Original Article

Comparative Evaluation of Load-deflection Property of Different Brands of Nickel-titanium Archwires

Abstract

Context: The tooth alignment and leveling constitute the preliminary clinical phase of any orthodontic procedure with fixed appliances. It has been accepted in orthodontics the principle that light and continuous forces would be desirable for physiologic and controlled tooth movement. For this purpose, it has been suggested that nickel-titanium (NiTi) archwires which offer a force-bending curve with a defined baseline and a larger activation range should be used **Aims:** The aim of this study was to evaluate and compare the force versus deflection properties of different brands of NiTi wires available in market. **Settings and Design:** Null hypothesis. There is no difference in force-deflection properties between different brands of same dimension NiTi archwires available in market. A cross-sectional study design was planned. **Subjects and Methods:** Different companies were identified producing their own version or marketing NiTi archwires of the following sizes: 0.016 inch round and 0.016 × 0.022 inch rectangular were selected because all companies produced or marketed these particular sizes, and in addition, these were selected because these wire sizes are commonly used clinically. The three-point bend test was utilized to test the various wires in accordance with the ISO 15841 standard for orthodontic wires with the exception that the bottom support span was 16 mm rather than 10 mm due to fixture limitations. **Statistical Analysis Used:** Data obtained from different brands of wires available in the Indian market Ormco, American Orthodontics, Ortho Organizers, Rocky Mountain Orthodontics 3M and MO which are manufactured in U.S.A,While as Natural, Orthomatix, JJ Orthodontics, Koden, Gdc, Rabbit force, and Optima are manufactered in china. and size 0.016 inch round wire and 0.16x0.022 inch rectangular wires were compared using ANOVA test.Statistical analysis was performed using SPSS 2.1. **Results:** In this study, the data show that minimum force during activation of 0.016 inch round wire at 1 mm was 95 ± 10 g whereas maximum was 165 ± 10 g with a difference of 70 ± 20 g. Whereas at 3 mm activation, minimum force generated was 150 ± 10 g and maximum was 225 ± 10 g with a difference of 75 ± 20 g. In 0.016 × 0.022 inch rectangular wire, minimum activation force at 1 mm deflection was 210 ± 10, whereas maximum was 340 ± 10 with a difference of 130 ± 20 g. For deactivation, the minimum force for 0.016 wire at 1 mm deflection was 40 ± 10, whereas maximum force was 125 ± 10 with a difference of 85 ± 20 g, and for the 0.016 × 0.022 wire, the minimum load at 1 mm deflection was 150 ± 10 g, whereas the maximum was 295 ± 10 g with a difference of 145 ± 20 g. The deactivation force in majority of brands (8) at 1 mm deflection was <80 g whereas at 3 mm, majority brands have force levels >150–195 g. The deactivation force at 3 mm deflection in five brands was between 235 and 335 and five other brands between 335 and 445 whereas at 1 mm, deflection majority of brands was between 170 and 200 g. **Conclusion:** From this data, a comparative evaluation shows that there is a huge difference in force-deflection properties of same dimension wire from different brands, which means that its making the orthodontic treatment more indeterminate; some wires have shown less and some have shown more force.Wires of the same materials, dimensions, but from different manufacturers do not always have the same mechanical properties. There are significant differences in the activation and deactivation forces among the different manufacturers of NiTi archwires. Improvements should be made in the standardization of the manufacturing testing process of NiTi archwires to provide orthodontists with NiTi archwires that have consistent mechanical properties despite the manufacturing brand that produces them.

Keywords: *Force-deflection property, nickel-titanium archwire, three-point bend test*

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Introduction

The tooth alignment and leveling constitute the preliminary clinical phase of any orthodontic procedure with fixed appliances. It has been accepted in orthodontics the principle that slight and continuous forces would be desirable for obtainment of physiologic and controlled tooth movement. For this purpose, it has been suggested the superelastic and

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heat-activated nickel-titanium (NiTi) archwires, which offer a force-bending curve with a defined baseline and a larger activation range.[1,2]

NiTi due to its ability to apply a light force over a large range of activation is extremely useful during initial alignment of the teeth.[3] NiTi alloy's clinical advantages in orthodontics are based on the fact that these alloys can exist in two different crystal structures: martensite and austenite. At low temperatures and higher stress, the martensitic form is more stable, and at higher temperatures and lower stress, the austenitic form is more stable. The transition between these two phases/structures is fully reversible and occurs at low temperatures. The two different phases of NiTi are responsible for two clinically significant properties of NiTi: shape memory and superelasticity.[4,5]

Shape memory refers to the ability of the wire to return to its original shape after being plastically deformed. Cooling below the transition temperature will transform into the martensite form and it can plastically deform. Once it is heated back above the transition temperature, the wire will return back to the austenite phase and return to its original form. Shape memory refers to the temperature-induced change in crystal structure, and it is also known as thermoelasticity.[6]

