EVALUATION OF PHYSICAL PROPERTIES OF SILVER COATED AND UNCOATED NiTi ARCH WIRES – AN IN VITRO STUDY

Dissertation submitted to

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the degree of

MASTER OF DENTAL SURGERY

BRANCH - V

ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS

2017 - 2020

CERTIFICATE BY THE GUIDE

This is to certify that the dissertation titled **"EVALUATION OF PHYSICAL PROPERTIES OF SILVER COATED AND UNCOATED NiTi ARCH WIRES– AN INVITRO STUDY**" is a bonafide work done by **Dr. S. INDUMATHI,** postgraduate student, during the course of the study for the degree of **MASTER OF DENTAL SURGERY** in the specialty of **ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS,** Vivekanandha Dental College for Women, Tiruchengode, during the period of 2017-2020.

Date:

Place:

Signature of the H.O.D and Guide.

Prof. Dr.S.Nagalakshmi, MDS.

Prof and Head of the Department,

Department of Orthodontics and

Dentofacial Orthopaedics,

Vivekananda Dental College for Women.

ENDORSEMENT BY THE HEAD OF DEPARTMENT AND HEAD OF THE INSTITUTION

This is to certify that **Dr. S. INDUMATHI**, post graduate student (2017-2020) in the **DEPARTMENT OF ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS**, Vivekanandha Dental College for Women, has done this dissertation titled **"Evaluation of physical properties of silver coated and uncoated Niti arch wires – An invitro study**" under our guidance and supervision in partial fulfilment of the regulations laid down by the Dr. M.G.R. Medical University, Chennai- 600032 for MDS **BRANCH- V**.

Seal & Signature of H.O.D
Prof. Dr. S. Nagalakshmi, MDS
Department Of Orthodontics and
Dentofacial Orthopedics
Vivekanandha Dental College for Women

Seal & Signature of Principal
Prof. Dr. N. Balan, MDS
Principal,
Vivekanandha Dental College for
Women

DECLARATION

TITLE OF DISSERTATION	Evaluation of physical properties of silver coated and uncoated Niti arch wires – An invitro study.
PLACE OF STUDY	Elayampalayam, Tiruchengode, Namakkal district
DURATION OF COURSE	3yrs (2017-2020)
NAME OF THE GUIDE	Dr. S. Nagalakshmi, MDS
HEAD OF THE DEPARTMENT	Dr. S. Nagalakshmi , MDS

I hereby declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission of the Principal, Vivekanandha Dental College for Women, Tiruchengode. In addition, I declare that no part of this work will be published either in print or electronic format without the guide who has been actively involved in the dissertation. The author has the right to reserve publishing of work solely with prior permission of the Principal, Vivekanandha Dental College for Women, Tiruchengode.

Head of the Department   Guide   Signature of the Candidate

<u>PLAGARISM CERTIFICATE</u>

This is to certify that this dissertation work titled "**EVALUATION OF PHYSICAL PROPERTIES OF SILVER COATED AND UNCOATED NiTi ARCH WIRES – AN INVITRO STUDY"** of the candidate **Dr. S. INDUMATHI ,** with registration number **241719501**for the award of degree **MASTER OF DENTAL SURGERY** in the branch of **ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS**. I personally verified the urkund.com website for the purpose of plagiarism check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows 2% of plagiarism in the dissertation.

Guide and Supervisor sign with seal.

URKUND

Urkund Analysis Result

Analysed Document:	indumathi.docx (D62971110)
Submitted:	1/25/2020 10:04:00 AM
Submitted By:	${Xml.Encode(Model.Document.Submitter.Email)}
Significance:	2 %

Sources included in the report:

sasirekha.docx (D62813871)
https://www.researchgate.net/publication/51523513_Aesthetic_nickel_titanium_wires_-_How_much_do_they_deliver
https://progressinorthodontics.springeropen.com/articles/10.1186/s40510-015-0110-0

Instances where selected sources appear:

6

ACKNOWLEDGEMENT

Prima facie, I am grateful to God for giving me all that were necessary to complete this task.

I wish to express my sincere thanks *to* ***Dean,Capt.Dr.S.Gokulnathan,*** Principal, ***Prof.Dr.N.Balan,*** Vivekanandha Dental College for Women, for the immense support for my Post Graduate Curriculum and for providing all the necessary facilities for my research

I would like to express my heartfelt gratitude to my respected Head of the Department and my postgraduate Guide ***Prof.Dr.S.Nagalakshmi,***., Professor, Department of Orthodontics and Dentofacial Orthopaedics, Vivekanandha Dental College for Women for the continuous support of my research, for her patience, motivation, and immense knowledge. I could not have imagined having a better advisor.

I am extremely thankful to my co guide ***Dr.D.Dhayanthi,*** for his encouragement and help to build my research in every step.

I am heart fully thankful to my associate ***Professors Dr.B.K.Rajkumar, Dr.K.R.Ramesh Kumar****,* ***Dr.Syed Khalid Altaf*** for sharing their expertise, and rendering valuable guidance and in the PG curriculum.

I am enormously grateful to ***Readers Dr.S.Vinoth and, & Senior Lecturers Dr.D.Pawan Kumar Bhandari, Dr.K.Preethi,*** for their encouragement and help to build my research in every step.

I acknowledge my batch mate ***Dr.A.Sasirekha***, my seniors, ***Dr.Ann Nimmy Rajeev, Dr.R.Maivizhi*** and my juniors ***Dr.S.Anupuma***, ***Dr.C.Sharmila , Dr.C.Indirasena*** for their passionate participation in my study.

Last but not the least, I would like to thank my family for giving me the physical, mental and spiritual support throughout this task and for giving an unceasing encouragement, support and attention in my life

With Humbleness & Gratitude,

Dr. S. Indumathi

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ANNEXURES

LIST OF ABBREVATIONS

NiTi	Nickel titanium
3D	3Dimensional
SEM	Scanning Electron Microscope
SS	Stainless Steel
TMA	Titanium Molybdneum
Ag	Silver

INTRODUCTION

INTRODUCTION

Maintenance of oral hygiene is mandatory for patient who uptake fixed orthodontic treatment Fixed appliances have various attachments and retentive plaque forms the nidus for colonization of microorganism with the risk of white spot lesion.

Julina Mattos Correa et al[1] stated that silver has been used in medicine for centuries because of its anti-bacterial properties. Silver nanoparticle incorporated in to several biomaterials, as their small size provide greatest antimicrobial effect at low filler level. In dentistry, these nano particles reduce biofilm formation over surfaces. L.F Episona –Cristobal et al[2] studied the antibacterial effect of silver nanoparticle on Sterptococcus mutans. It was found that silver nano particles has antibacterial activity against Sterptococcus mutans. Mohadese Azarsinea et al[3] conducted a study to evaluate the antimicrobial properties of composite resin containing nano silver against streptococcus mutants and lactobacillus, it was found that addition of nano silver to composite resin had a significant effect on reduction of the number of streptococcus mutans and lactobacillus colonies.

Masek et al[4] stated that silver coated NiTi wires had antibacterial activity by preventing adhesion of lactophillus acidophilus which in turn prevent the plaque and caries during orthodontic treatment..

When arch wires are coated with any material, there are chances for alterations in the desired physical properties. There are different opinions in the literature concerning aesthetic coated archwires. Kapoor et al[5]in his study compared the force level of aesthetic and conventional NiTi wires from four different manufacturer and he concluded that aesthetic wire exhibit significant decrease in force value when compared to conventional NiTi wires. This study were in contrast with the study done by Rego et al[6] he stated that esthetic coatings on the NiTi orthodontic wires did not influence the load deflection ratio at lower activations. On the contrary, the Eurodonto coated wires exhibited greater force levels during 3mm deflection.

Studies have proven the antimicrobial activity of silver coated NiTi wire, but no study has been done to evaluate whether the silver coating affects the physical properties of the wires. Hence the study was designed to evaluate the physical properties of silver coated and uncoated NiTi wires.

AIM AND OBJECTIVES

AIM AND OBJECTIVES

AIM OF THE STUDY:

To compare the load deflection rate and surface roughness of silver coated and uncoated NiTi arch wire.

OBJECTIVE:

1.To evaluate the load deflection rate of silver coated and uncoated round and rectangular NiTi wire using universal testing machine

2. To evaluate the surface roughness silver coated and uncoated round and rectangular NiTi wire using three dimensional optical profilometer

3.To compare the load deflection rate and surface roughness of silver coated round and rectangular wire with uncoated round and rectangular NiTi wire of same dimension.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Watters et al (1975)[7] in his article mentioned about the physical properties of arch wires and also the tests used for evaluating them .The physical properties such as flexibility, resilience, ease of deformation and susceptibility to fracture and the tests used to evaluate these properties are explained and two new tests have also been mentioned that is the elastic recovery test and Mandrel test. The elastic recovery test is used for wire supplied in straight lengths that are tied to the arch without forming. The Mandrel test measures the elastic recovery when different strains are applied to the wire. On comparison of round and multiple strand wires, it was found that multiple stand wires are more flexible as it is based on the diameter of the each strand.

George F. Andreasen and Ray E.Morrow (1978)[8] conducted a laboratory and clinical analysis of nitinol wire. They compared the physical properties of nitinol with stainless steel wire by bend testing, torsion testing, stored energy comparisons, spring and clinical application such as cross bite correction, up righting impacted canines, opening the bite. They concluded that Nitinol has an exceptional working range and larger Nitinol wires readily accomplished and maintained desired rotations and levelling without increasing the patient's discomfort. The limitations were that nitinol cannot be bent which causes problems in placement of in out bends, loops and torques.

