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RESEARCH ARTICLE

Deflection test on different orthodontic wire materials sized 0.016 x 0.022 inches

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ABSTRACT

The development of technology in orthodontic field produces some orthodontic wires that have different deflection abilities. Loading force is the force needed to place an orthodontic wire in bracket slot (activation). Unloading force is the force produced by an orthodontic wire to move tooth (deactivation). Deflection test with three-point bending technique is a technique that is often used to determine the magnitude of the activation and deactivation force of orthodontic wire. Stainless steel (SS), nickel titanium (NiTi), copper nickel titanium (CuNiTi), and beta titanium (TMA), are the types of frequently used wires. This study aimed to compare loading and unloading force on the deflection test of SS, NiTi, CuNiTi, and TMA orthodontic wires sized 0.016 x 0.022 inch on the load-deflection graph. This is a laboratory experimental research on a total of 16 pieces of SS, NiTi, CuNiTi, and TMA orthodontic wires sized 0.016 x 0.022 inches. The group was divided based on the type of material. The deflection test was performed using a universal testing machine with a press speed of 5 mm/minute. Loading and unloading forces were recorded on deflections of 0.5; 1; and 1.5 mm. Statistical tests of differences among groups were carried out by ANOVA analysis (p-value ≤ 0.05) and post-hoc analysis with T-test. There were significant differences in the loading and unloading forces recorded on deflections of 0.5; 1; and 1.5 mm; except for deflections of 0.5 mm of the SS and nickel-titanium wires. The wire deflection force from the lowest to the highest was CuNiTi wire, nickel-titanium wire, TMA wire, and stainless-steel wire.

Keywords: deflection test; loading force; orthodontic wire; unloading force; universal testing machine

INTRODUCTION

Orthodontic treatment is a treatment in the field of dentistry which aims to improve crowding, correct the relationship between maxillary and mandible, create ideal occlusion, and improve aesthetics. Fixed orthodontic appliances consist of passive and active components. Passive component serves as a place for the active component on teeth, while active component is the part that produces the force of tooth movement. Active components, for example, are rubber separator, elastic rubber, springs, and orthodontic archwire.[1,2]

The development of technology produces various kinds of alloy metal wires such as nickel-titanium wire (NiTi), beta titanium (TMA), and copper-nickel titanium (CuNiTi) with different mechanical properties. Stainless steel wire is used in orthodontic treatment due to its excellent mechanical properties, such as having high stiffness, being easy to form, and having low prices. Nickel-titanium wire has shape memory properties, which is the ability to return to its initial shape without deforming the wire. Titanium beta wire is an alternative to SS and NiTi wire because it does not contain nickel so it can be used for orthodontic patients with nickel hypersensitivity. Nickel-titanium added with copper (Cu) element produces shape memory properties so that the wire will become active at a certain temperature.[2,3]

Ideal orthodontic wire requirements are high elastic modulus, easy to mold, large spring back, low stiffness, low resilience, non-toxic, corrosion resistance, and low friction. Modulus of elasticity, spring back, stiffness and resilience are mechanical properties of orthodontic wire. The absence of ideal type of wire at each stage of treatment requires clinicians choose different types of shapes, sizes, and mechanical properties. Deflection test can determine the mechanical properties for orthodontic wire because the type of deformation produced approaches the clinical condition.[2,4] The process of tooth movement in orthodontic treatment is divided into two stages as follows: the first stage is the activation stage of orthodontic appliance; at this stage, wire or other active devices are placed in bracket slot so that wire bending or deflection occurs. The force required at this stage is called activation force. The next stage is the ligation of wire in bracket slot, and the process of tooth movement depends on the ability of wire to return to the initiatial position before deflection occurs. The force produced by wire on tooth movement is called deactivation force.[5]

The amount of activation and deactivation force of orthodontic wire is challenging to determine clinically at the time of treatment. For this reason, mechanical testing is needed which can replicate the conditions in the mouth. Deflection test with three-point bending technique is a frequently used technique to determine the magnitude of the activation and deactivation force of orthodontic wire.[6] Loading force describes the amount of wire activation force, and unloading force illustrates the magnitude of wire deactivation force.[3]

Research on loading and unloading forces in the deflection test of SS rounded initial wire, superelastic NiTi, multistranded SS, thermal NiTi, and multistranded coaxial NiTi conducted by Khatri and Mehta in 2014 suggests that there are significant loading and unloading forces in the wire group.[5] Another study conducted by Mathew on loading and unloading force of SS wire, NiTi, superelastic NiTi, and TMA sized 0.016, 0.016 x 0.022, and 0.017 x 0.025 inches states that there are also significant differences.[7] Researchers have not conducted any study on the differences in the loading and unloading forces in the deflection test of SS wire, NiTi, TMA, and CuNiTi sized 0.016 x 0.022 inches. The purpose of this study was to determine the differences between loading and unloading forces in the deflection test of SS, NiTi, TMA, and CuNiTi wire sized 0.016 x 0.022 inches.

