91	1.92 ± 0.52	0.1
		2	10	2.49 ± 0.51	1.94 ± 0.75	0.06
		3	10	2.38 ± 0.53	1.93 ± 0.77	0.13
	Unloading	2.5	10	2.36 ± 0.55	1.95 ± 0.79	0.18
		1.5	10	2.35 ± 0.53	1.97 ± 0.97	0.28
		0.5	10	2.32 ± 0.51	1.97 ± 0.99	0.32
OPAL	Loading	1	10	2.32 ± 0.49	1.99 ± 0.89	0.29
		2	10	2.37 ± 0.79	2.19 ± 0.39	0.52
		3	10	2.39 ± 0.77	2.17 ± 0.49	0.45
	Unloading	2.5	10	2.49 ± 0.79	2.07 ± 0.47	0.15
		1.5	10	2.5 ± 0.96	2.19 ± 0.73	0.42
		0.5	10	2.45 ± 0.9	2.12 ± 0.7	0.36
GH	Loading	1	10	2.41 ± 0.59	2.17 ± 0.33	0.26
		2	10	2.45 ± 0.52	2.2 ± 0.82	0.42
		3	10	2.41 ± 0.58	2.02 ± 0.67	0.16
	Unloading	2.5	10	2.49 ± 0.63	2.19± 0.52	0.25
		1.5	10	2.33 ± 0.92	1.79 ± 0.41	0.09
		0.5	10	2.34 ± 0.78	1.79 ± 0.53	0.07
RMO	Loading	1	10	2.45± 0.63	1.91 ± 0.74	0.08
		2	10	2.47 ± 0.39	2.15 ± 0.63	0.17
		3	10	2.71 ± 0.91	2.13 ± 0.57	0.09
	Unloading	2.5	10	2.78 ± 0.87	2.15 ± 0.65	0.07
		1.5	10	2.36 ± 0.83	2.19 ± 0.09	0.52
		0.5	10	2.5 ± 0.91	2.2 ± 0.67	0.4

*SD indicates standard deviation: n, number of wires used for analysis, TP, TP Orthodontics: AO, American Orthodontics
*Statistically significant at P< .05

1. Each of the 6 groups had 20 wires each. This was further divided into 12 subgroups containing ten wire specimens of 0.016′′ diameter round and 0.016 x 0.022′′ cross rectangular, prepared using the following protocol: a 30 mm section was cut using a common cutter and the remaining portion was discarded. The cross section of each 30 mm section was then verified using the micrometer and marked with a permanent marker at 15mm. Any damaged or deformed wires within correct dimensions were discarded
2. Nickel titanium wires were procured from six commercial companies.
3. Forestadent, (Germany).
4. American Orthodontics, (Sheboygan WI).
5. TP Orthodontics, (La Porte, IN).
6. OPAL, (Jordan).
7. G&H, (Franklin, IN).
8. RMO, (Denver, USA).
9. Maxillary preformed segments of 0.016′′ and 0.016 x 0.022′′ cross sections were used. These segments were roughly the shape of an upper case —U.
10. All specimens were prepared by cutting a segment of 30 mm from both of the straight ends of the preformed orthodontic wire. The 30 mm span of wire was marked

Table 2: Comparison of mean force (N) between coated and non coated Nickel – Titanium wires at different Deflections (mm) by Manufacturers. (Rectangular Archwires).

