

Comparison of mechanical properties of three orthodontic wires between levelled and unlevelled brackets: An in vitro study

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Abstract

Background: The objective of this study was to compare the mechanical properties of three orthodontic wires between levelled and unlevelled bracket using a three-point bending test.

Methods: Three groups of ten Nickel titanium, Betatitanium and CuNiTi wire segments (0.017 × 0.025-in. diameter) were used. Two brackets were bonded to an acrylic jig with a 10-mm interbracket distance. Deflection test was done in two scenarios, one with aligned brackets and other with 2-mm horizontal displacement of the brackets to simulate malaligned teeth. Forces of loading and unloading of the wires during both tests were compared by an analysis of variance (ANOVA) tests.

Results: The difference of LDR between levelled and unlevelled brackets during loading in NiTi wire was 0.1 N, Beta-titanium wire 0.2 N and CuNiTi wire was 1.5 N. The difference of LDR between levelled and unlevelled brackets during unloading in NiTi wire was 0.2 N, Betatitanium wire was 0.3 N and CuNiTi wire is 0.5 N.

Conclusions: The study showed some significant differences in forces generated during loading and unloading among the three different types of wires tested. During both the scenarios only CuNiTi wire showed significant difference. Betatitanium wire exhibited highest force followed by NiTi and CuNiTi.

Keywords: NiTi, Beta-titanium, CuNiTi wires, Three-point bending test, Load deflection rate (LDR), Newtons (N).

Introduction

An Orthodontic archwire is one of the important components of the fixed orthodontic appliance and it should move teeth with a light, continuous force. This force should be such that it reduce patient discomfort, tissue hyalinization and root resorption.⁽¹⁾ Briefly, many materials have been used for orthodontic wires in the past. Until a shortage in 1930, gold was the dominant wire after which stainless steel replaced gold as the dominant wire in orthodontics.⁽²⁾ Knowledge of basic wire properties and biomechanical aspects can help the orthodontist select the wire material, geometry and size that is optimal for each case or make various technique combinations that will optimize the quality of the treatment provided.⁽³⁾ Various studies^(4,5,6) have evaluated orthodontic wires in laboratorial in vitro tests during deflection tests, in order to assess their load/deflection behaviour and their elasticity module. Although many authors^(7,8,9) have investigated the properties of arch wires, most published studies have tended to concentrate on evaluating properties of various wires at specific deflections and have considered their complete behaviour on loading and unloading in a levelled brackets. In order to simulate a better clinical situation, 2-mm horizontal displacement was done between the brackets and will be tested to evaluate if the load/deflection behaviour changes. 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. If arch wires with high LDR used, they not only apply excessive force on teeth, but also their strength decreases quickly

with tooth movement. But wires with low LDR used, they generate light and continuous force.

The objective of the study was therefore to evaluate the mechanical properties of Nickel Titanium, Betatitanium, Copper NiTi orthodontic wires between levelled and unlevelled bracket alignment scenarios using universal testing machine.

Materials and Methods

The load-deflection rate of each wire from each group were evaluated using three-point bending test. All the testing was performed at dry condition.⁽¹⁰⁾ A specially designed jig made up of acrylic was bonded on to the machines support. Two brackets of MBT 0.022 slot were used which is bonded to the acrylic jig. 0.017X0.025 inch NiTi, CuNiTi and Betatitanium. Wires were used. These wires were cut into 30 mm length with the aid of digital calliper. Each wire is fixed on to the bracket with the help of ligature wire. In the first part of the experiment the brackets were placed parallel to each other (Fig. 1) and in the second part of the experiment brackets were displaced 2mm in order to simulate the malaligned teeth⁽¹¹⁾ (Fig. 2). Ten specimens from each group (Table 1) are ligated to the bracket with the help of ligature wire and load deflection test is performed. Testing was done using a Universal testing machine⁽¹²⁻¹⁵⁾ (:Mecmesin- Multitest 10 -i). The upper movable head of the testing machine was attached with a striker. The tip of the striker was on the midpoint of the test-wire span. The wider surface of the wires faced the striker. The crosshead speed for loading and unloading was 1 mm per minute.⁽¹⁶⁾ The mid portion of the wire was

deflected. The loading values for each sample were recorded at 1, 2, and 3 mm.⁽¹⁷⁾ Forces necessary for the deformation test were recorded directly into the computer.



Fig. 1: Jig in the universal testing machine with levelled brackets



Fig. 2: Jig in the universal testing machine with unlevelled brackets

Table 1: Groups of arch wires

Groups	No. of arch wires	Materials
1	10	NiTi
2	10	Beta Titanium
3	10	CuNiTi

Statistical analysis: LDR during loading and unloading between levelled and unlevelled among three groups (Group-1 NiTi, Group -2 Betatitanium and Group-3 CuNiTi) were compared with the aid of analysis of variance (ANOVA) test with “P” value < 0.005 considered significant.