MATERIALS AND METHODS

The research method was an experimental laboratory of 16 pieces of SS, NiTi, CuNiTi, and TMA orthodontic wires (n=4) sized 0.016 x 0.022 inches, with a length of 30 mm. The study was conducted at the light structural laboratory of industrial engineering center of Bandung Institute of Technology in December 2017. The group division was carried out based on the types of material. Each wire was taken with the length of 30 mm. The deflection test was performed using a universal testing machine with a press speed of 5 mm/minute. Loading and unloading forces were recorded on a deflection of 0.5, 1, and 1.5 mm. The homogeneity test was carried out by Bartlett test with p-value of 0.00 and normality test was carried out by chi-square 0.5. Statistical tests on differences between groups were carried out by ANOVA analysis, with p-value of ≤ 0.05, and t-test for post hoc analysis.

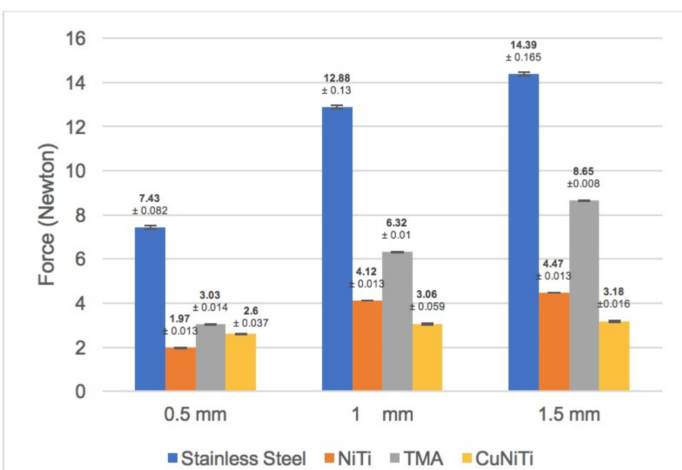

Figure 1. Mean and standar deviation of loading force on four types of wire diagram

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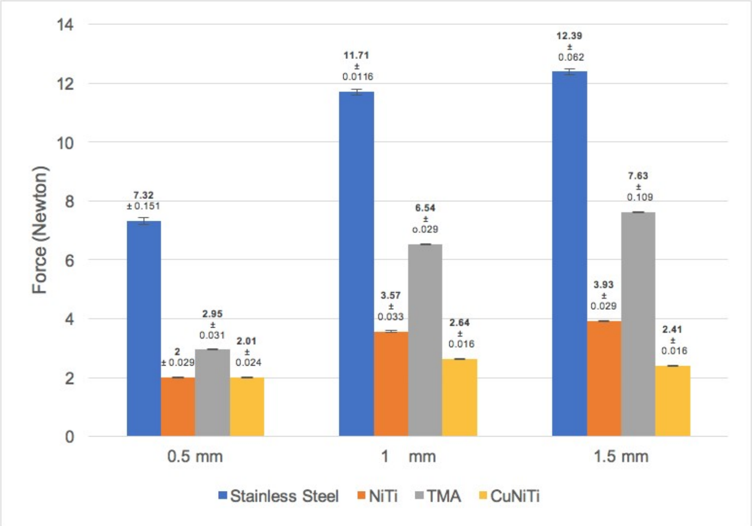

Figure 2. Mean and standard deviation of unloading force on four types of wire diagram

Table 1. Mean of unloading force of all types of wire in all deflections and the results of analysis of variance (ANOVA)

Type of wire	Deflection	Mean	Std. Dev	p-value
SS	0.5 mm	7.32	0.151	0.00
	1 mm	11.71	0.116	
	1.5 mm	12.39	0.062	
NiTi	0.5 mm	2.00	0.029	
	1 mm	3.57	0.033	
	1.5 mm	3.93	0.029	
TMA	0.5 mm	2.95	0.031	
	1 mm	6.54	0.029	
	1.5 mm	7.63	0.109	
CuNiTi	0.5 mm	2.01	0.024	
	1 mm	2.64	0.016	
	1.5 mm	2.41	0.016	

Table 2. Comparison of loading and unloading force of all types of wire in the same deflection using t-test