Manufacturer	Variable Deflections	mm	n	Coated Mean±SD,N	Noncoated Mean±SD,N	P value
Forestand	Loading	1	10	3.1 ± 0.91	2.9 ± 0.67	0.58
		2	10	3.11 ± 0.96	2.92 ± 0.79	0.63
		3	10	3.12 ± 0.83	2.91 ± 0.61	0.52
	Unloading	2.5	10	3.13 ± 0.45	2.98 ± 0.91	0.64
		1.5	10	3.11 ± 0.81	2.99 ± 0.67	0.72
		0.5	10	3.19 ± 0.86	3.0 ± 0.87	0.64
AO	Loading	1	10	3.2 ± 0.89	3.08 ± 0.67	0.73
		2	10	3.15 ± 0.88	3.07 ± 0.57	0.81
		3	10	3.14 ± 0.61	3.03 ± 0.51	0.66
	Unloading	2.5	10	3.16 ± 0.69	3.05 ± 0.57	0.70
		1.5	10	3.15 ± 0.87	3.09 ± 0.8	0.87
		0.5	10	3.14 ± 0.91	2.95 ± 0.63	0.59
TP	Loading	1	10	3.13 ± 0.82	2.91 ± 0.71	0.52
		2	10	3.14 ± 0.71	2.92 ± 0.82	0.52
		3	10	3.15 ± 0.91	2.96 ± 0.28	0.53
	Unloading	2.5	10	3.18 ± 0.67	2.99 ± 0.29	0.41
		1.5	10	3.17 ± 0.29	3.01 ± 0.78	0.54
		0.5	10	3.18 ± 0.91	3.09 ± 0.82	0.82
OPAL	Loading	1	10	3.16 ± 0.68	3.04 ± 0.39	0.63
		2	10	3.14 ± 0.89	3.01 ± 0.67	0.71
		3	10	3.1 ± 0.77	3.03 ± 0.67	0.83
	Unloading	2.5	10	3.19 ± 0.69	3.07 ± 0.49	0.65
		1.5	10	3.18 ± 0.76	3.06 ± 0.59	0.69
		0.5	10	3.16 ± 0.59	3.08 ± 0.76	0.79
GH	Loading	1	10	3.17 ± 0.39	3.09 ± 0.72	0.76
		2	10	3.16 ± 0.91	3.06 ± 0.97	0.81
		3	10	3.15 ± 0.99	3.09 ± 0.79	0.88
	Unloading	2.5	10	3.19 ± 0.64	3.07 ± 0.81	0.71
		1.5	10	3.16 ± 0.37	3.05 ± 0.98	0.74
		0.5	10	3.12 ± 0.73	3.07 ± 0.8	0.88
RMO	Loading	1	10	3.11 ± 0.71	3.01 ± 0.68	0.75
		2	10	3.12 ± 0.91	3.03 ± 0.86	0.82
		3	10	3.16 ± 0.86	3.09 ± 0.91	0.86
	Unloading	2.5	10	3.18 ± 0.39	2.98 ± 0.99	0.55
		1.5	10	3.11 ± 0.93	2.9 ± 0.9	0.61
		0.5	10	3.13 ± 0.49	2.96 ± 0.89	0.60

*SD indicates standard deviation: n, number of wires used for analysis,TP,TP Orthodontics: AO, American Orthodontics

*Statistically significant at $P< .05$

with a permanent marker at 15 mm and placed in a fulcrum manufactured to the ISO15841 standard dimensions.

11. The custom manufacturing of this fulcrum and indenter along with the standards precise indications for wire placement allowed for reproducible data collection once the experimental setup was correct.
12. The wires were sorted and tested (by the investigator) by the company and not a random number generator, as to facilitate the slight deviation in curvature between the different arch forms from each company.
13. Additionally, because of the distinct nature of each wire, blinding was not necessary. This convention was followed from the current literature.

“Wire specimens of 0.016-inch diameter round and 0.016 x 0.022-inch cross-section rectangular were prepared using the following protocol: as specified in the ISO 15841 standard, a 30 mm section was taken from the straightest portion of the distal ends of a preformed wire using a common cutter, and the remaining portion was discarded. The cross section of each 30 mm section was verified using a micrometer, marked with a permanent marker at 15 mm, and tested based on the three-point bend method specified in the standard ISO 15841. The results were analysed stastically. A sample of 10 wires in each study group were used in accordance with usual practice in the orthodontic literature".

3.1. Statistical analysis

Statistical analysis was done using SPSS version 11.5 (Chicago, III). Analysis of variance was performed with Sheffe post hoc for the mean comparison among the measurements of each loading and unloading deflection for coated and non-coated wires. Student's t-tests was performed for the mean comparisons between non coated and coated groups for each deflection.

4. Results

Comparisons of mean force (N) between coated and non-coated wires at different deflections (mm) by Forestadent.

The distribution of mean force in the samples of coated and non-coated rectangular wires did not differ significantly at each type of deflection (P-value>0.05 for all).

The distribution of mean force in the coated and non-coated round wires did not differ significantly at each type of deflection (P-value>0.05 for all).

Comparisons of mean force (N) between coated and non-coated wires at different deflections (mm) by G&H manufacturer.

The distribution of mean force in the samples of coated and non-coated rectangular wires did not differ significantly at each type of deflection (P-value>0.05 for all).

The distribution of mean force in the coated and non-coated round wires did not differ significantly at each type of deflection (P-value>0.05 for all).

Comparisons of mean force (N) between coated and non-coated wires at different deflections (mm) by AO manufacturer.

The distribution of mean force in the samples of coated and non-coated rectangular wires did not differ significantly at each type of deflection (P-value>0.05 for all).

The distribution of mean force in the coated and non-coated round wires did not differ significantly at each type of deflection (P-value>0.05 for all).

Comparisons of mean force (N) between coated and non-coated wires at different deflections (mm) by RMO manufacturer.

The distribution of mean force in the samples of coated and non-coated rectangular wires did not differ significantly at each type of deflection (P-value>0.05 for all).