Results

Means and standard deviations of the 1-mm deflection loading force between levelled and unlevelled brackets can be seen in Table 2. The ANOVA test showed a statistical significant difference between the wires of different materials. During loading the

difference of LDR between levelled and unlevelled brackets in NiTi wire was 0.1 N, Betatitanium wire was 0.2 N and CuNiTi wire is 1.5 N.

Table 2: Comparison of LDR during 1mm deflection between levelled and unlevelled brackets during loading

Wires		Loading	
		Mean(N)	SD
Levelled	NiTi	9.12	0.0357
	Betatitanium	18.51	0.0631
	CuNiTi	9.11	0.0488
Unlevelled	NiTi	9.11	0.0488
	Betatitanium	18.49	0.0788
	CuNiTi	7.57	0.3433

Means and standard deviations of the 1-mm deflection Unloading force between levelled and unlevelled brackets can be seen in Table 3. During unloading the difference of LDR between levelled and unlevelled brackets in NiTi wire was 0.2 N, Betatitanium wire was 0.3 N and CuNiTi wire was 0.5N.

Table 3: Comparison of LDR during 1mm deflection between levelled and unlevelled brackets during Unloading

Wires		Unloading	
		Mean(N)	SD
Levelled	NiTi	3.59	0.0383
	Betatitanium	6.59	0.0545
	CuNiTi	2.22	0.0403
Unlevelled	NiTi	3.57	0.0257
	Betatitanium	6.56	0.0586
	CuNiTi	2.17	0.0340

Discussion

The concept of optimal orthodontic forces has been discussed since the early 20th century. Nowadays, “light continuous forces” are thought of as physiologically suitable and efficacious, but in this case, the term is used somewhat arbitrarily. Clinicians must judge for themselves the most suitable force for each particular clinical situation.⁽¹⁸⁾ Selection of the appropriate wire for a particular clinical condition should be based on the ability of these wires to produce a constant moment over different degrees of deflection.⁽¹⁾ Three point bending test was used to evaluate the load deflection rate, which is one of the important parameters to evaluate the amount of force exerted by the wire for the tooth movement . No study was conducted in the past to compare the LDR between levelled and unlevelled brackets between NiTi, Betatitanium and CuNiTi wires, but studies conducted to find the load deflection between levelled and unlevelled brackets for different brands of Betatitanium wires.⁽¹¹⁾

Table 2 shows that during loading the difference of LDR between levelled and unlevelled brackets in NiTi wire was 0.1 Newtons, betatitanium wire was 0.2

Newtons and CuNiTi wire is 1.5 newtons. Table 3 shows that during unloading the difference of LDR between levelled and unlevelled brackets in NiTi wire was 0.2 Newtons, betatitanium wire was 0.3 Newtons and CuNiTi wire is 0.5 newtons. During loading and unloading, only CuNiTi wire tested exhibited a statistical significant difference between levelled and unlevelled brackets. Among all the wires tested Betatitanium wire exhibited highest forces followed by NiTi and CuNiTi wire, indicating the presence of different forces for the same amount of deflection when using different commercially available wires. Beta titanium wires which exhibited the highest force, indicated that these wires have higher stiffness during deflection followed by NiTi and CuNiTi wire which exhibited lesser forces indicated that they need the lesser force to deflect the wire. Clinically, the wires that requires lower forces to deflect represent a favourable characteristic for dental tooth movement and can be successfully used in the control of the system of forces between tooth and periodontal structures. Therefore, a clinician with clear understanding of the properties inherent in each wire has to choose the wire needed at that particular stage of treatment.

Limitations of this Study & Scope for further studies

This is an in vitro study which provided information about the LDR. In this study, we assessed a deflection force of 1mm and results obtained from this degree of displacement. Deflection forces produced my change if it is more than 1mm. The type of ligation may have an effect on the result. This study is conducted in dry condition, results may vary if the study was done in the wet condition. Only two brackets were used in this study, the effect of force may vary when more than two brackets were used. Therefore, although the present findings are a useful guide to the anticipated clinical behaviour of the different wires used in the field of Orthodontics, further clinical studies have to be conducted to reinforce the results and to identify the properties of the wire with more deflection, various ligation methods and different brackets.

Conclusion

Based on the three point bending test, the following conclusions were made:

- 1) The study showed significant differences in LDR produced by wires between levelled and unlevelled bracket during loading and unloading.
- 2) There was a significant statistical difference only for CuNiTi wire when compared between levelled and unlevelled brackets during loading and unloading.
- 3) In both the scenarios Betatitanium wire exhibited highest forces followed by NiTi and CuNiTi.

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