Variables	Loading	Unloading	p-value
SS	0.5 mm	0.5 mm	0.25
SS	1 mm	1 mm	0.00*
SS	1.5 mm	1.5 mm	0.00*
NiTi	0.5 mm	0.5 mm	0.1313
NiTi	1 mm	1 mm	0.00*
NiTi	1.5 mm	1.5 mm	0.00*
TMA	0.5 mm	0.5 mm	0.00*
TMA	1 mm	1 mm	0.00*
TMA	1.5 mm	1.5 mm	0.00*
CuNiTi	0.5 mm	0.5 mm	0.00*
CuNiTi	1 mm	1 mm	0.00*
CuNiTi	1.5 mm	1.5 mm	0.00*

Notes *: Significant difference ($p \leq 0.05$)

Table 3. Comparison of loading force among all types of wire in the same deflection using the t-test

Variable	Loading	p-value
SS vs. TMA	0.5 mm	0.00*
SS vs. NiTi	0.5 mm	0.00*
SS vs. CuNiTi	0.5 mm	0.00*
SS vs. TMA	1 mm	0.00*
SS vs. NiTi	1 mm	0.00*
SS vs. CuNiTi	1 mm	0.00*
SS vs. TMA	1.5 mm	0.00*
SS vs. NiTi	1.5 mm	0.00*
SS vs. CuNiTi	1.5 mm	0.00*
TMA vs. NiTi	0.5 mm	0.00*
TMA vs. CuNiTi	0.5 mm	0.00*
TMA vs. NiTi	1 mm	0.00*
TMA vs. CuNiTi	1 mm	0.00*
TMA vs. NiTi	1.5 mm	0.00*
TMA vs. CuNiTi	1.5 mm	0.00*
NiTi vs. CuNiTi	0.5 mm	0.00*
NiTi vs. CuNiTi	1 mm	0.00*
NiTi vs. CuNiTi	1.5 mm	0.00*

Notes *: Significant difference ($p \leq 0.05$)

Table 4. Comparison of unloading force among all types of wire in the same deflection using the t-test

Variable	Unloading	p-value
SS vs. TMA	0.5 mm	0.00*
SS vs. NiTi	0.5 mm	0.00*
SS vs. CuNiTi	0.5 mm	0.00*
SS vs. TMA	1 mm	0.00*
SS vs. NiTi	1 mm	0.00*
SS vs. CuNiTi	1 mm	0.00*
SS vs. TMA	1.5 mm	0.00*
SS vs. NiTi	1.5 mm	0.00*
SS vs. CuNiTi	1.5 mm	0.00*
TMA vs. NiTi	0.5 mm	0.00*
TMA vs. CuNiTi	0.5 mm	0.00*
TMA vs. NiTi	1 mm	0.00*
TMA vs. CuNiTi	1 mm	0.00*
TMA vs. NiTi	1.5 mm	0.00*
TMA vs. CuNiTi	1.5 mm	0.00*
NiTi vs. CuNiTi	0.5 mm	0.46
NiTi vs. CuNiTi	1 mm	0.00*
NiTi vs. CuNiTi	1.5 mm	0.00*

Notes *: Significant difference ($p \leq 0.05$)

RESULTS

Figure 1 shows the mean and standard deviation of the loading force of SS, NiTi, TMA, and CuNiTi wires. The largest loading force was generated at a deflection of 1.5 mm, and the smallest at a deflection of 0.5 mm.

Figure 2 indicates a diagram of the unloading force of SS, NiTi, TMA, and CuNiTi wires, the CuNiTi wire in all deflections had the smallest unloading force compared to other types of wire. This result indicated that the CuNiTi wire produced lower deactivation power than different types of wire.

NiTi wire ranked the second, followed by TMA, and SS wire consecutively. Table 1 shows there were significant differences in the loading and unloading force of the deflection test among SS, NiTi, TMA, and CuNiTi wires sized 0.016 x 0.222 inches.

Based on t-test analysis in Table 2, it can be seen that there were significant differences in the loading and unloading force of various types of wire in different deflections, except for NiTi and SS wires with a deflection of 0.5 mm. A significant difference of loading force was also seen in several types of wire in the same deflection.

Based on the t-test results, there were significant differences in the loading force of all types of wire in the same deflection on the variables listed in Table 3. Based on the results of t-test analysis, there was a significant difference in the unloading force between all wire types in the same deflection on the variables listed in Table 4.

DISCUSSION

This research was conducted to examine the loading and unloading forces on a deflection test of different orthodontic wires sized 0.016 x 0.022 inches. The deflection test was performed using the three-point bending test technique by universal testing machine.