Burstone et al (1985)[9] conducted a study on super elastic properties of Chinese NiTi wire for the use in orthodontics by means of bending test. They assessed stiffness, spring back and maximum bending movement. Chinese NiTi has unusual deactivation curve which produce constant force over a longer period of activation. Flexural stiffness were evaluated by amount of activation. Stiffness is 7% for larger activation of NiTi wires comparable to SS wire and smaller activation 28% of stainless steel wire for same activation the force produced were 36% which is comparable to Nitinol wire. Clinically NiTi has excellent spring back capacity. It can deflect 1.6times as that of Nitinol wire and 4.4times to SS wire without permanent deformation.

Fujo Miuro et al (1986)[10] studied super-elastic property of the Japanese NiTi alloy wire for use in orthodontics. They evaluated the wire stiffness, spring back, shape memory and super elasticity by tensile tests, bending test and measurements of the influence of special heat treatment on the wire. They concluded that Japanese NiTi possesses excellent spring back property, shape memory and super-elasticity.

Schaus et al (1986)[11]conducted an invitro study to evaluate the transverse flexural stiffness of five preformed arch wire in three activation direction. at five separate sites on simulated dental arches the appliance were fixed .it was found that elastic moduli, number of stands and inter bracket distance were observed to be less substantial than the elastic bending theory and Other factor such as bracket wire friction, curvature at the activation site, preactivation fit of preformed arch wire affect, transverse, localized flexural stiffness.

Kapila et al (1989)[12] reviewed the archwire mechanical properties and its clinical application of stainless steel, cobalt chromium, NiTi, TMA and multistranded wire. They evaluated the mechanical properties of these wire by tensile testing and torsional testing. Comparing the mechanical properties of these five wires, stainless steel had a good formability, biocompatibility, environmentally bio suitable. Cobalt chromium properties were similar to stainless steel. TMA has spring back capacity, stiffness and good formability. Multistranded wired had high spring back low stiffness compared to stainless steel. The optimal use of these wires depends on wire type and size.

Ditmar Segner and Dagmar Ibe (1995)[13] studied the properties of super elastic wires and their relevance to orthodontic treatment. They continued three parameter as necessary to describe a super elastic arch wire 1) the distinctiveness of the pseudo elastic plateau.2) the deflection at the beginning of the plateau and 3) the force level of the plateau. Among the 16 different arch wire that they studied, many did not show pseudo elastic properties and desired characteristics began only when the wires were displaced by 1mm or more.

Robert P.kussy (1997)[14]reviewed the arch wire properties and characteristics that were then available in the order of the development .In search of an ideal arch wire, he emphasized on specific properties and characteristic, such as strength, stiffness, range, formability and weldability .He concluded that it is of utmost importance to understand the elastic property ratio of the arch wire to determine at which stage of treatment it can best used.

Justin et al (1998)[15] clinically assessed the 0.016x22 inch medium force and graded force active martensitic Niti of same dimension and 0.0155 inch multistranded stainless steel wires. Full records of 98 archwires from 51 patients were analyzed and the cast were measured using reflex microscope. It was found that that in spite of arch wire type upper labial segment movement found higher compared to lower segment. In randomized clinical trial, heat activated NiTi shows less performance when compared with multistranded stainless steel wires. The inadequate response of active Martensitic wire to show superior ex-vivo properties was due to individual variation in metabolic response, tooth and their surrounding structures variation in ligation techniques.

Meling et al (1998)[16] conducted an in vitro study to investigate the temperature changes on the torsional stiffness of nickel titanium alloys. Eight rectangular NiTi of dimension 17x25 and 18x25 inch from four different manufacturers were used in the study. Torsional stiffness of nickel titanium wire were tested by single short term application of cold 10^0c or heat 8^0c. It was found that majority of the wire shows torque below sub baseline and the thermodynamic wire shows incremental reduction in torsional stiffness on repeated application of cold water. The torsional stiffness remains low and noted to be increased after 60minutes of post exposure restution.

JulinaMattos Correa et al(1998)[1] stated that silver has been used in medicine for centuries because of its anti-bacterial properties. Silver nano particle incorporated in to several biomaterials, as their small size provide greatest antimicrobial effect at low filler level. In dentistry, these nano particles reduce biofilm formation over surfaces.

Santro et al (2001)[17] **reviewed** the arch wire properties and their characteristics and organize Systemic reference to help the clinicians to give idea about use of orthodontic NiTi wires. It gives information about temperature transitional ranges of alloy. Thermo Mechanical behavior depends on relation between the temperatures transitional range and the oral cavity temperature range. It describes the mechanical properties of the alloy, magnitude of force delivered and their relation to the temperature transitional range.

Peter.D.Wilkson et al (2002)[18]investigated the load deflection characteristic of 7 different 0.016 initial alignment arch wires (twistflex, NiTi and 5 brands of heat activated super elastic nickel titanium [HANT])with modified bending test simulating a number of clinically uncountered conditions. They concluded that NiTi in wire provided highest unloading values for every test deflection and model design and all super elastic nickel titanium showed temperature sensitivity resulting in significant effects on unloading values.

Bartzela et al (2007)[19] conducted an in vitro study to evaluate the mechanical properties of thermodynamic wires. Load deflection of five brands of 0.16, 0.016x0.022, 0.017xo.025, and 0.018x0.025 inch NiTi wires were examined using three point bending test. The sample size was 48 NiTi wires. They have been divided in groups and classified based on their clinical plateau length. Loading up to 3mm and unloading to 0mm were measured. It was found that true superplastic wires with clinical plateau length ≥0.5mm. Borderline super elastic or borderline non superplastic wire with clinical plateau length > 0.05mm. Non super elastic wire with clinical plateau length ≤ 0.5mm

Elayan et al (2008)[20]conducted an in vitro study to examine the physical and mechanical properties of retrieved and as received 0.016inch coated arch wires. The load deflection property was assessed by three point bending test with conventional and self-ligating bracket system. Ten unused samples were tested for load deflection properties and their surface roughness measured with contact styloprofilometer. To assess surface topography optical and scanning electron microscopy was used. Ten epoxy resin coated arch wires used in vivo for 4to 6 weeks and were subjected to same test. The remaining coating calculated with digital photography. It was concluded that lower unloading force was seen in retrieved coated arch wire compared to as received coated arch wire with conventional ligation with self-ligation same course value. Coated arch wires after in vivo use surface roughness and esthetic value decreased 25% of coating were lost in 33days after in vivo use.

Segal et al (2009)[21] conductedan in vitro study to assess the effect of stress and phase transformation on the corrosion properties of a superelastic NiTi wire. Sent alloy and TMA were used in this study. The wires were analyzed by3 point bending test, electrochemical corrosion test. Loading and unloading forces were recorded at two different temperature. It was found that significant difference on wire deflection observed on both the wires. They concluded that stress increased the corrosion rate in both the wires. Stress changes and corrosion behavior of NiTi and TMA wires differs.

Cristobal et al (2009)[2]studied the antibacterial effect of silver nano particle on Streptococcus mutans. It was found that silver nano particles have antibacterial activity against Stretococcus mutans.

Elayan et al (2010)[22]conducted an invitro study to examine the physical and mechanical properties of coated NiTi wires with conventional NiTi arch wires using conventional and self-ligating bracket system. Two coated and two uncoated NiTi of size 0.016 and 0.018x0.025 has been examined using three point bending test with conventional and self-ligating bracket system. Loading 2mm and unloading 1.5, 1 and .5 for each coated wire has been measured. It was found that coated wire shows lower forces compared to uncoated wires in both loading and unloading.

Lambardo et al (2012)[23] conducted an in vitro study to investigate and compare the characteristic of traditional and heat activated initial arch wires by making graphs to assess three parameter to describe the plateaue phase. 48 samples were examined with seven different companies of size 0.010 to 0.016. NiTi wires. Modified three point bending test was done in 3 samples of each type of arch wires. For each resulting curve plateau was isolated and plateau force, length and slope were obtained for each wire. Statically significant difference was seen in all wires and all three parameter. Heat activated wire produce lighter forces longer plateau compared to traditional NiTi wires. Force level increases on increasing the diameter of the wire.

Miguel et al (2012)[24]conducted an in vitro study to compare the load deflection of 0,019x0.025rectungular wires .Total 40 pre formed arch wire of 5 conventional NiTi and 5heat activated NiTi from four different manufacturer(abzil,moerlli,3m unitek,oemco)were used in the study, The arch wire were place in typhodont and teeth with universal testing machine connected to computer, it was found that lowest mean deflection ratio was found in 3mm unitek followed by ormco, morelliand abzil. Comparing mean deflection ratio in heat activated NiTi ratio Lowest mean deflection ratio was seen in ormco wire followed by 3m unitek, abzil and morelli. Comparing heat activated and conventional NiTi mean deflection, heat activated shows lower compared to conventional NiTi.

Kapoor et al (2012)[5]conducted an in vitro study to evaluate and compare the force level of aesthetic and conventional NiTi wires of dimension 0.016x0.022 from four different manufacturer G&H, TP, Orthodontic, GAC International and Ortho organizer .They were divided in to four groups and using three point bending test loading and unloading value were evaluated loading 1mm,2mm,3mm and un loading 0,5,1,5 and 2,5 mm were recorded, They concluded that aesthetic wire in group 1.III,IV exhibit significant decrease in force value when compared to regular NiTi wires. No significant differences in force value in group II.

