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Original Research Article

Comparison of Frictional Resistance in Four Different Types of Nickel Titanium Wires: An Invitro Study

Canmany. E[1], Jayanthy M. S[2], Sumitha. S[3]

[1]Associate Professor, Department of Orthodontics, Mahatma Gandhi Post Graduate Institute of Dental Sciences, Pondicherry, Tamilnadu, India

[2]Senior Assistant Professor, Department of Orthodontics & Dentofacial Orthopedics, Tamilnadu Government Dental College & Hospital, Chennai, Tamilnadu, India

[3]Orthodontist and Private practitioner, Rootz and Clipz dental Clinic, Coimbatore, Tamilnadu, India

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Corresponding author: Jayanthy M. S

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Abstract:

Introduction: Orthodontic biomechanics are largely based on delivering optimal and predictable force system, which is often mediated by metal wires. From the 19th century NiTi wires played a major role in orthodontics with their extremely spring back property. But still they have their own drawbacks of increased frictional resistance. This in-vitro study was done to compare and evaluate the changes in the frictional resistance characteristics of four types of NITI wires in as received condition and after subjecting them to a simulated oral environment for a duration of 4 weeks.

Materials and Methods: The four types of nickel titanium wires, M-Nitinol, Teflon coated M-Nitinol, thermodynamic super elastic NiTi (Neo Sentalloy), super elastic ion implanted NiTi (bio force Sentalloy with longuard) are selected. The selected wires were assigned in to four major groups. Each group had a sample of 16 wires. Individual groups were further divided into 2 sub samples- sub sample A and sub sample B each containing 8 wires. Sub sample A in each group were used as controls tested in as received condition. Sub sample B were used as experimental group tested after subjecting them to a simulated oral environment over a duration of 4 weeks. They were tested for the frictional resistance.

Results: Paired T test and Anova followed by Tukey HSD test showed Statistical significance at 1% level.

Conclusion: Surface modified Nickel Titanium wires; Teflon coated M Nitinol and Ion implanted NiTi perform more efficiently in reducing the frictional resistance of the wires, heat activated Neosentalloy showed very minimal stress relaxation in simulated oral environment.

Keywords: Frictional Resistance, Nickel Titanium Wires, Super Elasticity, Ion Implantation, Surface Roughness.

Introduction

Orthodontic biomechanics are largely based on delivering optimal and predictable force system, which is often mediated by metal wires. These wires are capable of storing and distributing biologically tolerable forces, by means of which teeth are moved precisely and permanently to a predetermined position. Constant unrelented search for an ideal wire, which can deliver optimal orthodontic force had led to the invention of number of innovative wires.

Initial use of wires in orthodontics started with piano and gold wires, later in 19th century the use of stainless steel and chromium cobalt wires were preferred for their extreme formability. Later years of 19th century NiTi wires played a superior role on orthodontic field for their extremely good spring back property and with the advent of titanium based arch wires, orthodontic bio mechanics changed from varying cross section orthodontics to modulus orthodontics [1]. This enabled the orthodontics to select arch wires based on their modulus of elasticity rather than their cross-sectional area. NiTi arch wires had their own draw backs of increased frictional resistance, corrosion and bio degradation with increased surface roughness [2, 3,4,5].

To overcome the drawbacks of NiTi wires, various methods were attempted to modify the surface property of the wire which would make their surface inert by improving their surface characteristics, frictional resistance and corrosion resistance property. This part of research had led to the invention of coated and ion implanted wires[6] Ion implantation of beta titanium and nickel titanium wires produced more tooth movement than their untreated counterpart and also improved corrosion resistance and decreased friction.

This in-vitro study was done to compare and evaluate the changes in the frictional resistance characteristics of four types of NITI wires. The M-Nitinol, Teflon coated M-Nitinol, thermoactive A NiTi (Neosentalloy), super elastic ion implanted A NiTi (Bioforce Sentalloy with longuard) in as received condition and after subjecting them to a simulated oral environment for a duration of 4 weeks.

