Quest Journals
Journal of Medical and Dental Science Research
Volume 9~ Issue 3 (2022) pp: 21-25
ISSN(Online) : 2394-076X ISSN (Print):2394-0751
www.questjournals.org

Research Paper

"Comparative Evaluation of Mechanical Properties of Silver Coated and Conventional Nickel – Titanium Orthodontic Archwire: An In vitro study."

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ABSTRACT
BACKGROUND: *Surface modification of archwire with silver has shown that they have reduced the friction along with antimicrobial and antiadherent property of silver. This silver coating may have effect on mechanical properties of orthodontic wires.*
AIM: *To evaluate and compare mechanical properties of silver coated and uncoated Nickel titanium orthodontic archwires.*
MATERIAL AND METHODS: *40 Nickel titanium archwires wires were divided into two groups of 20 each: Group 1- 0.016 inch Ni- Ti wires (silver coated), Group 2- 0.016 inch Ni- Ti archwires (Control). Surface modification of wires was carried out by the thermal vacuum evaporation method with silver (10nm size) using vacuum coating unit model. The load deflection, tensile strength, modulus of elasticity and yield strength of all 40 wires were checked using Universal Testing Machine (UTM).*
RESULTS: *There was no significant difference found in load deflection, tensile strength, modulus of elasticity and yield strength between silver coated and uncoated 0.016 inch nickel titanium archwires group.*
CONCLUSION: *Overall silver coating did not affect the mechanical properties of 0.016 inch Nickel titanium archwires. Findings suggest use of silver coated SS wires in routine orthodontic practice and implementation after further in-vivo human clinical trials.*
KEY WORDS: *Silver coated wires, Load deflection, tensile strength, yield strength, modulus of elasticity, Universal Testing Machine*

***R**eceived 01 Mar, 2022; **R**evised 11 Mar, 2022; **A**ccepted 13 Mar, 2022 © The author(s) 2022.*
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I. Introduction

There were many advances within the discipline of mechanotherapy to enhance the patient care which in turn has brought about the creation of recent orthodontic materials inclusive of archwires, brackets, elastomeric materials etc. One have to have thorough understanding of composition, biomechanical thing and clinical application of archwires. So that you can determine which kind of archwire may be used clinically and might have greater outcome[1].

In aligning and leveling phase especially resilient wires are required so that they get greater deflected and gets easily engaged into maligned teeth. Highly deflected wire have long working range so less frequent change of archwire is required. Excessive wire deflection may generate greater forces that may lead to concomitant damage to the teeth and supporting structures[2].

Most usually Nickel Titanium (Ni-Ti) archwires are used for aligning the teeth as these archwires have unique properties of super elasticity and shape memory. One crucial intention in the course of the alignment phase of orthodontic treatment is to apply appropriate and predictable force levels[3]. The quantity of the generated force is determined by the mechanical properties of the inserted archwires. Therefore, a good enough understanding of mechanical properties of NiTi archwires is necessary[2].

Knowledge of basic wire properties and biomechanical aspects can help the orthodontist select the wire which is suitable for every case. Thus quality of treatment can be improved. Various studies (2, 4 and 5) have evaluated mechanical properties of orthodontic wires. Load deflection test has been performed in laboratory to assess flexural, ultimate tensile strength, yield strength and modulus of elasticity of archwires[6]. Since ancient period silver is understood for its antimicrobial activity. One of the study conducted showed that Surface modification of Ni-Ti wires with silver can be used to prevent the accumulation of dental plaque and the development of dental caries during orthodontic treatment[7]. However to the best of our knowledge till date, mechanical properties of silver coated archwires have not been studied. The aim of this study is to evaluate and compare the tensile strength, yield strength, modulus of elasticity and load deflection characteristics of conventional and silver coated Ni-Ti archwires.

II. Methodology

In these in vitro study, total forty 0.016 Nickel Titanium archwires (G & H orthodontic archwires) was purchased that was commercially available in the market. These archwires was divided into two groups each. Group I was Conventional Ni-Ti archwire and in Group II - Silver coated Ni-Ti archwire was included.

Procedure to carry out Silver coating on Ni-Ti archwire:

Thermal evaporation method was used to carry out coating procedures of 0.016" Nitinol arch wire. Silver was heated through its vaporization temperature in a closed chamber with HINDHIVAC vacuum coating unit model no-15 F6 (Hind High Vacuum Co. Bangalore) (figure 1). Pure silver (99.9%) was used to obtain thin coating on orthodontic archwire. In this study, 10-nm thick silver film was used for coating orthodontic archwire to avoid any significant change in its dimension. Then vapours was allowed to pass through a valve which was controlled according to the desired thickness. The thickness of coating was kept constant to 10nm to avoid mechanical alteration in the wire.