MohadeseAzarsinea ,Shaninkasraei et al (2013)[3]conducted a study to evaluate the antimicrobial properties of composite resin containing nano silver against streptococcus mutants and lactobacillus, it was found that addition of nano silver to composite resin had a significant effect on reduction of the number of and Lactobacillus colonies.

Dosho etal (2013)[25] conducted an in vitro study to compare the load deflection characteristics of 3 different wires of size 0.06 inch stainless steel ,nickel titanium and glass reinforced polymer composite (GFRPC).60 wires divided in three groups according to the type of wires .They evaluated the tensile strength by three point bending test using ceramic brackets and the deflection 1,2.3 mm were recorded .They concluded that stainless steel has higher mean force value compared to NiTi and glass reinforced polymer composite wires .Stainless steel exhibit permanent deformation after 3mm deflection. NiTi wires how shape memory effect. Glass reinforced polymer composite wires presented with fracture and loss of strength.

Gatto et al (2013)[26] conducted an in vitro study to examine the mechanical properties of super elastic and thermal NiTi wire of size 0.014 and 0.016 inch .The load deflection were assessed using three point bending test .it was found that thermal NiTi exhibit lower force compared to super elastic wires. The force level of both thermal and super elastic wire increases on increasing the diameter of the wire.

Masek et al (2015)[4] stated that silver coated NiTi wires had antibacterial activity by preventing adhesion of lactophillus acidophilus which in turn prevent the plaque and caries during orthodontic treatment.

Abaas et al (2015)[27] conducted an in vitro study to evaluate and compare the load deflection and force level of six brands of 0.016 and 0.019x0.015 coated NiTi wires. The sample size of each group was ten. Load deflection assessed using modified three point bending test with palatal and gingival deflection .Loading 2mm and unloading 1.5mm were measured .it was found that significant difference in load deflection were found in all wire and epoxy coated wire produce lower forces compared to polymer and Teflon coated wires.

Aghili et al(2016)[28] conducted an in vitro study to evaluate the physical properties of aesthetic coated wires. Three brands of wire were taken in this study of dimension 0.016 inch conventional uncoated NiTi, HUBIT (Tefloncoated), G&H (epoxy coated). Two types of bracket conventional ceramic and metal type and, a specially designed fixture resembling dental arch were used. Each specimen were tested using three point bending test to assess load deflection with acrossed speed of 1mm per minute. Loading up to 3mm deflection and unloading forces up to 0mm were recorded for each sample. It was found higher mean values in loading and unloading force was observed in uncoated NiTi when compared to coated aesthetic wires .G&H wire and metal insert ceramic shows longest clinical plateau length and lowest values.

Rego et al (2016)[6] evaluated the effect of esthetic coating on load deflection ratio of nickel titanium arch wires. The esthetic coatings on the NiTi orthodontic wires did not influence the load deflection ratio at lower activations. On the contrary, the Eurodonto coated wires exhibited greater force levels during at 1, 2,3mm deflection.

Walyet al (2017)[29]conducted a study to investigate the influence of coated and uncoated super elastic nickel titanium arch wires on load deflection, surface roughness and frictional resistance. In this study four different types of wires were used. It was concluded that the esthetic coating decreases unloading force of some wire brands, does not affect others. The effect of ethetic coating on the critical function related properties of orthodontic wires varies from one manufacturer to another.

Ycet al (2017)[30] conducted an in vitro study to compare the mechanical and surface characteristic of initial and working aesthetic arch wires with uncoated conventional arch wires. Rhodium coated nickel titanium 0.018 inch initial wire compared with uncoated 0.018 inch NiTi wires and working wire, Polytetrafluroethylene labial coated stainless steel wire. To assess the load deflection characteristic of arch wire three point bending test was used, surface hardness was measured by Vickers micro hardness test and field emission scanning electron micro hardness test was used to assess the surface roughness .it was found that initial aesthetic arch wire shows similar load deflection when compared to control group and working aesthetic arch wire shows increased load response than control group. Increased surface roughness observed in both aesthetic arch wire when compared to control group.

Argalji et al (2017)[31]conducted an in-vivo study to compare coating dimension and surface characteristic of two different esthetic coating rectangular NiTi wire (Titanol cosmetic and bio cosmetic) as received and after oral exposure .using stereomicroscope their coating thickness were measured .scanning electron microscope and 3 D profilometer were used to evaluate their surface roughness. Inner height and thickness shows statistically significant difference in both the esthetic coating wires .After oral exposure coating loss were observed.

Rotiawal(2018)[32] conducted an in vitro study to evaluate mechanical properties of coated wires. Six group of 0.019 x0.025 rectangular coated and uncoated SS, NiTi, TMA wires were taken in the study. Each group were tested for tensile test, bending test, elongation test, friction test by 3 point bending test, hardness tested by Vickers micro hardness testing machine, and Scanning electron microscope used for evaluating surface roughness .it was found that tensile strength increased in coated wires, load deflection found to be higher ,increased micro hardness and reduced friction were observed in coated wires. Ductility found to be decreased for coated wires when compared to uncoated wires.

MATERIALS AND METHODS

MATERIALS AND METHODS

The ethical clearance was obtained from the institutional ethical committee, Vivekananda Dental college for women (No:VDCW/IEC/85/2017).Conventional upper super elastic NiTi wires of diameter 0.016inch -40 numbers and 0.016 × 0.022 inch-40 numbers(G&H Wire Company) were used in this study. In 40 numbers of 0.016 inch and 40 numbers of 0.016x0.22 inch NiTi wires, 20 numbers of 0.016 NiTi and 20 numbers of 16 x22 NiTi arch wires randomly selected and silver coating of NiTi wires was done with thermal evaporation method .Grouping of the wires done as per the sample size calculation, In each group the sample size was 20 .Grouping of the NiTi wires shown in Table 1.

Sample size calculation

- Single Mean-Hypothesis testing –one population man
- Standard Deviation=0.04
- Sample mean=1.05
- Population mean=1.075
- Alpha Error(%)=5
- Power(%)=80
- Sided=2
- Effect Size=.625
- Number needed(n)=20

The sample size was calculated to achieve 80% power. The sample size calculation showed that 20 sample for each group was necessary

TABLE1: Orthodontic NiTi wires grouped according to coating and cross sectional diameter

Groups	**No**	**Arch Wires**
Group 1	20	Silver coated 0.016 inch round NiTi wire
Group2	20	Uncoated 0.016inch round NiTi wire
Group3	20	Silver coated0.016x0.022inch rectangular NiTi wire
Group 4	20	uncoated0.016x0.022inch rectangular NiTi wire

Fig1: 0.016 uncoated round and 0.016x0.022 uncoated rectangular NiTi wires

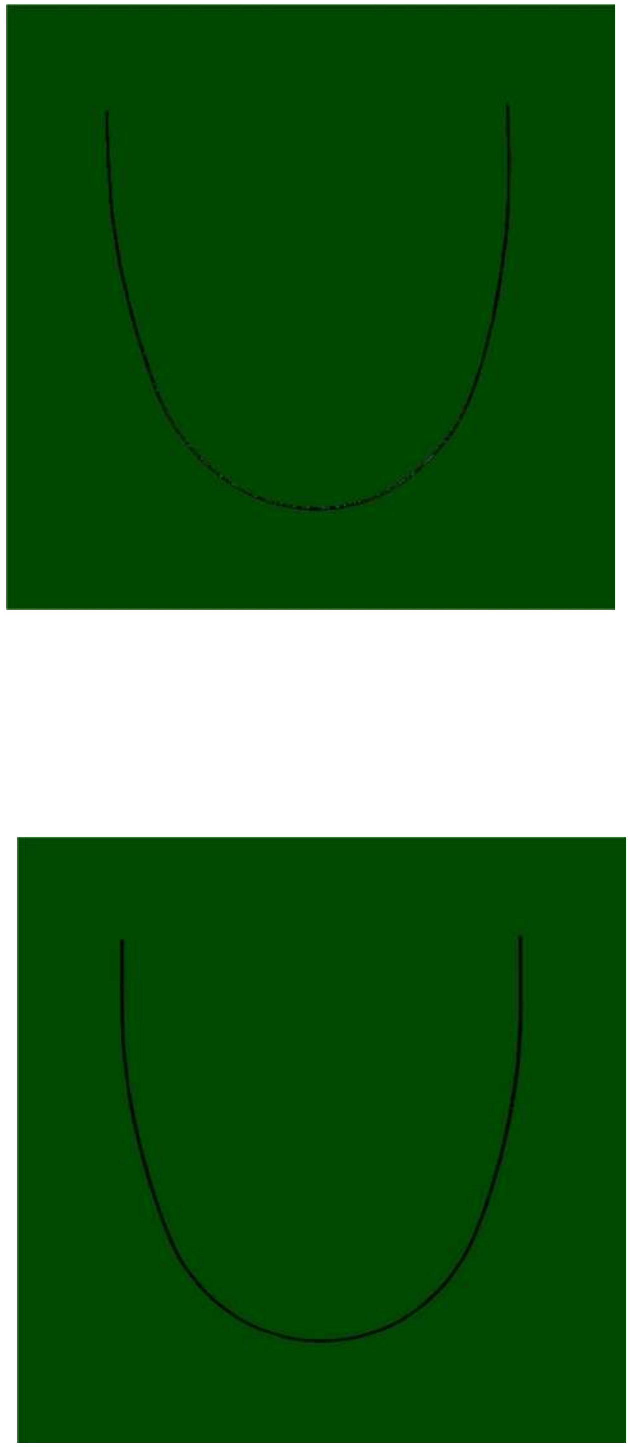
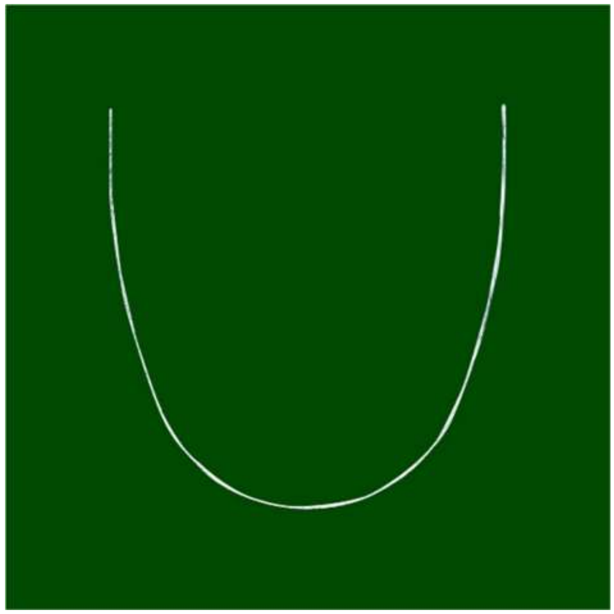