Materials and Methods

The four types of NiTi wires used in this study were

- M.Nitinol
- teflon coated M-Nitinol
- thermodynamic super elastic NiTi (Neo Sentalloy)
- super elastic ion implanted NiTi (bio force sentalloy with longuard)

These selected four varieties of NiTi arch wires were assigned to four major groups. Each group had a sample of 16 wires. Individual groups were further divided into 2 sub samples- sub sample A and sub sample B each containing 8 wires.

Sub sample A in each group were used as controls tested in as received condition. Sub sample B were used as experimental group tested after subjecting them to a simulated oral environment over a duration of 4 weeks. They are tested for the frictional resistance.

Armamentarium:

The four types of nickel titanium wires, M-Nitinol, Teflon coated M-Nitinol, thermodynamic super elastic NiTi (Neo Sentalloy), super elastic ion implanted NiTi (bio force Sentalloy with longuard).

- Brackets and buccal tubes of maxillary segments (0.022 slot, Roth prescription, Gemini stainless metal brackets, 3M Unitek).
- Heat cured acrylic maxillary typodont duplicated from patient study model.
- 0.009-inch SS ligature wire (American orthodontics)
- Elastomeric ligature (power ‘O’ modulus Ormco corp)
- Mathew needle holder, ligature cutter, tie and tucker
- Cyanoacrylate adhesive for mounting brackets
- Instron 4301 testing machine (lioyds, canton, mass)
- Incubator whose temperature set to 37 degree C (fig 1)
- Thermometer to adjust temperature of the water bath(fig 2)
- Simulated salivary machine according to Barrett et al (1993) consisting of
- Sodium chloride (Nacl)- 0.4grams
- Potassium chloride (kcl)-1.21grams
- Sodium hypophosphate (NaH2PO4).2H20- 0.78grams
- Sodium sulfide (Na2S.9H2O)- 0.005grams
- Urea (IO(NH)2)2-1gram
- Distilled and deionized water-1liter PH adjusted to 6.75+_0.015 with ION sodium hydroxide

