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Comparison of load deflection characteristics of laser-treated CuNiTi archwire with other aligning orthodontic wires: An in vitro study

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***Abstract*---**Aim: To compare the load deflection characteristics of laser treated SmartArch wires with other orthodontic wires. Materials and Method: In this in vitro study 10 samples of 3 different orthodontic wires were included. The wire samples were divided into three groups - GroupA: NiTi wire, group B: heat-activated CuNiTi wire and group c: laser-treated CuNiTu wire. The archwires were subjected to 2 and 4 mm of deflection forces and load deflection characteristics were studied on the Instron machine. IBM SPSS software version 23, was used for statistical analysis. The Shapiro-Wilk test for normality and one-way ANOVA test, descriptive statistics were used to compare the means of the three groups. Results: The ANOVA test revealed that wire type had no significant effect ($P > 0.05$) on the forces produced. At 2 mm loading, the descriptive tests revealed a mean ranging from 0.83 to 0.96 MPa, and at 4 mm loading, 2.64 to 3.53 MPa. However, none of the wires experienced any appreciable increases in force as the deflection increased from 2 to 4 mm. Conclusion: The current study's findings showed that SmartArch wire had a lower load deflection than NiTi wire and heat-activated CuNiTi wire. However, this was not statistically significant.

***Keywords*---**Load deflection, laser-treated wires, Smartarch wire, alignment wires.

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Introduction

In orthodontics the first stage of treatment is the dental arch alignment and leveling. This is accomplished by using flexible wires when it is fully engaged into the brackets and each arch. (1,2) The real mechanics behind the orthodontic system is the engagement of the archwire to the bracket which generates the biomechanical force necessary to move the teeth.(3) In order to enhance tooth movement and reduce patient discomfort, wires with low stiffness are preferred to produce mild forces as the alignment happens.(4) Burstone stated that the main reason for an orthodontist to select a particular wire is based on the wire's load deflection rate or stiffness. (5)

Nickel-Titanium(NiTi) alloys are widely used in the field of orthodontics for arch alignment due to their characteristic superelastic and shape memory properties.(6) These archwires can transform between the austenitic and martensitic phases by applying stress or heat. The shape memory effect is due to the transition of the two phases which is a result of the plastic deformation of NiTi wires from the martensite phase to an austenite crystal structure. (7,8) The shape memory property can be enhanced by the addition of copper which increases the corrosion resistance and controls the hysteresis width. (9) Thermal NiTi wires are a martensitic active alloy and exhibit a thermally induced shape memory effect. (10) For these latter wires, transition temperatures from martensite to austenite occur in the region of the ambient oral temperature.(11)

Recently a laser- treated seven source zone archwire - SmartArch wire by Ormco has been introduced in the market. They advertise ideal physiological forces being delivered by the wire to each tooth in the arch.(12) The stiffness modification is made by the selected vaporization of nickel atoms, with laser. The stiffness in each interbrackets distance was calculated so that each tooth has an optimized force to be moved. At last, SmartArch is the first wire in Orthodontics considering both the root support and interbrackets distance, and has experimental and finite elements data proving that all the teeth will be submitted to forces with ideal proportions to move them (13)wever there aren't much studies on this material. Hence, this study was conducted.

A method of study called the three-point bend test was created to evaluate a material's mechanical characteristics. The nature of orthodontic wires and their load-deflection characteristics, which are frequently the most important factors in influencing the physiological behavior of tooth movement, can be understood using this method in orthodontics.(14) In addition, compared to other mechanical tests like the tension test, the three-point bend test most accurately depicts the way the wires deform and their clinical character.(15)

Aim and Objective

To compare the load deflect properties and force levels of laser treated SmartArch wire with other orthodontic NiTi wires.

Materials and Methods

Study design

An in-vitro three-point bend test using Instron machine was designed to evaluate the loading and unloading forces of the selected archwires at fixed deflections at specific regions along the arch wire.

Sample selection

Three different archwires were selected for the current study - heat-activated CuNiTi (Ormco), NiTi (G&H Orthodontics) and SmartArch(Ormco) wires. [Table 1] The dimensions of all the included archwires were 0.016 inches .

