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FORCE-DEFLECTION PROPERTIES OF INITIAL ORTHODONTIC ARCHWIRES

***Aim:** This in vitro study measured the force-deflection behavior of selected initial alignment archwires by conducting three-point bending tests under controlled conditions. The study tested four wire designs: multistranded stainless steel, conventional stainless steel, superelastic nickel-titanium, and thermoactivated nickel-titanium archwires. **Method:** The wires (n = 15) were ligated into stainless steel brackets with steel ligatures. A testing machine recorded deactivations at 2.0 mm of deflection at 37°C. Force-deflection measurements were recorded from only deactivation. Forces on deactivation were compared by one-way analysis of variance (ANOVA) and Tukey post-hoc tests. **Results:** Significant differences ($P < .05$) in deactivation forces were observed among the tested wires. The multistranded stainless steel wire had the lowest mean deactivation force (1.94 N), while the conventional stainless steel group had the highest value (4.70 N). The superelastic and thermoactivated Ni-Ti groups were similar to the multistranded wire ($P > .05$). **Conclusion:** Both nickel-titanium and multistranded steel archwires tested are potentially adequate for use during the leveling and aligning phase of orthodontics.*
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Dental-arch alignment and leveling is the initial stage of orthodontic treatment. Satisfactory completion of this first stage is essential if esthetics, function, and stability are to be achieved. A well-planned orthodontic treatment starts with very flexible wires fully engaged into the brackets on each arch.[1] Usually, the ideal archwire for that vital first stage generates a continuous and light force over a long period of time.[2,3]

The type of archwire most frequently recommended in contemporary practice for the initial stage of the orthodontic treatment is the superelastic nickel-titanium and thermoactivated type.[1,3–9] However, some authors still prefer multistranded steel archwires: They are cheaper and have not been shown to be less clinically effective than nickel-titanium archwires.[2,10] Laboratory tests can be helpful in the assessment of aligning archwires by providing basic information on physical properties, including resilience, rigidity, and accumulated energy.[2]

The aim of this study was to compare the mechanical properties of four types of archwires used in the initial stage of orthodontic treatment with mechanical three-point flexion trials. The null hypothesis was that there would be no difference in the deactivation force among groups superelastic nickel-titanium, thermoactivated nickel-titanium, multistranded stainless steel, or conventional stainless steel.

Table 1 Orthodontic wires tested in this study

Alloy type	Wire size and brand	Manufacturer
Multistranded stainless steel	0.0155-in PentaCat	GAC International
Thermoactivated Ni-Ti	0.016-in Thermal Ni-Ti	G&H Wire
Superelastic Ni-Ti	0.016-in Sentalloy L	GAC International
Stainless steel	0.014-in Nubryte Gold	GAC International

Table 2 Ranking of wires by deactivation force at 2-mm deflection

Wire size and brand	Mean + SD* (Newtons)	Tukey#
0.0155-in PentaCat SS	1.943 ± 0.037	A
0.016-in Thermal NiTi	2.474 ± 0.026	B
0.016-in Sentalloy L	2.545 ± 0.037	B
0.014-in Nubryte Gold SS	4.697 ± 0.142	C

* Standard deviation; #Tukey post-hoc test ($P < .05$).

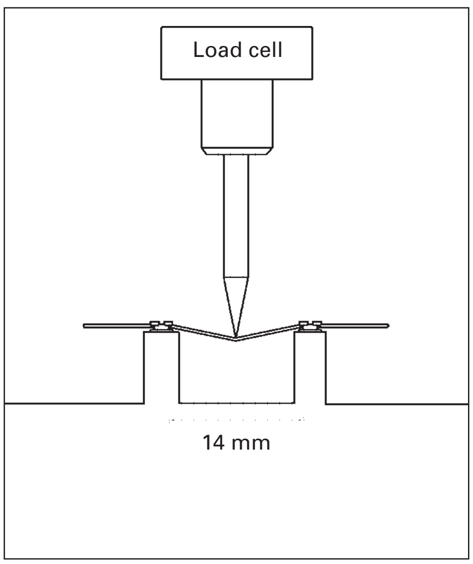

Fig 1 Mechanical three-point bending test device.