Figure 1: Incubator setting at 37°C

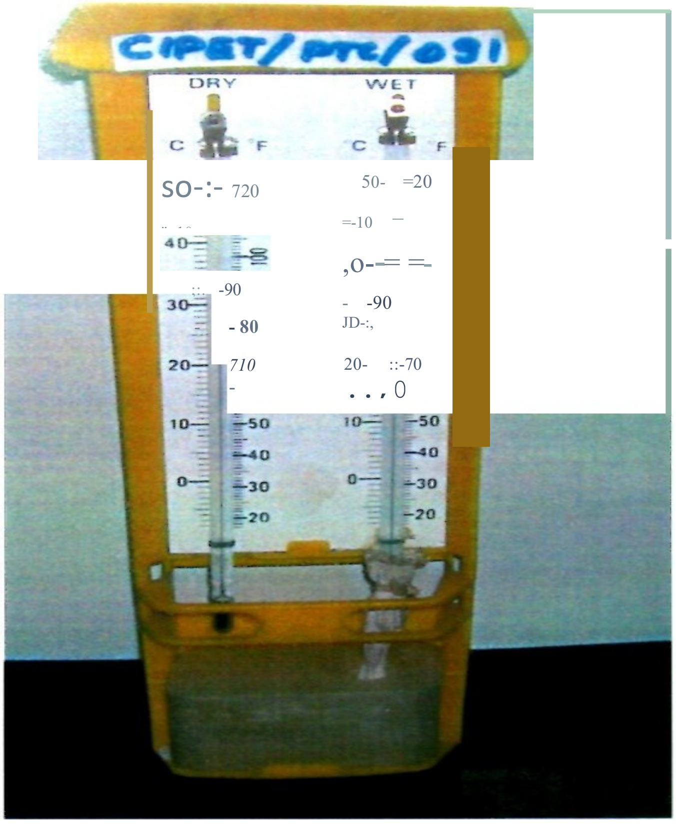

Figure 2: Thermometer

Typhodont Setup and Bracket Mounting Criteria for Selection of Typhodont

An average sized maxillary study model with an ovoid arch form from a male patient of 15 years was chosen for the study. The maxillary arch was well aligned in the posterior segment while anterior segment revealed moderate crowding with lingual displacement of 22 by 3mm. the study model was well polished and duplicated with heat cure acrylic. 16 acrylic typhodonts were totally duplicated. The 0.022 slot brackets (Roth prescription) with upper first molar tubes were bonded on to the tooth surface with cyanoacrylate adhesive at their midpoint of clinical crowns with mesio distal axis coinciding

Test Methodology

The frictional resistance of the NiTi wires was tested according to method described by prososki et al (1991). The straight right posterior segment of arch wire extending from the distal of 13 to 16 was cut off from the arch wire. The larger segment for removed from the typhodont. The smaller straight segment with its typhodont bracket assembly was positioned in the Instron machine. The friction generated by the testing unit consisting of wire, brackets and elastomeric ligatures were measured using an Instron 4301 testing machine with a load cell of 10N. kinetic friction forces were recorded while 5mm of wire was drawn through the brackets at a speed of 1mm/min. for study purpose measurements of kinetic friction were performed at every 1mm displacement and then averaged and the force generated was expressed in newtons. All the wires in control groups were tested with similar experimental testing described above and results were tabulated.

The entire test was carried out in water bath whose temperature was adjusted to be within 35-37degree C. After testing all the wires in control group, the new set of wires in the experimental group was mounted in typhodont. The wires were secured into the brackets of 21, 23 with steel ligatures, while the other segment of the wire was secured with elastomeric ligatures. The wire was also ligated into the lingually displaced 22 with stainless steel ligature. Now the typhodont mounted brackets and arch wires were immersed in artificial medium stored in separate containers and were stored in incubator whose temperature setting was adjusted to 37degreeC for 4weeks (fig 3). After 4 weeks typhodonts removed and assessed for frictional resistance. Now the typhodont assembly with buccal segment arch was positioned in Instron machine (fig 4) and kinetics frictional resistance of arch wires were recorded (fig 5). All the wires in experimental group were tested and results tabulated.

Figure 3: Typhodont and wire assembly immersed in artificial saliva

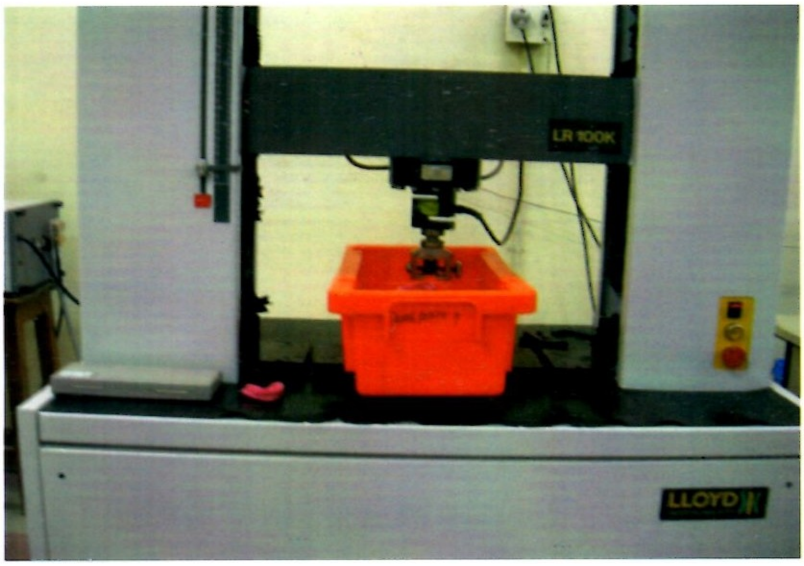

Figure 4: Instron testing apparatus illustrated with water bath maintained at 37°C