Load deflection test:

The load–deflection rate of each wire from each group was evaluated using three-point bending test. The block was prepared by an acrylic with the dimensions 5" × 4" (length × width) as per shown in (figure 2a).The block was reduced in the center to create a well. Two brackets of MBT 0.022 slot for central incisor was attached on either side of the well on acrylic block. The interbracket distance was 10 mm according to the upper central incisor tooth width. The posterior segment of preformed NiTi archwires was cut into 30 mm length with the help of digital calliper (figure 2b). Each wire was fixed on to the bracket with the help of ligature wire. The block was mounted on the fixed lower end of the machine. The striker was attached to the upper movable head of the universal testing machine so that its tip was placed on the midpoint of the test-wire span. The mid portion of the wire was deflected. The loading values for each sample was recorded at 1, 2, and 3 mm. Forces necessary for the deflection test was recorded directly into the computer and results were analysed.

Figure 1

HINDHIVAC vacuum coating unit model no-15 F6 (Hind High Vacuum Co. Bangalore) used for silver coating of Nitinol archwires

Tensile strength, yield strength and modulus of elasticity:

Figure 2

a) Acrylic model with MBT (slot 0.22) brackets was attached on either side of well in the centre. Silver coated Ni-Ti archwire (0.016) was inserted into brackets with the help of ligature wires.

b) Vernier calliper used to cut wire segment of 30mm length

Tensile strength, yield strength and modulus of elasticity was measured using the Universal testing machine (figure 3). The machine was operated in tensile mode with the load of 1000 N and crosshead speed of 1mm/month. The span of the wire between the crossheads was standardized as 40 mm and the load taken to break the wire was noted.

Statistical analysis

The data was analysed with IBM SPSS 20 for windows statistical software. Statistical analysis was analysed using a sample t test. For all statistical analysis, probability levels of $P < 0.05$ was considered as statistically significant. The data collected was analysed thoroughly by applying Descriptive Statistics (Mean, SD, CI) and Unpaired t test.

III. Results

In the present study, the load deflection, tensile strength, yield strength and modulus of elasticity was evaluated and compared between the uncoated and silver coated stainless steel archwire. Total 40 samples were selected for the study out of which 20 samples were of silver coated archwire and 20 samples were of uncoated 0.016" Ni- Ti archwires for quantitative measurement.

IV. Quantitative observation

Table 1

Table 1 shows that load deflection values at 1, 2 and 3mm of silver coated NiTi archwire was less as compared to uncoated archwire. But these difference were statistically insignificant.

Table I shows that load deflection values at 1, 2 and 3mm of silver coated and uncoated NiTi archwire

Load Deflection	Force	Group 1 (Ag Coated 0.016 NiTi wires)		Group 2 (Uncoated 0.016 NiTi wires)		Mean Difference	t-value	P Values
		Mean	Standard deviation	Mean	Standard deviation			
Loading values	1mm	1.58698	0.001	1.63378	0.001	-0.046	-317.240	0.147
	2mm	2.6853	0.156	2.8343	0.005	-0.149	-6.004	0.428
	3mm	1.5568	0.005	3.1245	0.005	-1.5677	-1087.528	0.454

Table 2

Table 2 shows that the values of tensile strength, Modulus of elasticity and yield strength of silver coated archwire was more as compared to uncoated archwire but the values were insignificant.

Table II shows that Tensile strength, Modulus of elasticity, Yield strength values at 1, 2 and 3mm of silver coated and uncoated NiTi archwire

variable	Group 1 (Ag Coated 0.016 NiTi wires)		Group 2 (Uncoated 0.016 NiTi wires)		Mean Difference	t-value	P Values
	Mean	Standard deviation	Mean	Standard deviation			
Tensile Strength	12651.50	0.599	12517.58	1.533	133.925	26.856	0.234
MOE	32123.53	0.784	32113.35	0.622	10.175	64.291	0.432
Yield strength	649.8608	0.895	582.4195	0.925	67.441	331.286	0.025

V. Discussion

Nickel-Titanium (NiTi) archwires are most commonly used for alignment and levelling of the arches because of its properties such as super elasticity, shape memory and low load deflection rate. One of the advantage of nickel-titanium (NiTi) archwires is that they apply light and constant forces for longer period of time. They also provide large range of action and requires less frequent activation[8]. One of the shortcoming is that, the Ni-Ti archwires have high surface roughness and high friction coefficient, therefore requires high amount of orthodontic force to overcome resistance to sliding so as to obtain desirable tooth movement. The use of excessive forces can cause loss of anchorage, unwanted tooth movement and root resorption. Other disadvantage is that due to high surface roughness bacterial adhesion also occurs more[9].

