International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: 6.614
Available Online at www.journalijcar.org
Volume 7; Issue 3(J); March 2018; Page No. 11082-11085
DOI: http://dx.doi.org/10.24327/ijcar.2018.11085.1909

Research Article

# EVALUATION OF FORCE DEFLECTION PROPERTIES OF NICKEL TITANIUM ARCH WIRES

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A R T I C L E I N F O

*Article History:*

Received 8th December, 2017
Received in revised form 20th January, 2018 Accepted 4th February, 2018
Published online 28th March, 2018

*Key words:*

Ni-Ti archwires, Load deflection curve, deactivation force

A B S T R A C T

The aim of the study was to measure the force deflection behavior of 3 different dimensions of 5 commercially available brands of orthodontic arch wires used in initial stages of orthodontic treatment, with use of a universal testing machine. 20 samples of 3 different dimensions of 5 brands wires were tested, so total of 300 wires were tested. Four standard metallic pre adjusted edge wise brackets (0.022") were attached to a acrylic jig in order to simulate clinical scenario. The test was carried out with a crosshead speed of 1 mm/min to a depth of 2 mm. Load deflection graph was plotted for each sample. Results showed that, deactivation forces varied among the different commercially available brands of nickel titanium wires and variation was found in the same dimension of wires between different brands. GAC orthodontic archwire produced least and efficient force during loading and unloading for all 3 dimensions of wires tested. The deactivation force was found to be least in 0.014" GAC orthodontic wire, suggesting it to be suitable choice during initial stage of treatment as it produces low and continuous force following 0.014" AO archwire.



## INTRODUCTION

Fixed orthodontic appliance therapy is a treatment modality based on the theory that applying light continuous force tooth can be moved optimally through the alveolar bone of the jaws without causing permanent damage[1]. It follows the principle of elastic storage and its conversion to mechanical work through the tooth movement. Each time the orthodontic appliance is activated it stores, controls, and deliver the determined forces. An optimal control of tooth movement requires the application of a system of special forces which is properly supported by accessories such as orthodontic wires, brackets, ligature ties etc.[2] Hence it is very necessary to select a correct type of archwire, from the wide plethora of archwire available.

The wires are selected depending on the type of tooth movement required. The requirement changes from initial stage of treatment to the final stage of treatment. Dental arch alignment and leveling is the initial stage of orthodontic treatment. The ideal archwire for initial stage of treatment should produce continuous and light force over a long period of time[3].

Arch wires used in initial alignment stage are Nickel Titanium (superelastic), heat activated NiTi, Co-axial and multistranded stainless steel and small diameter Australian supreme graded wires andmore recently multistranded co-axial NiTi (supercable) wires have been introduced.

When the tooth displacement is marked, the first arch wire should be low in stiffness and high in range. Ideally the initial arch wires should have low load deflection rate. The load deflection rate (LDR) is defined as the external loading needed for the unit deformation and, in orthodontics, signifies the force generated by the unit length deformation. Orthodontic arch wires with high LDR not only apply excessive force on teeth, but their strength decreases quickly with tooth movement. Wires with low LDR, however, generate light and continuous force.

NiTi archwires can easily be transformed between an austenite and a martensite phase either by temperature changes or by stress application. Superelasticity is the transformation from austenitic to martensitic that occurs by stress application within a temperaturerange and is manifested by a flat or nearly flat plateau in a force-deflection curve. Studies have shown, however, that the commercially available NiTi alloys behave in a variablemanner, which often deviates from superelasicity. The forces that play to align and level the teeth is not the activation force, but the deactivation force or unloading force of the appliance. Hence the knowledge of deactivation behavior is important to the clinician for optimal wire selection[5].

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Recently many NiTi orthodontic archwires have been introduced in market. Since the mechanical properties can greatly influence treatment outcome, the need was felt to assess the load deflection properties of these arch wires to provide better insight to clinician for their clinical usage. Hence the present study has taken up to determine the force deflection and mechanical properties of 5 different commercially available NiTi wires with the use of Universal testing machine.

***Aims and Objectives***

- To measure the force deflection behaviour of initial orthodontic archwires during unloading.
- To compare the mechanical property (force deflection) of 5 different brands of archwires used in initial stages of orthodontic treatment, with use of a universal testing machine.