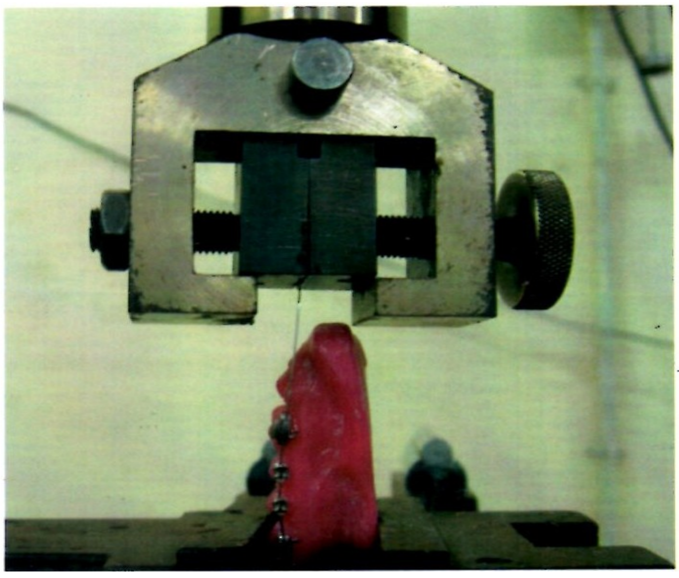

Figure 5: Frictional resistance testing

Statistical Analysis

The results obtained were statistically analysed with paired "t" test, (table 1) ANOVA (table 2) and students Neuman keul test. Paired 't' test was performed to compare the results from sub sample A and sub sample B (control group) and experimental group within a group. ANOVA and students Neuman keul test, which was a multi range test performed to intercompare the results obtained among the four groups I-IV.

Table 1: Paired 't' test for frictional resistance of NiTi wires in control and experimental group

Groups	Control Group		Experimental Group		P value
	Mean	SD	Mean	SD	
I - M Nitinol	152.75	4.89	189.88	13.28	< 0.001**
II - Teflon coated M Nitinol	74.75	3.37	78.25	3.49	0.002**
111- Heat activated NiTi	117.25	2.71	148.38	10.54	< 0.001**
IV - Ion implanted 3 superelastic NiTi		2.83	90.13	5.77	0.476

** denotes statistically significant at 1% level.

Table 2: ANOVA followed by Tukey HSD test for frictional resistance between groups I, II, **111, IV.**

Groups	Control Group		Experimental Group	
	Mean	SD	Mean	SD
I - M Nitinol	152.75	4.89	189.88	13.28
11 - Teflon Coated M Nitional	74.75	3.37	78.25	3.49
111 Heat Activated Niti	117.25	2.71	148.38	10.54
Iv - Ion Implanted Superlastic Niti	91.63	2.83	90.13	5.77

P value < 0.001** < 0.001**

Discussion

The aim of this study was to compare and evaluate the frictional resistance of 4 different types of NiTi wires and also to evaluate the frictional resistance of these 4 types of NiTi wires when subjected to simulated oral environment for duration of 4 weeks. The cumulative effects of surface corrosion and prolonged stress in altering the behavior of wires were studied. Of the selected four types of wires, two were conventional surface unmodified wires while the other two were surface treated wires (Teflon coated Nitinol and Ion implanted superelastic NiTi). The conventional nickel titanium wires were introduced to orthodontics in 1970's was martensite stabilized structure formed by cold working which had better spring back and low stiffness, but lacked super elasticity and shape memory. Later super elastic and thermoelastic NiTi wires were introduced with active austenitic grain structure. However, there were several drawbacks with the nickel titanium wires which included its increased surface roughness, increased susceptibility to corrosion and breakdown of passivity in oral environment and increased frictional resistance. The increased surface roughness had been confirmed by scanning electron microscopy and laser spectroscopic studies by garner et al, kusy et al[7]. Many studies authors have proved the increased susceptibility of NiTi wires to corrosion. schwaninger et al [8] Brantley et al, huang. H [9] in their studies observed pitting corrosion and breakdown of passivity on the surface of NiTi wires in artificial salivary medium therefore Increased surface corrosion had been attributed to decrease in performance of NiTi wires and also decreased fatigue resistance is observed. NiTi wires showed increased frictional resistance compared to stainless steel10. The major contributing factor for increased frictional resistance of NiTi wires are surface roughness, (gammer et al).