Superelasticity refers to the large, reversible strains that the NiTi wires can withstand due to the martensite-austenite transition. This property also referred to as pseudoelasticity, is possible due to the transition temperature between the two crystal phases is very close to room temperature. This property is evident in the almost flat section of the load-deflection curve. This property of NiTi is useful clinically due to archwire can exert the same force whether it was deflected a small or large distance.[6]

Optimum orthodontic movement is produced by light and continuous forces. These light and continuous forces are the most efficient and biologically safe method of tooth movement. . Using high orthodontic force risks pulp vitality as well as root resorption. Rock and Wilson asserted that there is a consensus that the ideal orthodontic forces should vary between 15 and 500 gf.[7]

Light and continuous force lead to smooth progression of tooth movement, as a result from frontal resorption. However, if a continuous heavy force is applied, tooth movement will be delayed due to undermining resorption instead of frontal resorption. As a result, heavy and continuous forces are to be avoided in orthodontics.[8,9]

The force required to push the wire into the bracket attached to tooth is activation force; the force applied by the NiTi wire to return back to its original shape is deactivation force, this deactivation force is responsible for the tooth movement as shown in Figure 1.

Despite the small number of available alloys for the manufacture of orthodontic archwires, there are a large number of trade brands of available archwires. The manufacturing companies invest in advertising calling the archwires superior and emphasize that they provide better performance due to the appropriate mechanical properties. However, these properties not always are described on the product package. Thus, the variety of brands, the large number of manufacturing companies, and the lack of information about the material properties make it difficult for the professional to choose the most adequate material and with better cost-benefit for use.

Hirokazu Nakano *et al* Studied Fourty two brands of NiTi arch wires from nine manufacturers were used conducting three-point bending tests under uniform testing conditions the amount of force varied greatly from brand to brand. The brands of wire must be selected carefully by taking into consideration the severity of the malocclusion and the stage of orthodontic treatment in each case.[10]

Peter D. Wilkinson *et al* tested a sample of 7 brands: The wires were subjected to 3-point bending tests and were also tested with 2 types of orthodontic brackets on 2 designs of acrylic models, giving a total of 5 test models Comparisons of 3-point bending results with those of a similar recent study suggest possible inter-batch variation of some of these wires.[11]

Bartzela TN *et al* evaluated the mechanical properties of commercially available thermodynamic wires and to classify these wires mathematically into different groups. available from five manufacturers. Three-point bending test under uniform testing conditions. A fraction of the tested wires showed weak superelasticity, and others showed no superelasticity. Some of the products showed permanent deformation after the three-point bending test. The practitioner should be informed for the load-deflection characteristics of the NiTi orthodontic wires to choose the proper products for the given treatment needs.[12]

Renée C.Pompei-Reynolds Evaluated mechanical properties of two manufacturersthey were tested for transition temperature ranges and force delivery using

Figure 1: Different brands of wires

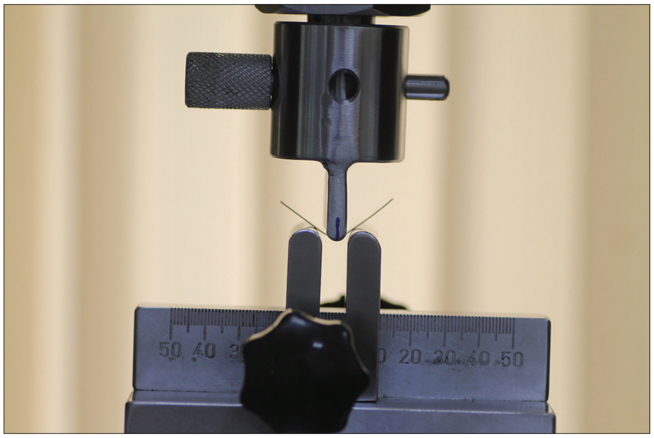

Figure 2: Three-point bend test in progress

differential scanning calorimetry and the 3-point bend test, respectively.Orthodontic wires of the same material, dimension, and manufacturer but from do not always have similar mechanical properties. copper-nickel-titanium wires might not always deliver the expected force, even when they come from the same manufacturer, because of inter-lot variations in the performance of the material.[13]

There is a lack of evidence that wires different brands of wires provide specific and better properties as compared to each other. Thus, the goal of this study is to test various manufacturers' NiTi archwires to see if their mechanical properties are comparable.

Subjects and Methods

Different brands of NiTi archwires available in market were identified Ormco, American Orthodontics, Ortho Organizers, Rocky Mountain Orthodontics, 3M, MO, Natural, Orthomatix, JJ Orthodontics, Koden, Gdc, Rabbit force, and Optima.