## MATERIALS AND METHODS

***Materials***

- The samples consisted of 300 NiTi orthodontic wires commercially available from five manufacturers.
- These samples included 300 Superelastic preformed NiTi arch wires tested of dimensions: 0.014", 0.016",0.018"commonly used for the 0.022 pre-adjusted edgewise technique.

**Table 1**

| Sl. No | Archwire Brands | Dimensions | Number |
|---|---|---|---|
| 1 | Unique Orthodontics **GROUP 1** | 0.014 | 20 |
| | | 0.016 | 20 |
| | | 0.018 | 20 |
| 2 | JJ Orthodontics **GROUP 2** | 0.014 | 20 |
| | | 0.016 | 20 |
| | | 0.018 | 20 |
| 3 | Modern Orthodontics **GROUP 3** | 0.014 | 20 |
| | | 0.016 | 20 |
| | | 0.018 | 20 |
| 4 | GAC Dentsply **GROUP 4** | 0.014 | 20 |
| | | 0.016 | 20 |
| | | 0.018 | 20 |
| 5 | American Orthodontics **GROUP 5** | 0.014 | 20 |
| | | 0.016 | 20 |
| | | 0.018 | 20 |

**Experimental Jig**

**Instruments and ligature wire**


## METHODOLOGY

This study was conducted to examine the relationship between wire deflection and load. A three-point bending test was conducted using the universal testing machine. The load frame will be equipped with Instron's 100 N static cell. A experimental jig was used for the study.

***Fabrication of Customised JIG***

An acrylic block of 60 mm length and 30 mm width was fabricated. Four standard metallic pre-adjusted edge wise brackets (0.022") were attached to the acrylic block and 14 mm distance between neighboring wings of centre 2 brackets were kept in order to simulate clinical scenario.

***Determination of Loading Characteristics***

The testing wire was cut in to a length of 40 mm and tied to brackets with stainless steel ligatures and were turned several times using a Mathieu ligature tying pliers, then tucked under the bracket in an effort to simulate the clinical method of tying with steel ligatures. The mid portion of the wire segment was deflected at the speed of 1mm/min under the pressure from a metal pole of 5 mm in diameter. Each sample was then loaded until a deflection of 2 mm was produced. The samples were unloaded at the same crosshead speed until the force become zero. This was then followed by another assembly of specimen. 20 samples of each type of wire were tested.

The bending tests showed pronounced loading and unloading plateaus. The force-deflection diagrams were drawn from the available data. The unloading curve is the curve of interest for orthodontic tooth movement. The region of the superelastic plateau was estimated by algorithmetric calculation.[6]

Results obtained were analyzed statistically

***Statiscal Data***

Statistical data's used in this study were Analysis of variance (ANOVA), Paired t-test, un paired t-test and Tukeys HSD post hoc analysis

## RESULTS

**Table 1**

Comparison of mean force deflection(in N) during unloading between different companies for various dimensions using one-way ANOVA test followed by Tukey's HSD post hoc Analysis

| Dimensions | Companies | N | Mean | SD | Min | Max | F | P -Value |
|---|---|---|---|---|---|---|---|---|
| 0.014 | GROUP 1 | 20 | 1.505 | O.167 | 1.28 | 1.84 | 108.885 | <0.001* |
| | GROUP 2 | 20 | 0.851 | 0.085 | 0.74 | 1.01 | | |
| | GROUP 3 | 20 | 0.671 | 0.137 | 0.44 | 0.89 | | |
| | GROUP 4 | 20 | 0.389 | 0.331 | 0.06 | 1.66 | | |
| | GROUP 5 | 20 | 0.587 | 0.066 | 0.48 | 0.70 | | |
| 0.016 | GROUP 1 | 20 | 1.433 | 0.512 | 0.77 | 2.75 | 35.574 | <0.001* |
| | GROUP 2 | 20 | 1.263 | 0.133 | 1.02 | 1.50 | | |
| | GROUP 3 | 20 | 0.907 | 0.238 | 0.76 | 1.89 | | |
| | GROUP 4 | 20 | 0.526 | 0.195 | 0.02 | 0.84 | | |
| | GROUP 5 | 20 | 0.761 | 0.089 | 0.59 | 0.92 | | |
| 0.018 | GROUP 1 | 20 | 2.104 | 0.212 | 1.71 | 2.33 | 239.107 | <0.001* |
| | GROUP 2 | 20 | 2.099 | 0.087 | 1.88 | 2.21 | | |
| | GROUP 3 | 20 | 1.367 | 0.258 | 0.88 | 1.76 | | |
| | GROUP 4 | 20 | 0.640 | 0.061 | 0.51 | 0.76 | | |
| | GROUP 5 | 20 | 1.269 | 0.194 | 0.92 | 1.71 | | |