Mendes et al [11] observed a phenomenon called "stick slip process" in low velocity sliding mechanics. This process can cause energy loss (friction), surface damage (wear), and component failure (breakage). The controlling factors of this type of stick slip were the topography of the interfacing surfaces. The arch wire surface in oral environment were subjected to abrasive wear, oxidation, surface corrosion and contamination in the oral environment. The titanium based arch wires were more prone to adhesive friction wear, galling and fretting [12] which lead to increased friction of these wires. Therefore, those who underwent studies regarding this issue proposed surface modification of these wires as an effective alternative to reduce friction, improve corrosion resistance and prevent its biodegradation in oral environment. Various coatings like Teflon, diamond like carbon coating and plasma deposition had been applied to NiTi arch wires with carrying degrees of success. Hera Kim et al claimed epoxy coating decreased the corrosion potential of the NiTi wire. Further Teflon coating also reduced the frictional resistance of NiTi wires at a significant level. Ion implantation was also attempted on the surface of the arch wires13. Implantation created a surface that was extremely hard and a considerable amount of comprehensive forces was built on the material surface at the atomic level. It was accepted that increased compressive forces and increased surface hardness improved the fatigue resistance and ductility and reduced the coefficient of friction of the wires. Ion implantation also reduced the corrosion resistance of the arch wire. Therefore, surface modified wires perform better than their untreated counter parts. But studies on the performance of these NiTi wires in oral environment are limited. Hence this in vitro study was mainly carried out to assess the performance of two types of surface treated wires, Teflon coated NiTi wires and ion implanted NiTi wires against untreated counterparts. The wires were initially tested in as received condition, which were used as controls in the study, while the experimental group were tested after subjecting them to a simulated oral environment for a duration of 4 weeks

Frictional Resistance

Friction was quoted as a "function of relative roughness of two surfaces in contact and it arises when there is relative motion between the two surfaces". Frictional force was an integral component of sliding mechanics". It runs tangential to the contacting surfaces and opposes the intended tooth movement. Frictional forces were often detrimental and lead to considerable force losses in sliding mechanics. Increased friction also a major cause for loss of anchorage. The variables found to affect the levels of friction between the bracket and arch wire may be mechanical or biological. Of that arch wire alloy played a significant role. Surface treating can produce appreciable good effect. In this study two different wires were analysed and the frictional resistance of these modified wires were compared to their untreated counter parts and the role of corrosive environment in altering the frictional behavior of these arch wires also analyzed. The kinetic frictional resistance of the arch wire was recorded while 5mm of wire was drawn through the brackets at a speed of 1mm/min. the results obtained and the statistical data were listed in table 2 and 3. From the results it was observed that the maximum frictional resistance was exhibited by M.Nitinol wires in group 1 whose mean kinetic frictional resistance 155 newtons than compared to its surface modified Teflon coated M Nitinol whose frictional force resistance was around 75 newtons.

Among the super elastic alloy's ion implanted NiTi wires in group IV showed lesser friction than Neosentalloy in group III. When all these four wires were compared least frictional values was exhibited by Teflon coated M Nitinol followed by ion implanted Bioforce Sentalloy which was followed by Neosentalloy.