Some companies manufacture their wires whereas some others market it, for consistency, one round diameter wire size and one rectangular wire size were chosen to allow for comparison of properties. The sizes: 0.016 inch round and 0.016 × 0.022 inch rectangular were selected because all companies produced or marketed these particular sizes, and in addition, these were selected because these wire sizes are commonly used clinically.

It is important to note that the five segments of each wire tested in each category for the particular brand were from the same production lot, eliminating the possibility of interlot variability among the wires.

The three-point bend test [Figure 2] was utilized to test the various wires in accordance with the ISO 15841 standard for orthodontic wires with the exception that the bottom support span was 16 mm rather than 10 mm due to fixture limitations (ISO, 2014). It is one of the appropriate tests for force-deflection tests. It determines the activation (loading) and deactivation (unloading forces) present within the wire. Wire segments of each of the four different wire size combinations were cut (n = 5/size). The same investigator cut all wire segments. Forces for the deflection were recorded directly onto the computer software program. Appropriate statistical analyses were utilized for each test when indicated. The three-point bending test allows one to analyze the bending forces for a given deflection for all of the various wires. The test was conducted at 28°C. A 30 mm segment of each wire was utilized. Materials were tested in the condition they were received from the manufacturer. Samples were taken from the most distal segment of the archwires because distal segment is straight as compared to anterior segment which is curved.

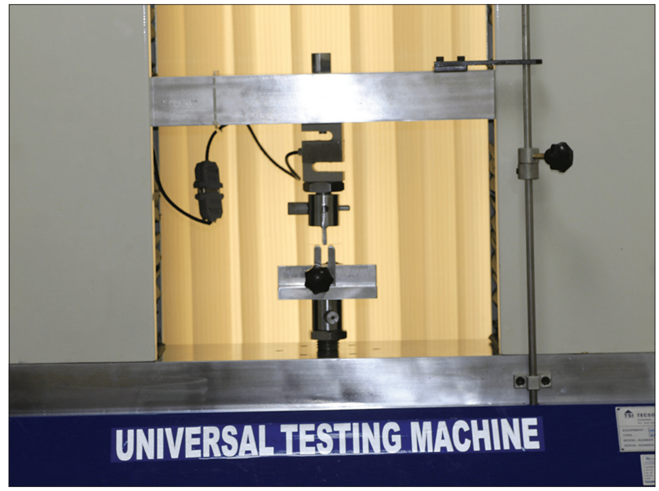

Figure 3: Universal testing machine

Wires were deflected with the universal testing machine (Tec-sol India) [Figure 3] at a rate of 1 mm/min to a mid-span deflection of 3.1 mm and then reversed. The space between lower supports was 16 mm, with the upper member being centered at 8 mm. Force was monitored during loading and unloading The linear slope was measured from the collected data, and values at 1.0, 2.0, and 3.0 mm were obtained from the test for comparison.

Results

In this study, the data show that minimum force during activation of 0.016 inch round wire at 1 mm was 95 ± 10 gm whereas the maximum was 165 ± 10 gm with a difference of 70 ± 20 gm Whereas at 3mm activation, minimum force generated was 150 ± 10 gm and maximum was 225 ± 10 gm with difference of 75 ± 20 gm.

In 0.016 × 0.022 inch rectangular wire, minimum force at 1 mm deflection was 210 ± 10 whereas the maximum was 340 ± 10 with a difference of 130 ± 20 gm.

For deactivation, the minimum force for 0.016 wire at 1 mm deflection was 40 ± 10 whereas maximum force was 125 ± 10 with a difference of 85 ± 20 gm, and for 0.016 × 0.022, wire the minimum load at 1mm deflection was 150 ± 10 gm whereas maximum was 295 ± 10 gm with a difference of 145 ± 20 gm.

From this data, a comparative evaluation shows that there is huge difference in force/deflection properties of same dimension wire from different brands, which means that its making the orthodontic treatment more indeterminate, some wires have shown less and some have shown more force.

Conclusion

Wires of the same materials, dimensions, but from different manufacturers do not always have the same mechanical properties. There are significant differences in the activation and deactivation forces among the different manufacturers of NiTi archwires. Improvements should be made in the standardization of the manufacturing testing process of NiTi archwires to provide orthodontists with NiTi archwires that have consistent mechanical properties despite the manufacturing brand that produces them. Although this study supports the earlier studies done in the other countries and different brands, there are some limitations of this, study experiment was done at 28°C while as in oral cavity temperature will be 37°C; hence, the force-deflection value will change, all the wires were taken from the same lot intralot bias can be there, dimensions of wires were not determined by investigators, change in dimension will lead to change in properties.

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Conflicts of interest

There are no conflicts of interest.

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