The mean force deflection during unloading gave the following results. 0.014 dimension of wire in Group 1, Group 2, Group 3, Group 4 and Group 5 showed, 1.505 ± 0.167 N, 0.851 ± 0.085 N, 0.671 ± 0.137 N, 0.389 ± 0.331 N and 0.587 ± 0.066 N respectively. 0.016 dimension of wire in unique orthodontics JJ orthodontics, Moern Orthodontics, GAC and AO showed 1.433 ± 0.512 N, 1.263 ± 0.133 N,0.907 ± 0.238 N, 0.526 ± 0.195 N and 0.761 ± 0.089 N respectively. 0.018 dimension of wire in Group 1, Group 2, Group 3, Group 4 and Group 5 showed 2.104 ± 0.212 N, 2.099 ± 0.087 N, 1.367 ± 0.258 N, 0.640 ± 0.061N and 1.269 ± 0.194 N respectively. (Table 2)

The mean force deflections for Group 1 wires of dimension 0.014, 0.016, 0.018 were 1.736 N, 1.323 N, 2.068 N respectively. The mean force deflection for Group 2 wires of dimension 0.014, 0.016,0.018 were 1.208 N, 1.330 N, 1.733 N respectively. The mean force deflection for Group 3 wire of dimension 0.014, 0.016, 0.018 were 1.112 N, 1.615 N, 1.909 N respectively. The mean force deflection for Group 4 of dimension 0.014,0.016,0.018 were 0.957 N, 1.321 N, 1.168 N respectively. The mean force deflection for Group 5 wires of dimension 0.014, 0.016, 0.018 were1.039 N, 1.456 N, 1.759 N respectively. (Table 3,4,5,6,7)

## DISCUSSION

Clinical evidence has suggested that NiTi alloy wires are more effective initial tooth alignment because of their unique properties of superelasticity and shape memory. These wires have gained wide acceptance in orthodontics because of their properties of low load-deflection ratio and better control of

**Table ,3,4,5,6,7**

**Comparison of mean force deflection (in N) during unloading & unloading in Unique company for various dimensions using Student Paired t test**

| Group | Dimensions | Time | N | Mean | SD | Mean Diff | t | P-Value |
|---|---|---|---|---|---|---|---|---|
| GROUP 1 | 0.014 | Loading | 20 | 3.241 | 0.218 | 1.736 | 35.145 | <0.001* |
| | | Unloading | 20 | 1.505 | 0.167 | | | |
| | 0.016 | Loading | 20 | 2.756 | 0.163 | 1.323 | 12.711 | <0.001* |
| | | Unloading | 20 | 1.433 | 0.512 | | | |
| | 0.018 | Loading | 20 | 4.171 | 0.230 | 2.068 | 55.341 | <0.001* |
| | | Unloading | 20 | 2.104 | 0.212 | | | |

**Comparison of mean force deflection (in N) during unloading & unloading in JJ company for various dimensions using Student Paired t test**

| Group | Dimensions | Time | N | Mean | SD | Mean Diff | t | P-Value |
|---|---|---|---|---|---|---|---|---|
| GROUP 2 | 0.014 | Loading | 20 | 2.059 | 0.170 | 1.208 | 28.725 | <0.001* |
| | | Unloading | 20 | 0.851 | 0.085 | | | |
| | 0.016 | Loading | 20 | 2.593 | 0.087 | 1.330 | 54.100 | <0.001* |
| | | Unloading | 20 | 1.263 | 0.133 | | | |
| | 0.018 | Loading | 20 | 3.832 | 0.202 | 1.733 | 38.952 | <0.001* |
| | | Unloading | 20 | 2.099 | 0.087 | | | |

**Comparison of mean force deflection (in N) during unloading & unloading in Modern company for various dimensions using Student Paired t test**

| Group | Dimensions | Time | N | Mean | SD | Mean Diff | t | P-Value |
|---|---|---|---|---|---|---|---|---|
| GROUP 3 | 0.014 | Loading | 20 | 1.783 | 0.142 | 1.112 | 21.401 | <0.001* |
| | | Unloading | 20 | 0.671 | 0.137 | | | |
| | 0.016 | Loading | 20 | 2.522 | 0.138 | 1.615 | 23.244 | <0.001* |
| | | Unloading | 20 | 0.907 | 0.238 | | | |
| | 0.018 | Loading | 20 | 3.276 | 0.322 | 1.909 | 20.581 | <0.001* |
| | | Unloading | 20 | 1.367 | 0.258 | | | |