MATERIALS AND METHODS

Sixty specimens were tested—15 round wires for each of the four designs: superelastic Ni-Ti alloy wire, thermoactivated Ni-Ti alloy wire, multistranded stainless steel alloy wire, and conventional stainless steel alloy wire (Table 1).

To examine the relationship between wire deflection and load, a three-point bending test was performed with a mechanical testing system (model DL 2000, EMIC, São Paulo, Brazil).

Two standard metallic edgewise 0.018-in orthodontic brackets (Dental Morelli, São Paulo, Brazil) were attached to an acrylic jig with 14 mm between their neighboring wings (Fig 1). This is the average distance between the labial centers of a mandibular lateral incisor and first premolar. A 40-mm wire was tied to the brackets with stainless steel ligatures. The specimens were inserted into the system, which was filled with 37°C water. The entire test was conducted at this temperature. The center of the each wire was deflected at a crosshead speed of 0.3 mm/min, with a 50-N load cell. Each specimen was loaded until a deflection of 2 mm was produced. The load exerted by each wire was measured during the subsequent unloading process. Samples were deactivated at the same crosshead speed until the load became zero.

Descriptive and inferential statistics were calculated on the data with Prism 4.0 (GraphPad Software, San Diego, California, USA). A one-way analysis of variance (ANOVA) with the Tukey post-hoc test was performed to compare the deactivation forces of the wires.

RESULTS

The null hypothesis was not accepted. The statistical analysis of the deactivation forces showed significant differences among the wires. The means and standard deviations for the forces at a given deflection are rank-ordered in Table 2 in Newtons. The multistranded stainless steel group had the lowest mean deactivation force (1.94 N), while the conventional stainless steel group had the highest value (4.70 N). The superelastic and the thermoactivated Ni-Ti groups were similar ($P > .05$).

DISCUSSION

When testing archwires, orthodontists want to know their potential clinical performance.[11] The geometrical similarity between the components makes it possible to apply formulae for loading, flexion, and tension in models that simulate specific situations during orthodontic treatment.[12] By using an experimental model, it is possible to evaluate the performance of a given material.

The results of this study detected significant differences in deflection forces between various alignment archwires. The multistranded steel and the Ni-Ti alloy wires exhibited lower deactivation forces than a conventional stainless steel wire. Therefore, multistrand and Ni-Ti wires might be more favorable clinically in situations of mild-to-moderate crowding. The amount of crowding should be a major consideration in the selection of the wire. Adequate adaptation of the wire in the bracket slot must be obtained, allowing for optimal biologic movement.[13]

Previous investigations have suggested that multistranded stainless steel wires are an economical alternative to nickel-titanium alloy wires.[14–16] Although multistranded wires might be an option, according to Taneja et al,[16] they do not display the consistently low and moderately decreasing forces at different degrees of deflection as Ni-Ti wires do. Therefore, the clinician must have knowledge of the behavior of multistranded wires when using them as Ni-Ti substitutes.

Although there may be statistically significant differences in the performance of individual wires in various mechanical test simulations, this does not necessarily indicate that such differences will exist in clinical performance. In a crowded dentition, the high forces may be dissipated through interdental contacts and in overcoming friction among the brackets, wire, and ligatures.[17–20] Evans et al[21] compared the alignment performance of multistrand stainless steel, superelastic Ni-Ti, and thermoactivated Ni-Ti over a longer period in a controlled randomized clinical trial and found no significant difference in the aligning capability of these three wires.

CONCLUSIONS

Under the conditions of this investigation, the results suggest a significant difference in deactivation force at 2-mm deflection between the initial alignment archwires evaluated. The conventional stainless steel wire had the highest mean deactivation force, while the multistrand steel wire had the lowest value. Superelastic and thermoactivated Ni-Ti archwires were not significantly different in relation to the deactivation force. The findings suggest that both the nickel-titanium and multistranded steel archwires tested have properties that favor their use during the leveling and aligning phase of orthodontic treatment.

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