Table 1. Study samples

Groups	Orthodontic archwire	Sample size
Group A	NiTi Archwire	10
Group B	Heat-activated CUNiTi wire	10
Group C	SmartArch wire	10

Method

A three-point bending test using the INSTRON universal testing machine was carried out to investigate the load–deflection mechanical characteristics of the wires at the White Lab, Saveetha Dental college and hospitals, Chennai, Tamil Nadu.[Figure.1] The archwires were subjected to bending tests at a constant temperature of 26°C. The samples were tested on brackets that were bonded with a water proof adhesive to a specially constructed 3D printed cast where the left first premolar were trimmed out creating a void in order to facilitate unhindered movement of the flex fixture in a labiolingual direction. Accurate slot alignment was achieved by using a plain 0.016 inch archwire as a former while the cement set.The bracket slots were filled with the proper length archwires, and the shutters were then closed. In the archwire the crimpable stops were placed as specified in the above table and crimped. The model was later placed in the universal testing machine with the help of the wax positioner. [Figure.2]

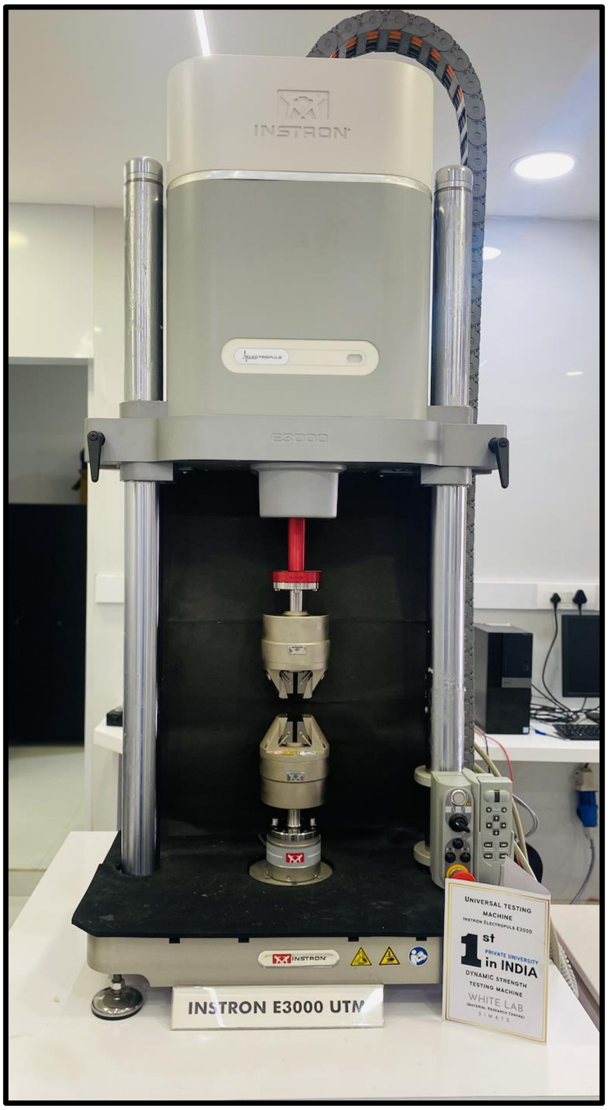

Figure 1. Instron machine

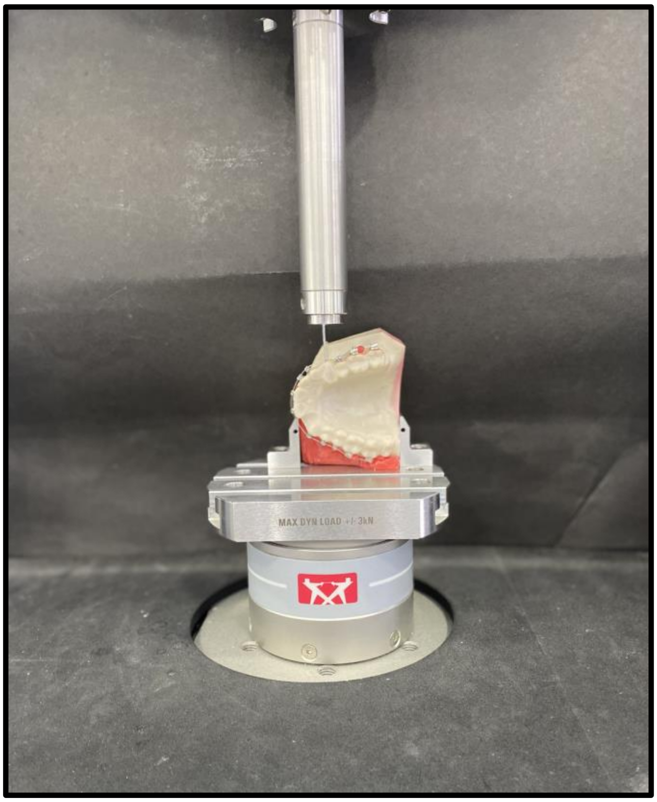

Figure 2. 3D printed cast subjected to Instron machine for testing load deflection

The force applied to the archwire was regulated by the universal testing machine which was connected to a 3 kN load cell. A metal blade was fixed to the load cell, which deflected 4 mm of each archwire at a speed of 1 mm/min. The unloading force was measured at the same speed until the force reached the starting point "0". The force-deflection measured at 0mm, 2mm, and 4mm. The measurements were recorded in MegaPascal (MPa).