Fig 2: Uncoated 0.016 round and 0.016x0.022 rectangular NiTi wires

Laboratory preparation of Silver coated NiTi.

Coating of nickel titanium orthodontic wire with silver was carried out by thermal evaporation method based on method done by Mhaskeet al[4].Silver was selected due to its anti-bacterial properties. The instrument used for coating is HINDHIVAC vacuum coating unit modelno-12A4 D (Hind High Vacuum Co. Chennai). The thermal evaporation method was used to obtain a thin homogenous, uniform pure film coating on archwire. Pure silver (99.9%) was used for thin coating on the archwires. Silver was heated through vaporization temperature in a closed chamber and vapors was allowed to pass through a valve which can be controlled according to desired thickness. In our study 10-nm thick silver film was coated on orthodontic wires. Coated arch wires was then stored in air tight container.

Fig 3: HINDHIVAC vacuum coating unit



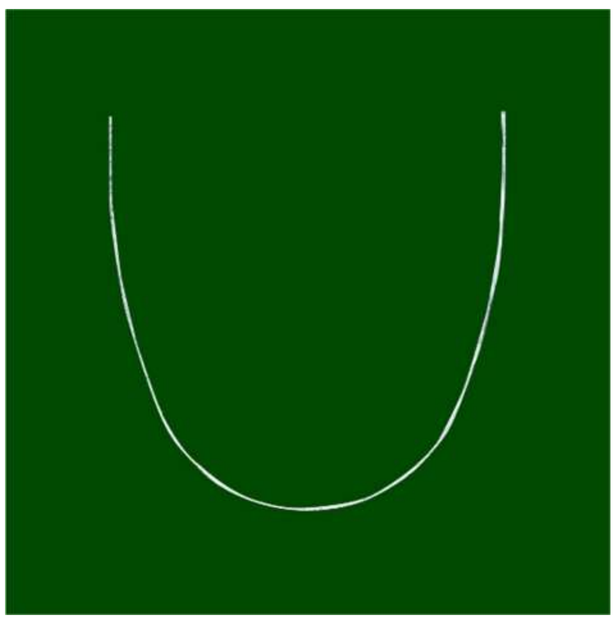


Fig 4: Silver coated 0.016 round and 0.016x0.022 rectangular NiTi wires

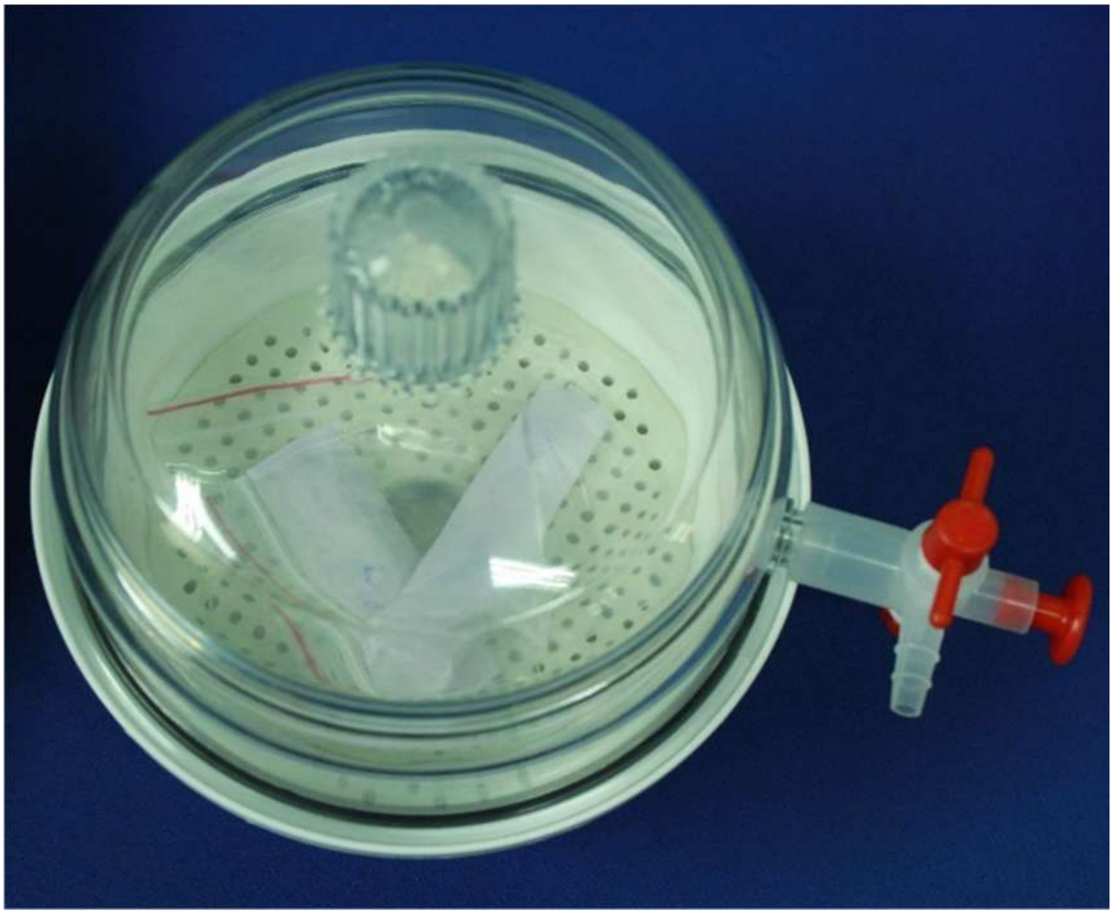


Fig 5: Silver coated wires in vacuum desiccator

Model Fabrication.

An Acrylic block model was prepared with a dimension of 60x 20x 50mm and an inner area of dimension of 10x10x10mm to hold the bracket and arch wire for testing load deflection. The 0.018 slot brackets (Leone, Mini brackets) were glued to the acrylic base to create interbracket span between two adjacent brackets.

.

Fig6: Acrylic block model

Fig 7: Mounted arch wire with brackets on acrylic block

<u>Three point bending test.</u>

The load deflection characteristics for each group were assessed using three-point bending test and the test was performed at room temperature using universal testing machine. The three point bending test was used to determine the use of super elasticity of NiTi wires. It demonstrates the spring back properties of wire. It also simulates the application of wire pressure on teeth in oral cavity.