Loading force is a force measured on an object due to a load process that leads to deflection of the object.[8] The magnitude of the loading force in this research was measured in the units of Newton (N) when the wire was pressed until it reached a certain deflection. The loading force application in the orthodontic field is the amount of force needed to place a wire in bracket slot or also known as activation force.[5]

Unloading force is the internal force produced by an object to return to its position after external force is removed.[8] The magnitude of the unloading force in this research was measured in the units of Newton (N) when the wire returned to its normal position. The higher the unloading force of a wire, the higher the force produced by the wire to move tooth.[9] The result of this study proved that there was a significant difference in the loading and unloading forces on SS, NiTi, TMA, and CuNiTi wires sized 0.016 x 0.022 inches. SS wire had the highest loading and unloading force compared to the other three types of wire, while CuNiTi wire had the lowest loading and unloading force.

SS wire produced loading and unloading force which was almost two times larger than TMA wire and four times larger than NiTi wire. This research showed that SS wire had the highest activation and deactivation force compared to other types of wire tested.[10]

TMA wire had loading and unloading forces between SS and NiTi. The results of this research stated that the activation and deactivation force of TMA wire was lower than that if SS wire but higher than those of NiTi and CuNiTi wires. The low loading and unloading force of TMA wire compared to SS wire also means that TMA wire had lower stiffness than SS wire, but higher than NiTi and CuNiTi wires. The results of this research were consistent with a research conducted by Goldberg and Burstone, stating that the advantages of TMA wire are the stiffness which is between the stiffness of SS and NiTi, easy to form, the ability of welding, and small possibility of hypersensitivity.[4]

Nickel-titanium wire has better loading and unloading force and flexibility than SS and TMA wires.[11] This statement is supported by the results of this research, showing that the unloading force of NiTi wire was lower than those of SS and TMA wires, but higher than that of CuNiti wire. This result showed that the deactivation force of NiTi wire was higher than that of CuNiTi wire. The results of this study were different from previous studies which state that the unloading force of CuNiTi wire does not differ significantly from that of NiTi wire.[12] This condition may be caused by the temperature settings that are often unstable during testing, making it difficult for consistent data retrieval, especially for CuNiTi wires that are sensitive to temperature changes.[3]

CuNiTi wire in this study used a wire with an activation temperature of 35 °C. CuNiTi wire in this study resulted in the lowest unloading force compared to the other types of wire. This result showed that the deactivation force of CuNiTi wire was the lowest compared to the other three types of wire. The results showed that the unloading force of CuNiTi wire was lower than that of NiTi wire. This result also showed that the deactivation force of CuNiTi wire was lower than that of NiTi wire. The results of this study are different from those of previous studies which state that the unloading force of NiTi wire does not differ significantly from that of CuNiTi wire.[12]

The mechanical properties of orthodontic wires such as stress, bending, and torsion can be known from several types of laboratory tests.[13] Deflection test is a test that aims to evaluate the mechanical properties of orthodontic wires, especially in deflection-style graphs.[7] Those various tests, however, do not describe the clinical condition on orthodontic treatment, but still provide a basic description of mechanical properties and inter-wire comparisons.[10] Deflection test provides a right overview if the first and second order bends are performed. Torsional test provides a right overview if the third order bends are performed.[14]

Information on the magnitude of deactivation force on various types of orthodontic wires can be an essential guide when orthodontists determine the type of wire used according to the treatment stage. When a light and continuous force is needed to be below 50 gram or 0.5, N, NiTi and CuNiTi wires are very suitable to be used in this treatment stage because of the low unloading force.[2] SS and TMA wires can also be used in a light force but there must be various types of bending performed to reduce a large unloading force.

SS wire is widely used in the final stages of treatment due to its high unloading force, which serves to guard the teeth against external factors and relapsing. SS wire is also used to correct more than one tooth in the same region, such as the correction curve of Spee in the case of open bite and deep bite.[15]

TMA wire can be used as the main wire in orthodontic treatment, or replacement wire of SS and NiTi wire for patients with nickel hypersensitivity. Copper nickel-titanium wire can be used as the main wire in orthodontic treatment or replacement wire of SS and NiTi wire for patients with low pain threshold.[12] The cost factor also becomes another consideration to choose wire type because TMA and CuNiTi wires are more expensive than SS and NiTi wires.

CONCLUSION

There are significant differences in the loading and unloading force on deflection test of SS, nickel-titanium, TMA, and CuNiTi wire sized 0.016 x 0.022 inches, except for the SS and nickel-titanium wire on the deflection of 0.5 mm. The sequence of wires from the lowest to the highest loading and unloading forces is CuNiTi wire, nickel-titanium wire, TMA wire, and SS wire.

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