**Comparison of mean force deflection (in N) during unloading & unloading in GAC company for various dimensions using Student Paired t test**

| Group | Dimensions | Time | N | Mean | SD | Mean Diff | t | P-Value |
|---|---|---|---|---|---|---|---|---|
| GROUP 4 | 0.014 | Loading | 20 | 1.346 | 0.149 | 0.957 | 11.556 | <0.001* |
| | | Unloading | 20 | 0.389 | 0.331 | | | |
| | 0.016 | Loading | 20 | 1.847 | 0.120 | 1.321 | 26.801 | <0.001* |
| | | Unloading | 20 | 0.526 | 0.195 | | | |
| | 0.018 | Loading | 20 | 1.807 | 0.091 | 1.168 | 49.438 | <0.001* |
| | | Unloading | 20 | 0.640 | 0.061 | | | |

**Comparison of mean force deflection (in N) during unloading & unloading in AO company for various dimensions using Student Paired t test**

| Group | Dimensions | Time | N | Mean | SD | Mean Diff | t | P-Value |
|---|---|---|---|---|---|---|---|---|
| GROUP 5 | 0.014 | Loading | 20 | 1.626 | 0.136 | 1.039 | 33.259 | <0.001* |
| | | Unloading | 20 | 0.587 | 0.066 | | | |
| | 0.016 | Loading | 20 | 2.217 | 0.150 | 1.456 | 36.554 | <0.001* |
| | | Unloading | 20 | 0.761 | 0.089 | | | |
| | 0.018 | Loading | 20 | 3.027 | 0.188 | 1.759 | 49.714 | <0.001* |
| | | Unloading | 20 | 1.269 | 0.194 | | | |

force magnitude. A relatively low and continuous force during its unloading thus making them the first choice of wire during the initial stages of treatment.

In the present study the force deflection behavior of 5 different brands of orthodontic wires of different dimensions, the superiority of one over another was evaluated, so that they can be used accordingly. The test was carried out with use of universal testing machine and testing jig same as the one proposed by Luca Lombardo *et al*.[8]

The significant differences between archwires of the same diameter and type for all parameters considered. This fact agrees with the study of Nokano *et al*.[7] who observed great variation in force values with different NiTi wires of same diameter indicating the wires are intrinsically different and therefore can be differentiated according to their characteristics. In fact, it is important to underline that mechanical properties of NiTi alloy wires are greatly are influenced by different technological parameters, such as chemical composition, heat treatment and degree of working.

In present study comparison of mean force deflection during loading between different companies for various dimensions (0.014”, 0.016”, 0.018”) showed that, Group 4 orthodontic archwire produced least and efficient force during loading. While Group 5 orthodontic wire showed high force during loading (Table 1). The mean force deflection during unloading showed Group 4 orthodontic archwire produced least and efficient force and Unique orthodontic wire showed high force.(Table 2). All 5 brands of orthodontic wires used in this study showed more force deflections for the larger dimension archwires when compared between 0.014”, 0.016” and 0.018”.

According to a study done by Theodosia N Bartzela *et al*. the true superelastic wires are indicated for the leveling and the borderline superelastic wire with longer plateau length for derotational procedures. The true superelastic should be recommended especially for the treatment of adult patients and stark crowding cases. The borderline superelasticarchwire considered suitable for mild to moderate crowding cases.

The measurements in this study are in agreement with the results of Segner and Ibe in that wires with larger dimension indicated the best superelastic properties.[9]

## CONCLUSION

- The deactivation forces varied among the different commercially available brands of nickel titanium wires and variation was found in the same dimension of wires between different brands.
- The deactivation force was found to be least in 0.014” Group 4 (GAC) orthodontic wire, suggesting it to be suitable choice during initial stage of treatment as it produces low and continuous force and was found maximum in Group 5 (Unique orthodontics).

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**How to cite this article:**

Dr.Sharmada.BK *et al* (2018) 'Evaluation of Force Deflection Properties of Nickel Titanium Arch Wires', *International Journal of Current Advanced Research,* 07(3), pp. 11082-11085. DOI: http://dx.doi.org/10.24327/ijcar.2018.11085.1909

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