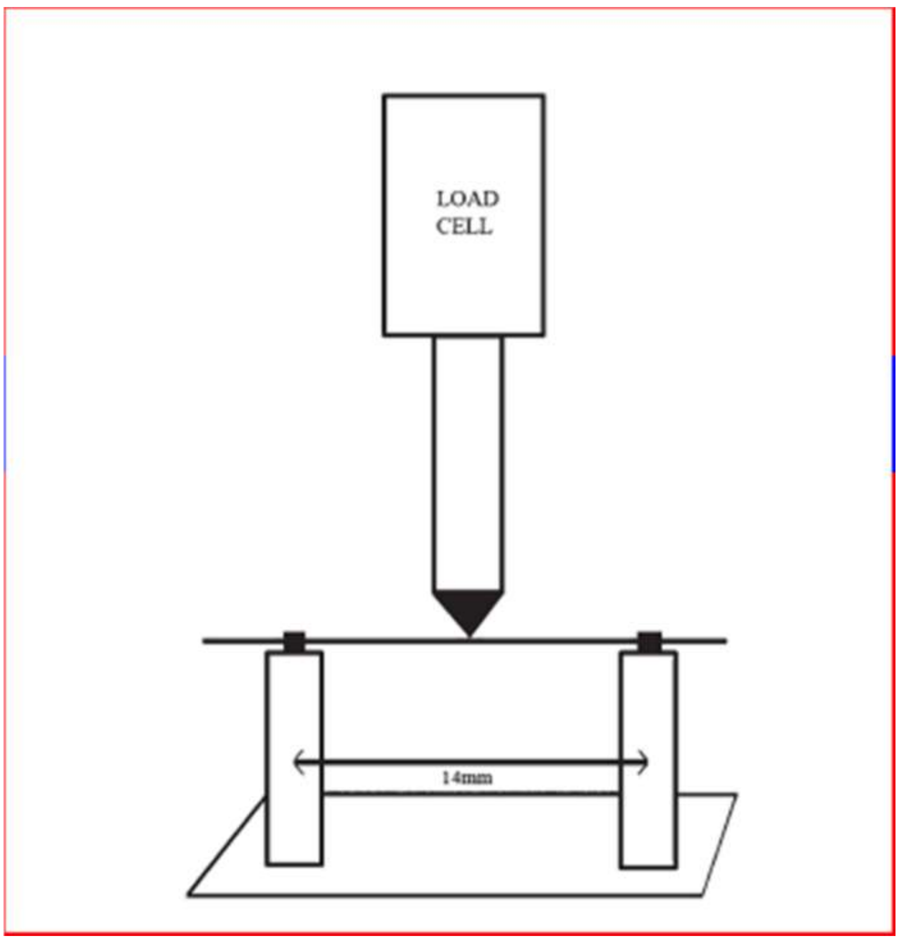


Fig 8: schematic diagram of three point bending test

Testing of silver coated and uncoated NiTi wires was done under universal testing machine (INSTRON model no 8874). The stylus was connected to the crosshead of an Instron machine and centered at midspan of each wire specimen. The span length of 14mm is considered to be the inter bracket distance between the central incisor and canine.

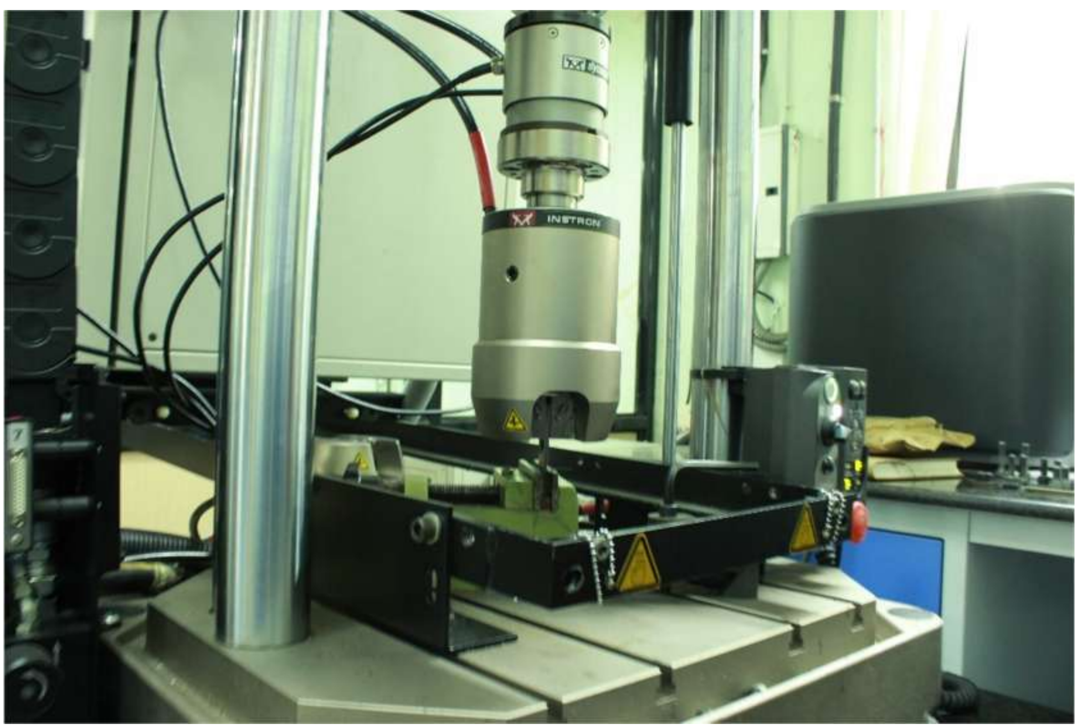


Fig: 9: Universal testing machine

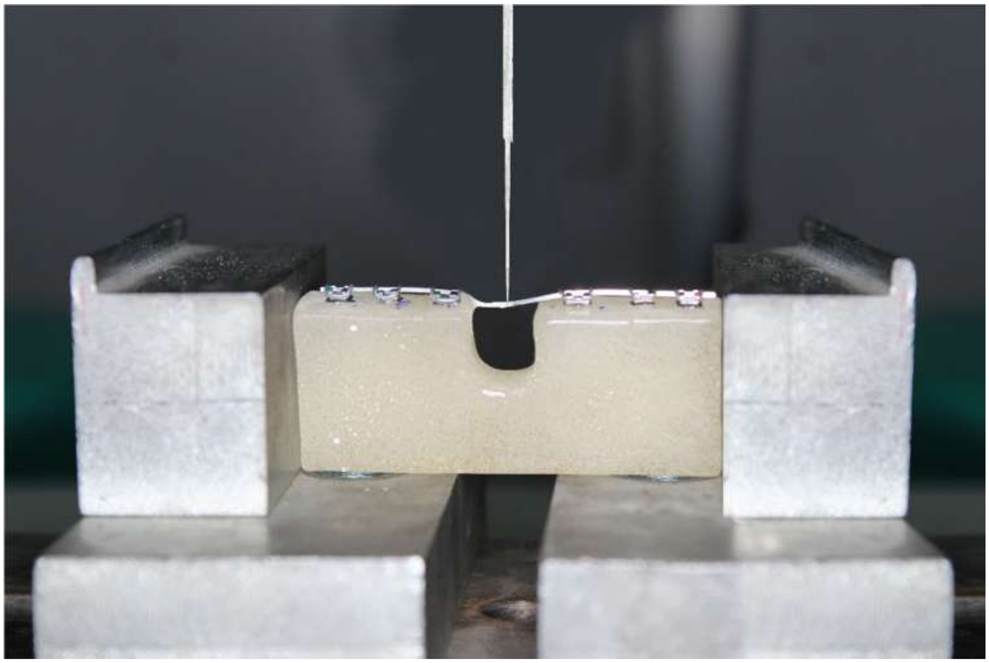


Fig 10: Deflection of arch wire across an acrylic block.

Sample to be tested was secured on bracket fixed on poles using elastomeric ligatures. The striker attached to the upper movable head of the Instron machine. The tip of the striker is the center of the test-wire span. The crosshead speed for loading and unloading was 1 mm per minute. The mid portion of the wire was deflected. The loading 1, 2, and 3 mm and unloading values 0.5, 1.5 and 2.5 for each sample was recorded. Loading value and unloading value for each sample was registered and the results were analyzed.

3-D Surface Profilometer.

The three-dimensional (3D) surface profilometry analysis was performed to assess the surface roughness of the arch wires. It featured rapid and contact free screening. The average absolute deviation of the surface (Sa) was assessed because of the importance of amplitude parameters. A surface profilometer (Talysurf PGI 1240) with 60mmlength, 2µm radius conisphere diamond stylus was used in this study. The scanning distance was 5mm each and the equipment determined the profilometric mean roughness from the surface profile. An area of 0.24mm^2 of each coated and uncoated surface was measured with a speed of 0.5mm/s, 0.8nm Z resolution and 0.125µm data spacing in X.

The wire was placed on the worktop and surface tip was positioned on the wire followed the profile of the surface. The mean roughness of each specimen was measured. Data were directly transferred to the connected personal computer with ultra-system software.

The reconstruction of 3D images was done according to the parameter Sa (µm) using the formula;

$$Sa = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l-0}^{N-1} \left| z(x_k; y_l) \right|$$

Where Z is the height of measured points in x and y coordinates.

Fig 11: 3 D Profilometer

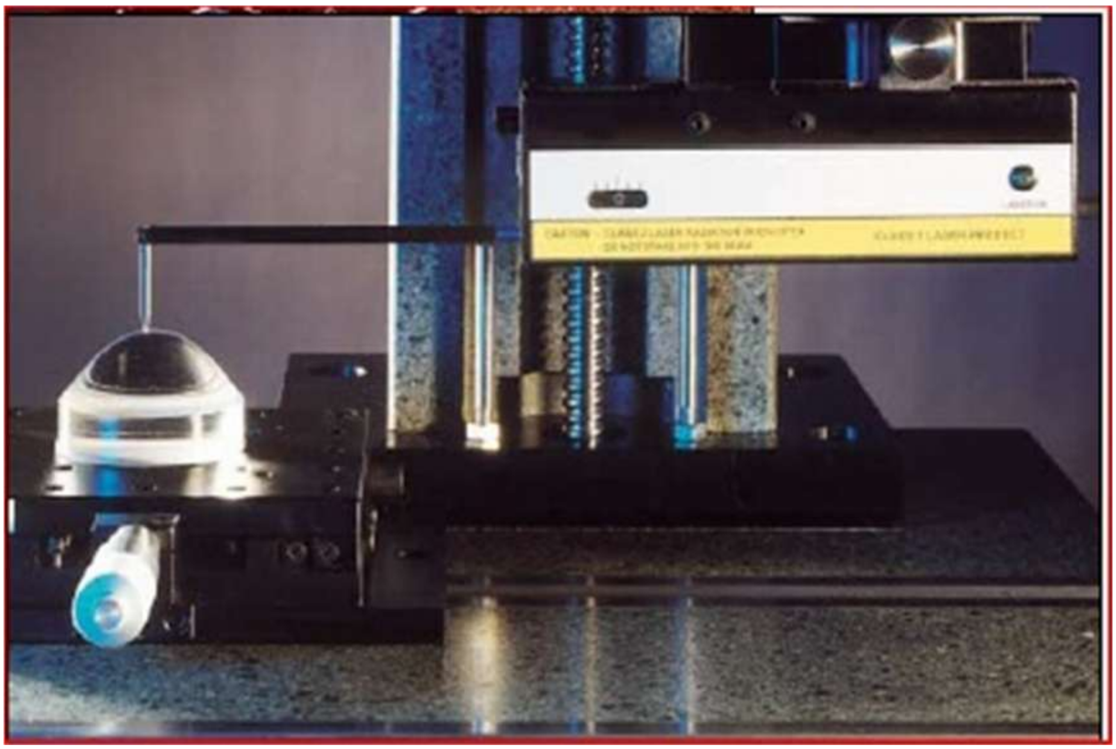


Fig 12: 3D Profilometer with stylus

Description Parameters in 3D Profilometery.