M Nitinol wires showed the highest friction among all the four. When subjected to simulated oral environment the kinetic frictional force significantly increased for M Nitinol wires, which showed the highest frictional forces followed by Neosentalloy. But both Teflon coated Nitinol and ion implanted NiTi in the experimental group showed no significant changes in their frictional forces compared to their control group (fig 6). The results obtained in this study was similar to the study conducted by Mendes et al 2003 41 and k. clocheret et al 2003 [14]. Hussmann et al 2004 33 also proved that any type of surface coatings can reduce the frictional forces than compared with an uncoated reference wire by the same manufacturer.

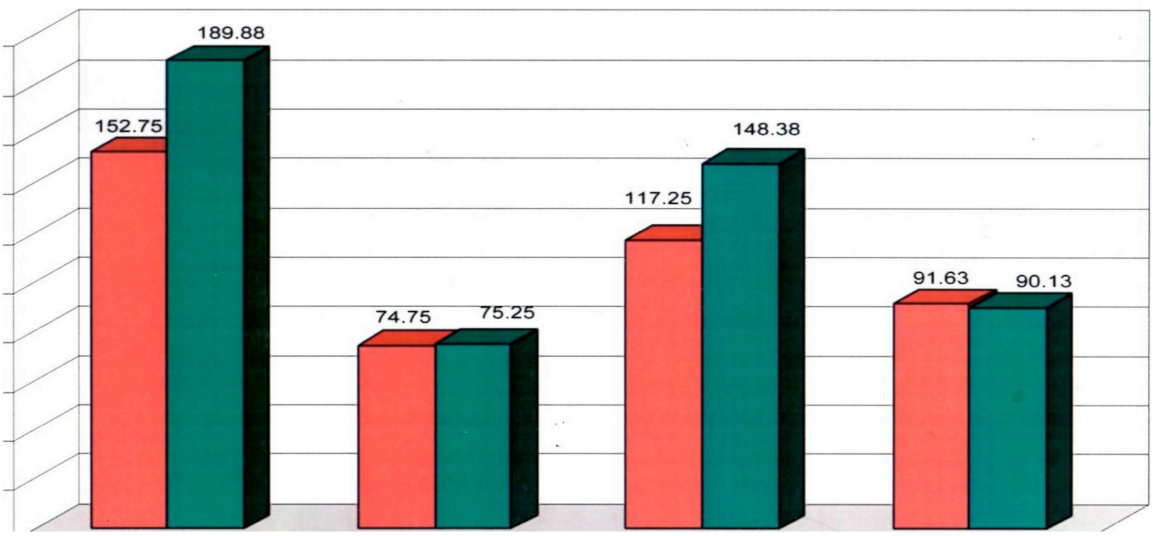

Figure 6: One way ANOVA test for frictional resistance of NiTi wires in control and experimental group

Ion implanted wires also exhibited lesser friction. This was similar to Ryan et al (1997) study. It was found that ion implanted wires produced faster tooth movement than compared to the conventional arch wires and generated lesser friction. Increased friction of M Nitinol and Neosentalloy showed increased pitting and surface corrosion[15] which increase the stick slip phenomenon in sliding mechanics which attributes to increased frictional resistance. This study clearly demonstrated that surface modification of the wires by ion implantation and Teflon coating can significantly reduce the frictional resistance of the NiTi wires.

Conclusion

NiTi wires with their superelastic property had revolutionized in the field of orthodontics. They incomparably deliver light continuous force in fixed appliance therapy. Surface modified nickel titanium wires; Teflon coated M Nitinol and Ion implanted NiTi perform efficiently in reducing the frictional resistance of the wires than compared to their untreated counterparts the M Nitinol and Neosentalloy. Among the four groups heat activated Neosentalloy showed minimal stress relaxation in simulated oral environment. However, as this study was conducted in static environment; the cumulative, chemical and thermal effects of oral environment were not taken into account. Therefore, a more extensive study involving dynamic changes and complexities of oral environment may be more beneficial in determining whether these wires still retain their desirable properties in the long run.

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