The distribution of mean force in the coated and non-coated round wires did not differ significantly at each type of deflection (P-value>0.05 for all).

Comparisons of mean force (N) between coated and non-coated wires at different deflections (mm) by Opal manufacturer.

The distribution of mean force in the samples of coated and non-coated rectangular wires did not differ significantly at each type of deflection (P-value>0.05 for all).

The distribution of mean force in the coated and non-coated round wires did not differ significantly at each type of deflection (P-value>0.05 for all).

Comparisons of mean force (N) between coated and non-coated wires at different deflections (mm) by TP manufacturer (n=40).

The distribution of mean force in the samples of coated and non-coated rectangular wires did not differ significantly at each type of deflection (P-value>0.05 for all).

The distribution of mean force in the coated and non-coated round wires did not differ significantly at each type of deflection (P-value>0.05 for all).

5. Discussion

The in vivo functionality of coated archwires with respect to friction and durability of the coating is well documented in the literature. Many studies have covered certain aspects of these wires, such as Husman et al. in 2002 who revealed that plastic coating decreases friction; or Kusy(1997) Who found that the wires were damaged in vivo. However, few studies have compared the basic force differences between these wires from different manufacturers. Coated metal archwires are nickel-titanium or stainless steel wires treated with polytetrafluoroethylene (PTFE), epoxyresin, parylene-polymer, or less commonly palladium covering to impart an enamel hue. Currently, the two most common aesthetic archwires are coated with either PTFE or epoxy-resin. The Goal of this study was to compare the force differences between the coated and non-coated, equivalent nickel titanium wires for each of six manufacturers, with a total of 12 groups. In this study a difference in forces generated was noted in forces between similar wires of different companies, this may be due to coatings of different materials on nickel-titanium arch wires or the manner in which they were coated. The standard method for evaluating orthodontic wires not containing precious metals is the three-point elastic bending test according to ADA specification no.32 It is a standardized testing method that makes comparison to other studies possible. One of the 24 wires tested (RMO round; RMO rectangular) exhibited statistically significant ($p \leq 0.05$) identical portions of the stress strain curves with coated and non-coated wires. Trends noted in groups with the aforementioned significance ($p \leq 0.05$) included: 1. A coated wire having a higher elastic modulus value when compared to the analogous non-coated wire 2. A coated wire having statistically significant ($p \leq 0.05$) higher loading curve when compared to the analogous non-coated wire.[7–12]

A higher elastic modulus value may come from either: (1) harder surface coating, (2) thinner surface coating, (3) stiffer underlying wire (in coated version) or a combination of all of these factors. Of the remaining, the majority exhibited the trend of the non-coated wire having a higher hysteresis due to a combination of higher loading forces and /or lower unloading forces. This was exhibited in the groups: TP orthodontics, G&H orthodontics, Forestadent, Opal, AO. These force characteristics could be attributed to the smaller cross-sectional area of the coated wires compared to the non-coated wire of the same nominal cross-section.

The strengths of this current study are numerous. As addressed earlier many studies have addressed the in vivo functionality of coated archwires with respect to friction and durability of the coating. However, these studies were mostly performed with stainless steel wires and still do not address the basic premise of whether the mechanical force values of the wire are changed by the coating. This current study compares these coated vs. non-coated wires from six manufacturers, which is more than any current publication, and also examines the mean difference between force values from equivalent non-coated wires. The use of the ADA- developed ISO 15841 standards in implementing this study was also extremely relevant. In the literature previous three- point bend test used an arbitrary span length (usually 14 mm the span from a central incisor to canine) was used, and the method of ligation varied from none to ligation with conventional or even self-ligating brackets. This is problematic because it is virtually impossible to compare these studies. This study directly relates to the clinician practicing evidence-based dentistry. This study was limited only by the lack of information available from manufacturers regarding their manufacturing process of super-elastic nickel titanium wires. Another weakness of this study is that the tests were performed at 23řC instead of the 36°C specified in ISO 15841. It also worth noting that ISO 15841 requires that the bending forces during unloading be reported. In this study, we reported bending forces for both loading and unloading. Future studies are abundant for this topic. Many of the major manufacturers were not tested in this study. Finally, these coated appliances are used in many auxiliaries such as ligature wires, and nickel titanium coils. Testing of the mechanical forces versus the non-coated counterpart would be meaningful.

6. Conclusion

There is no significant difference in load response between coated and non-coated nickel-titanium wires of the same size when subjected to the same deflections using a standard three-point bend test method

7. Acknowledgement

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8. Ethical approval

Study is approved by ethical committee of institute and MUHS research committee.

9. Conflict of Interest

The authors declare that they have no conflict of interest.

10. Source of Funding

None.

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