Parameter	Description	Comment
Sq	Root mean square deviation of the surface	Used to discriminate between different surfaces based on height information and to monitor manufacturing stability
Ssk	Skewness of the surface	Indicate aspects of load carrying capacity /lubrication
Sku	Kurtosis of the surface	Indicate spikiness of the surface
Sp	Highest peak	Largest peak height within the definition area
Sv	Lowest valley	Largest valley depth within the definition area
Sz	Ten point height of the surface	Used to evaluate extreme surface height deviations
Sa	Average absolute deviation of the surface	Non –preferred parameter

STATISTICAL ANALYSIS

STATISTICAL ANALYSIS

Load deflection rate of silver coated 0.016 round and 0.016x 0.022 rectangular Niti wire and uncoated 0.016 round and 0.016x 0.022 rectangular Niti wire were compared using independent sample t test with p value of <0.05.

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

P <0.05 was considered as the level of significance.

RESULTS

RESULT

I. load deflection.

I.A Load deflection rate comparison group 1 (silver coated) and group 2 (uncoated 0.016) round NiTiwires.

Load deflection rate of group 1 silver coated and group 2 uncoated 0.016 round Niti wire were compared using independent sample t test with p value of <0.05 as significant ..The mean force levels of silver coated 0.016 NiTi and uncoated 0.016 Niti on loading at 1mm,2mm,3mm and on unloading at 2.5mm,1.5mm,0.5mm is shown in table (2).The results were statistically insignificant.as $p>0.05$.

Deflection	Force	Group 1 (Ag Coated 0.016 NiTi wires)		Group 2 (Uncoated 0.016 NiTi wires)		P Values
		Mean	SD	Mean	SD	
Loading	1mm	1.578425	0.7507342	1.622949	0.6107448	0.146
	2mm	2.339725	0.7097009	2.489372	0.7639948	0.429
	3mm	1.661710	0.6239151	3.194235	0.6295472	0.457
Unloading	2.5mm	1.460070	0.4533167	2.013165	0.3644231	0.173
	1.5mm	1.144705	0.4039404	1.537100	0.3097892	0.39
	0.5mm	0.801265	0.4620350	0.973205	0.3614807	0.085

Table 2-Load deflection comparison of silver coated and uncoated 0.016roundNiTi wires.

IB. Load deflection rate comparison of group3 (silvercoated) and group 4 (uncoated) 0.016x0.22 rectangularNiTi wire.

Load deflection rate of group 3 silver coated 0.016 x0.022 rectangular Niti wire and group 4 uncoated 0.016x0.022 Niti wire were compared using independent sample t test with p value of <0.05 as significant.. The mean force levels of coated 0.016 x0.022 NiTi and uncoated 0.016 x0.022 Niti on loading at 1mm,2mm,3mm and on unloading at 2.5mm,1.5mm,0.5mm is shown in table (3).The results were statistically insignificant as p value greater than0.05

Deflection	Force	Group 3 (Ag Coated 0.016 x0.22Niti wires		Group 4 (Uncoated 0.016 x0.22Niti wires)		P Values
		Mean	SD	Mean	SD	
Loading	1mm	3.480250	.8166366	3.498950	.5698310	.085
	2mm	4.904105	1.2207603	4.946250	.8068081	.223
	3mm	6.074500	1.2506641	6.072350	.7106082	.149
Unloading	2.5mm	3.511550	.7722450	3.515350	.6875991	.469
	1.5mm	2.116400	6298853	2.268900	.5152222	.433
	0.5mm	1.351100	.3791639	1.431300	.2809141	.197

Table 3 -Load deflection comparison of silvercoatedand uncoated 0.016x0.22 rectangularNiTi wires.

II. Surface roughness.

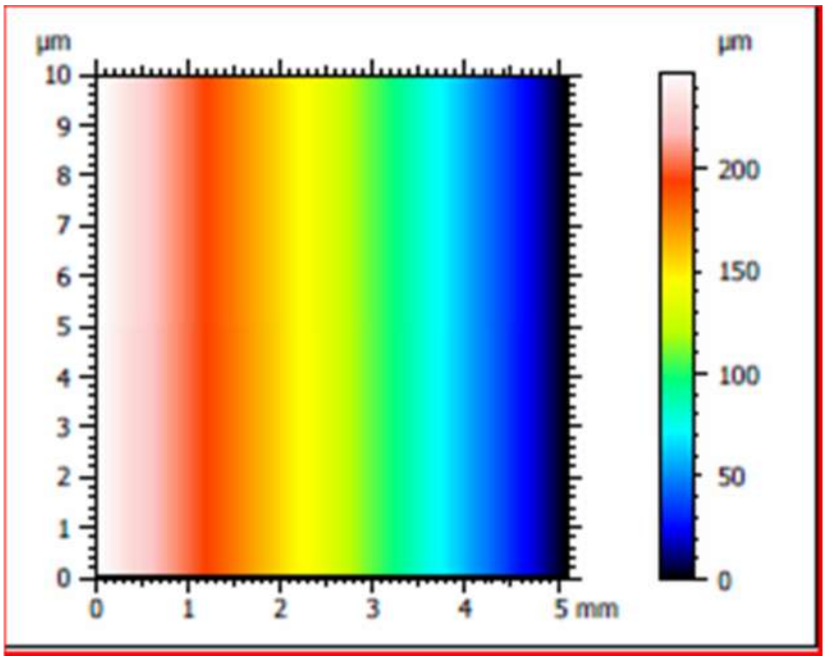
Surface roughness of silver coated 0.016round and 0.016x0.022 rectangular and uncoated NiTiwires.

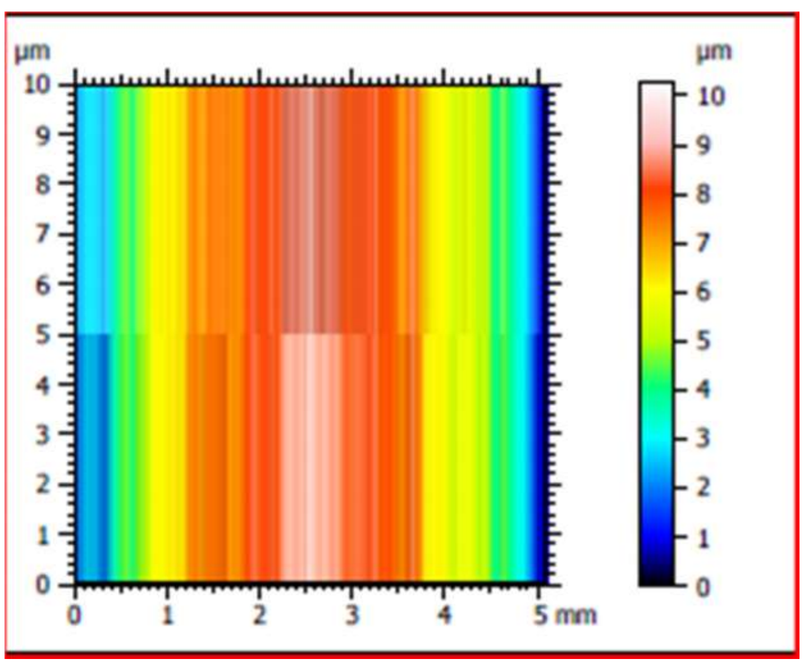
The surface roughness of silver coated 0.016 NiTi wires (group 1 mean -4.294370) found to be lesser than the surface roughness of uncoated 0.016 NiTi wires (group2 mean- 11.933395) and the surface roughness of silver coated 0.016x0.22 NiTi wires (group 3 mean -18.486070) found to be lesser than the surface roughness of uncoated 0.016x0.22 NiTi wires (group4 mean-40.357245).Surface roughness of group1and group2 were compared using independent sample t test with pvalue of<0.05 asstatistically significant. The results were statistically insignificant. Surface roughness of group 3 and group4werecompared using independent sample t test with pvalue of<0.05. The results were statistically significant with p value of 0 .022.