There are many methods mentioned in the literature which are carried out to reduce friction and improve the mechanical and biological properties of orthodontic wires such as modification in the bracket design, use of different types of alloys, surface treatment or coating of wires using various techniques and materials[10, 11].

The emergence of antibiotic resistant strain of bacteria has brought attention towards the use of antimicrobial agents such as silver nanoparticle for coating the surface of wires and brackets. These will reduce the bacterial growth and adhesion which in turn prevents the occurrence of white spot lesion. Surface coating of archwire with silver can be done by various methods such as physical vapour deposition method, electro deposition, metallurgical, photo catalytic method etc. In the present study, the thermal vacuum evaporation method was used for coating the Ni-Ti archwire with nanosilver which allows coating of 10-nm which will prevent significant alteration in its dimension[12].

The load deflection test was carried out to evaluate the load deflection property of archwire which is very important to determine the biologic nature of tooth movement. In these study, load deflection test was carried out by means of three point bending test. The advantage of three - point bending test is that it simulates application of wire pressure on the teeth in the oral cavity. The loading forces are the forces which are required to engage the archwire into the bracket[13]. Wire loading deflections of 1mm, 2mm, and 3mm were selected for present study which was similar to the study done by Kapoor et al[14]. In previous studies average range of 2mm to 4mm of loading values were used. Hence in our study, the deflection of loading values was within the recommended norm of the oral cavity that is within 4 mm of deflection.

In present study, loading values of silver coated archwire is less as compared to the uncoated NiTi archwires but it is statistically insignificant. This results were contradictory to the previous done study by Silva et al, where they evaluated and compared the mechanical properties and force levels of as-received and retrieved coated and regular NiTi archwires. Both as received and retrieved coated archwires produced significantly lower unloading force values than regular NiTi archwires[15]. Most of the studies of load defection of uncoated Ni-Ti and coated esthetic NiTi wires were evaluated which showed a statistically significant difference in loading and unloading hysteresis. In the previous study done by Hammad et al found that, the presence of ZnO nanoparticles on the wires has decreased the mean frictional forces in the coated wires by 34% as compared to non-coated wires (1.169 and 1.568 N, respectively). The coated wires showed a lower median frictional load (0.872 N) than uncoated wires (1.517 N), although no statistical significant difference could be found[15]. In the study done by Tikku et al found that esthetic coated Ni-Ti wires gave significantly lower mean load values, followed by heat activated and pseudoelastic NiTi wires[12]. In the present study, silver coated 0.016 NiTi archwire had mean loading deflection force at 1mm and 2mm was very close to the mean force of uncoated 0.016 NiTi archwire with very minimal variation. Silva et al evaluated and compared the tensile strength, modulus of elasticity and yield strength in as received coated and uncoated archwire and found that the as received coated archwires showed lower values for all the three properties, and the differences were highly significant for the ultimate tensile strength and modulus of elasticity. The yield strength also showed lower values, but these were not statistically significant. In the present study, the results were similar to the above research, the value for ultimate tensile strength, modulus of elasticity and yield strength of silver coated archwires were less than that of conventional Ni-Ti archwires but they were statistically insignificant. This could be due to the fact that in previous studies esthetic coating such as Teflon and epoxy resin were used which increases thickness of archwire by 0.0008–0.001 inch and 0.002 inch that may result in a smaller Ni–Ti inner core[12]. In present study as coating of wire was done of size 10 nm it provided a thin coating layer which doesn't altered the dimension of original Ni- Ti archwire and hence no changes in their mechanical property of wire is seen.

As the mechanical property of silver coated archwire depends on the coating done on the surface of the wire which can be wear under oral environment condition. Hence the surface characteristic, mechanical property and its antiadherent and antimicrobial property should be evaluated. Therefore further studies in the oral environment are required.

VI. Conclusion

The conventional 0.016" Nickel Titanium archwire after surface coating with silver of 10 nm shows insignificant difference in load deflection property, Tensile strength, Modulus of elasticity and yield strength. These concludes that silver coating of 10 nm do not alter the dimension of the archwire or the mechanical properties of archwire and hence silver coating can be used and benefit of its antibacterial property and frictional reduction may be used for enhancing the tooth movement without any side effect.

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Availability of data and materials

The author declare that all data generated or analyzed during this study are included in this published article and its supplementary information files.

Acknowledgments

The authors acknowledges Dr. Chetan Panchal of the Department of Applied Physics, M.S. University, and Vadodara for support in silver-coating procedure.

Funding:

The author did not receive any grant from commercial, not-for-profit, or financial sectors for these review.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Author’s contribution

The first author and second author performed the study. Both the authors read and approved the final manuscript.

Competing interests

There are no competing interests.