Statistical Analysis

Statistical analysis was performed using IBM SPSS software version 23. Normality of the data was assessed using the Shapiro-Wilk test. Descriptive statistics was performed and a one-way ANOVA test was also conducted to compare the means of three groups.

Results

The descriptive tests showed a mean ranging from 0.83 to 0.96 MPa at 2 mm loading and 2.64 to 3.53 MPa at 4 mm loading. The ANOVA showed no significant difference among the groups at all deflection and unloading points evaluated. [Table. 2] At 2 mm and 4 mm deflection on loading, NiTi wires exhibited highest load deflection, whereas SmartArch wire showed the least load deflection. Similar results were observed at 2mm and 4mm on unloading force. The increasing deflection from 2 to 4 mm produced modest increase in force but they were not significant for any of the wires. On unloading, SmartArch wire showed lesser deflection of 0.92 ± 0.56 MPa compared to NiTi [2.14 ±0.16 MPa] and CuNiTi [1.45 ±0.58 MPa] archwires. However this was not statistically significant.

Table 2. Deflection (MPa) of the test wires on loading and unloading forces using ANOVA test

	NiTI	HANT	Smart-Arch	Sig.
2 mm Loading	0.96 (0.13)	0.87 (0.22)	0.83 (0.29)	>0.05
4mm Loading	3.53 (0.49)	3.04 (0.54)	2.64(0.67)	>0.05
2 mm Unloading	2.14 (0.16)	1.45 (0.58)	0.92 (0.56)	>0.05
0 mm Unloading	0.92 (0.08)	0.84 (0.10)	0.79 (0.46)	>0.05

Discussion

In this study, the performance of two orthodontic archwires was compared to a typical nickel-titanium wire at various deflections in a simulated clinical setting. This was accomplished by placing wires on a fixed orthodontic appliance on a phantom head jaw that was maintained at a constant temperature of 26°C. Since wire deflections of 2 to 4 mm are typical in the mouth, these values were employed in the current study. Low load deflection rates provide the following : (1) the ability to apply lower forces, (2) a more constant force over time as the appliance experiences deactivation, and (3) greater ease and accuracy in applying a given force.

NiTi archwires are known to generate gentle forces that are equally distributed across the front and back teeth. However, these archwires typically result in the incisors moving more quickly than the premolars and molars in the early stages, causing the posterior segments to lag behind their anterior counterparts. As a result, overall tooth movement is frequently less effective, which lengthens treatment duration because more activations and archwire adjustments are required. (16) In order to produce more effective orthodontic tooth movement and minimize overall orthodontic tooth movement, the need for a more predictable and ideal force delivery system has resulted in the development of an archwire that can deliver the ideal physiological force to every segment or tooth in the arch simultaneously.(12) Individual forces can be applied to various segments or individual teeth of the arch with the advent of thermally treated and laser-engineered force gradient nickel- titanium (NiTi) orthodontic archwires, maximizing tooth mobility. Due to this, these wires are able to have "many memories" throughout a single archwire as opposed to the traditional NiTi archwires' single functioning. (17)

Light and continuous force delivery are necessary for efficient tooth motions. Superelastic NiTi arch wires display exceptional characteristics and are more effective at aligning than normal NiTi alloys, according to other in-vitro investigations.(18) According to Lombardo et al., CuNiTi exhibits noticeably lower forces and a longer plateau. (19)When compared to typical NiTi of comparable diameters, this equates to continuous forces. Due to these characteristics, CuNiTi is frequently used in clinical settings to give the light, constant force necessary for physiological tooth movement, reduce tissue hyalinization, and enhance patient comfort. Ormco's SmartArch archwire with revolutionary laser-engineered force gradient NiTi archwires has seven separate force zones based on the typical inter-bracket distances and the anatomy of the root and periodontal surfaces of each tooth in the arch. (12,20) In the current study, the SmartArch wire has shown lesser load deflection compared to NiTi and HANT wires indicating that it is a suitable wire for initial alignment purpose. However, there was no statistically significant result between the wires. Due to the recent advancement of this technology, additional research should be conducted to assess the force distribution of this new archwire in order to determine whether it has actually addressed prior shortcomings and whether it might ultimately result in more effective tooth movement, shorter treatment times, and higher-quality orthodontic care. (16)

Limitations

Although the in-vitro study's findings help us better understand the materials used in orthodontics, they cannot accurately duplicate the intricate interactions that occur in the mouth environment. This is a major limitation of this study.

Conclusion

The results of the current study indicated a reduced load deflection of SmartArch wire compared to NiTi wire and heat-activated CuNiTi wire. However, this was not statistically significant.

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