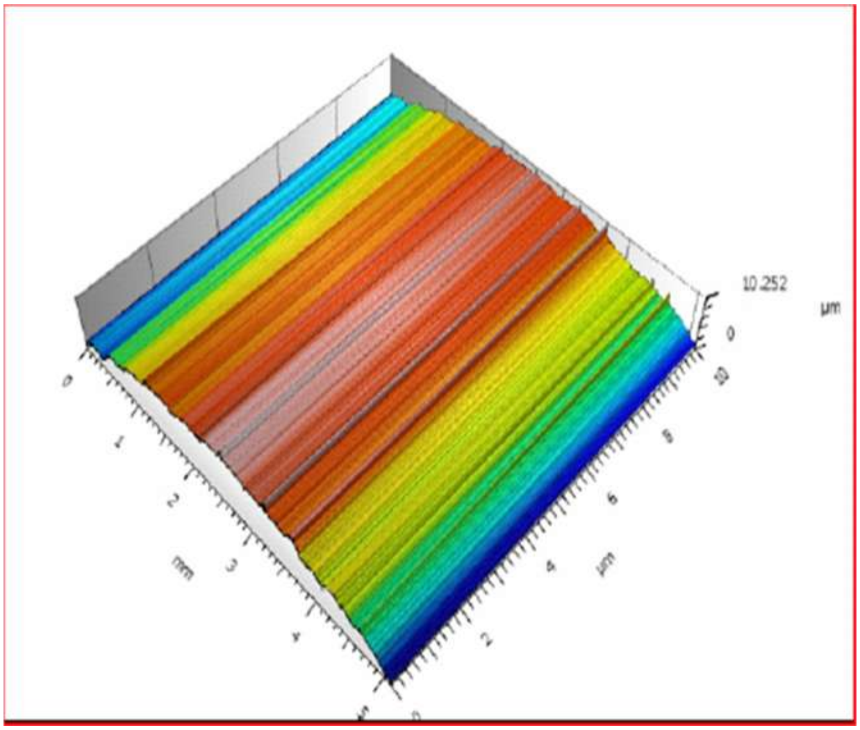
Surface roughness	Group	N	Mean	SD	P Value
Surface roughness - 0.016	(Ag Coated NiTi) Group1	20	4.294370	1.8077201	.652
	(Uncoated NiTi) Group2	20	11.933395	2.0051563	
Surface roughness - 0.016x0.022	(Ag Coated NiTi) Group3	20	18.486070	2.1916178	0.022*
	(Uncoated NiTi) Group4	20	40.357245	4.2285366	

Table 4-Surface roughness comparison of silver coated 0.016 round and 0.016x0.022 rectangular and uncoated NiTi wires.

Three dimensional profilometer view of a silver coated 0.016 NiTi wire(Group-1).



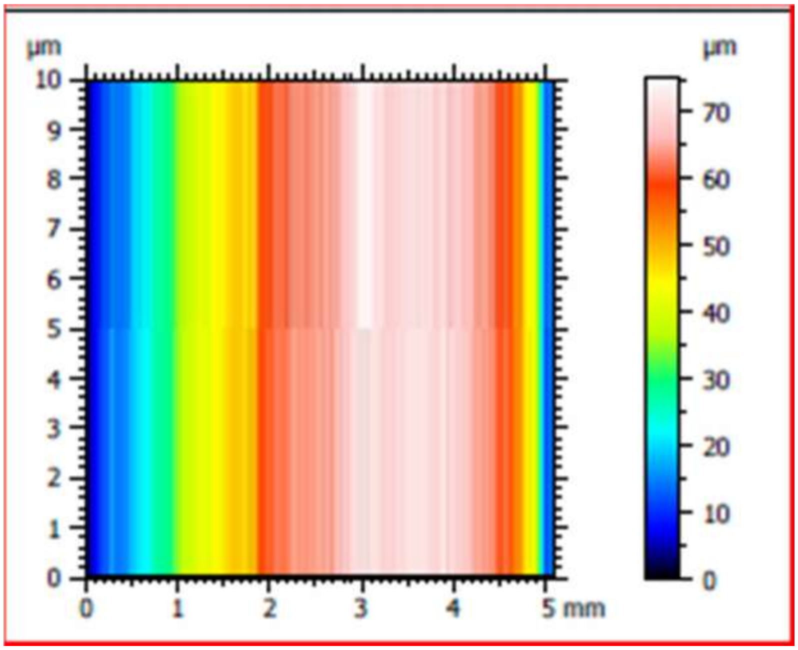


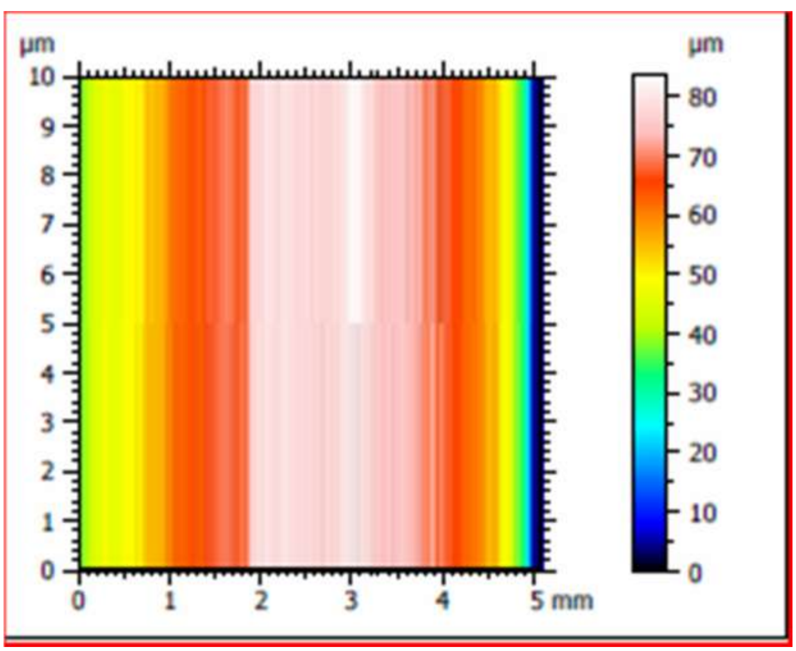


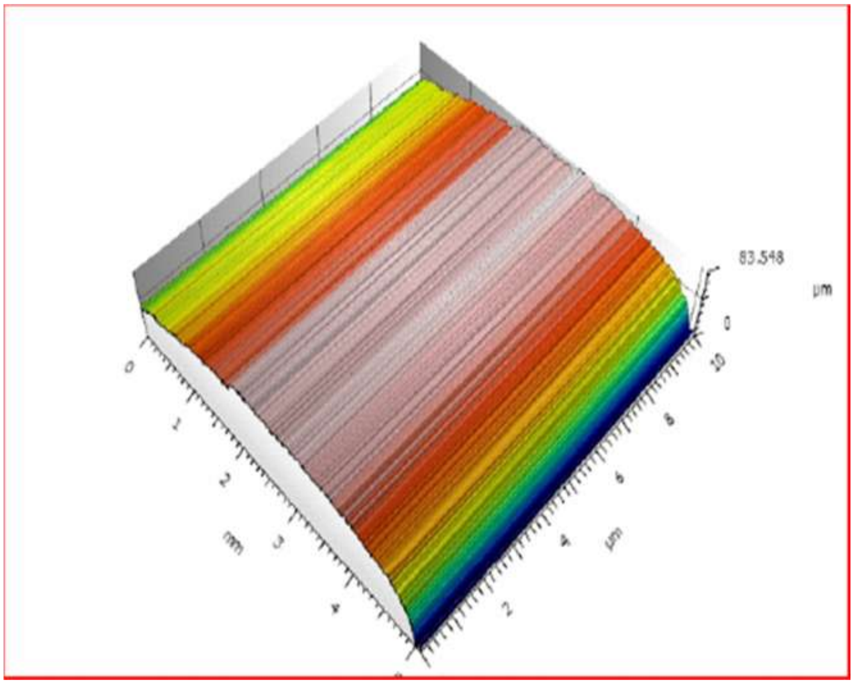
ISO 25178		
Height Parameters		
Sq	2.1876	µm
Ssk	-0.6821	
Sku	2.4762	
Sp	4.0440	µm
Sv	6.2080	µm
Sz	10.2520	µm
Sa	1.8354	µm

Fig 13: 3D Profilometer view of silver coated 0.016 NiTi wire.

<u>Three dimensional profilometer view of a uncoated 0.016 NiTi wire (Group-2).</u>



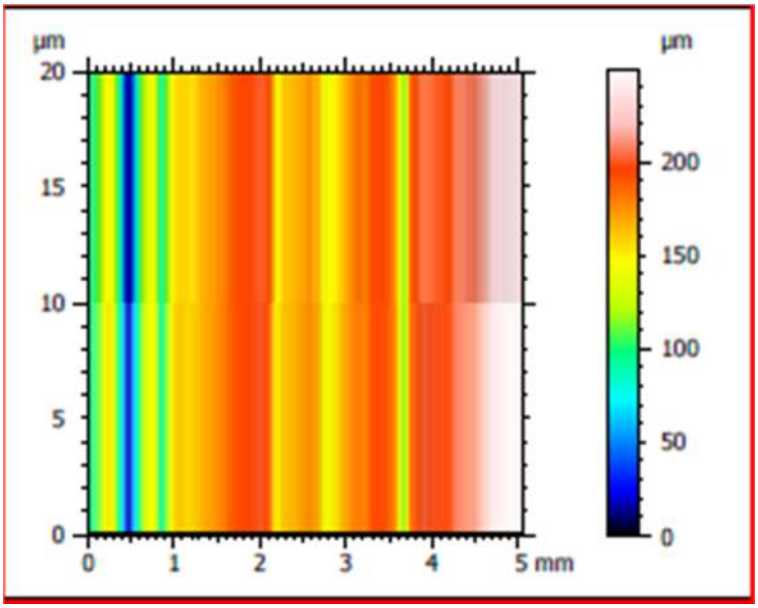


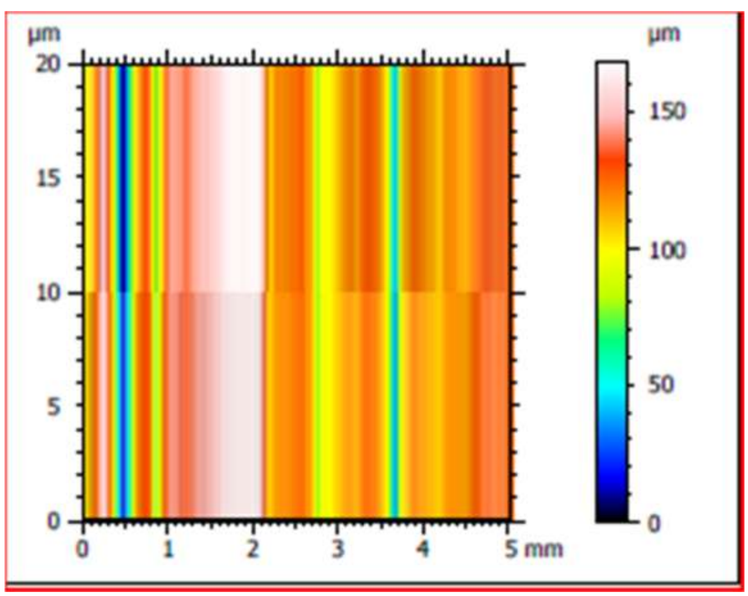


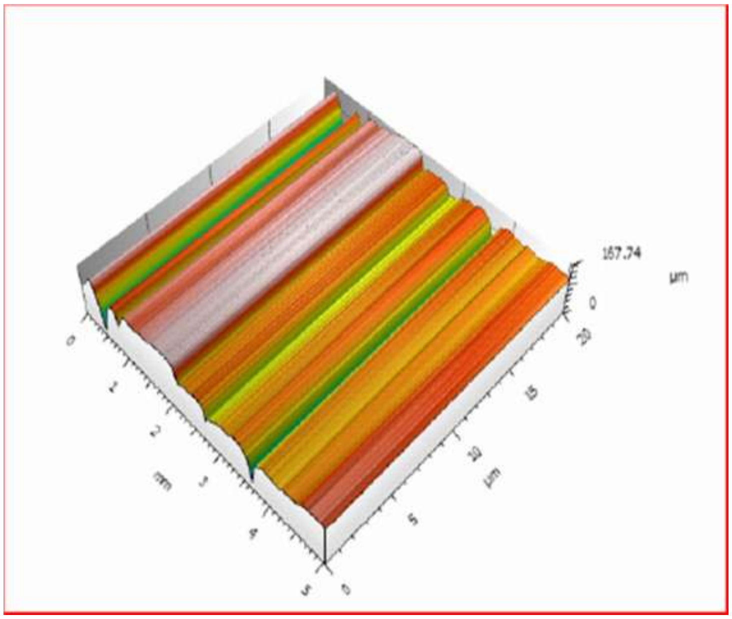
ISO 25178		
Height Parameters		
Sq	15.6552	µm
Ssk	-1.4296	
Sku	5.4440	
Sp	20.7240	µm
Sv	62.8240	µm
Sz	83.5480	µm
Sa	12.1786	µm

Fig 14: 3D Profilometer view of uncoated 0.016 NiTi wire .

Three dimensional profilometer view of a silver coated 0.016 x0.22 NiTi wire(Group-3).



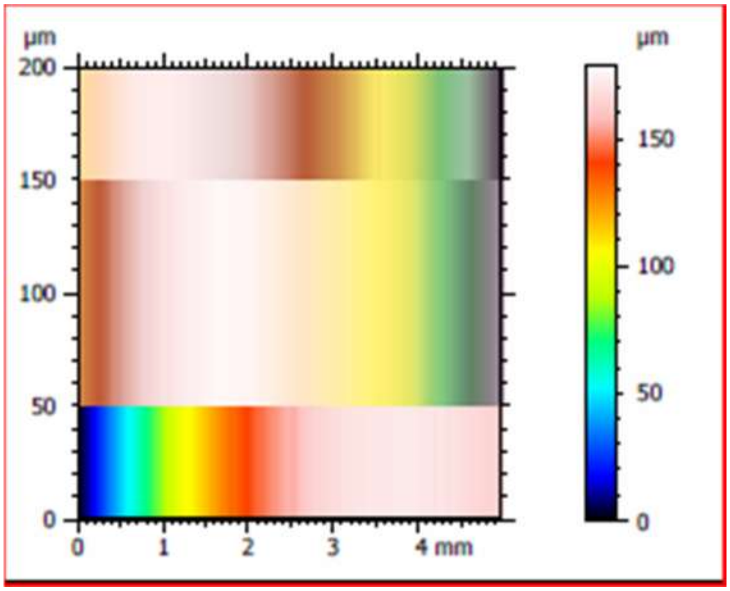


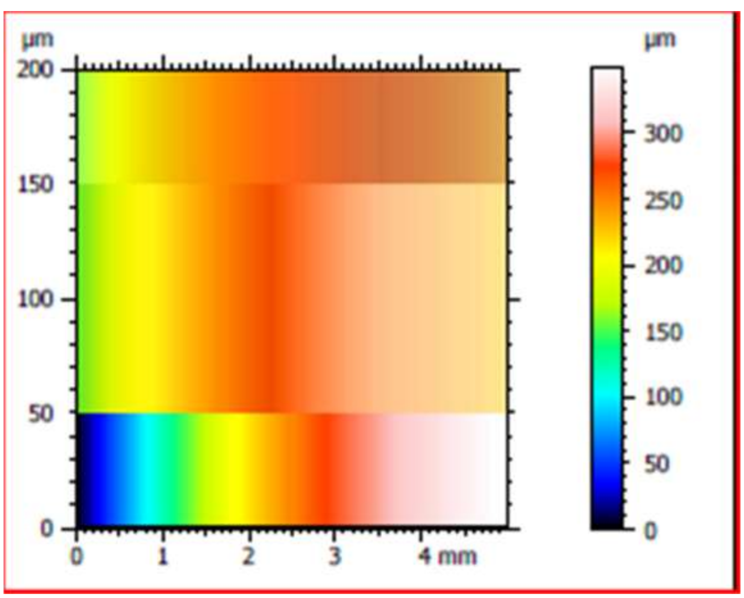


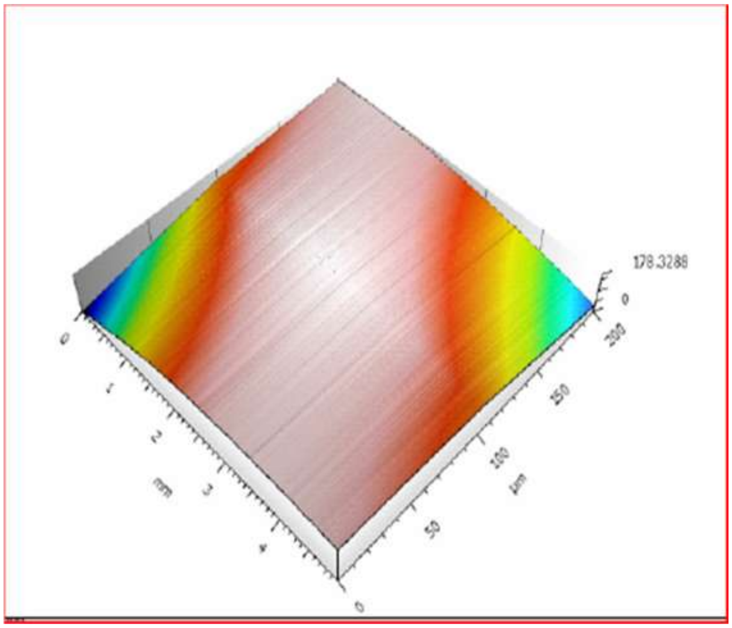
ISO 25178		
Height Parameters		
Sq	27.1216	µm
Ssk	-1.1647	
Sku	5.6432	
Sp	47.6992	µm
Sv	120.0408	µm
Sz	167.7400	µm
Sa	19.0857	µm

Fig 15: 3D Profilometer view of silver coated 0.016x0.22 NiTi wire

Three dimensional profilometer view of a uncoated 0.016 x0.22 NiTi wire (Group-4).







ISO 25178		
Height Parameters		
Sq	41.7621	µm
Ssk	-1.4659	
Sku	4.1970	
Sp	38.3464	µm
Sv	139.9824	µm
Sz	178.3288	µm
Sa	32.4584	µm

Fig 16: 3D Profilometer view of uncoated 0.016 x 0.22NiTi wire

DISCUSSION

DISCUSSION

The emergence of antibiotic resistant strain of bacteria leads to attention towards incorporation ofsilver nanoparticle with composites and coating the surface of wires and brackets so as to reduce the occurrence of white spot lesion by preventing the bacterial adhesion.[33]

Surface coating of silver done by physical evaporation, electro deposition, metallurgical, photo catalytic method etc., but all these method has various disadvantages like changes in colour of wires, heating the wire at high temperature leading to loss of its properties[34, 35, 36]. The thermal vacuum evaporation method was used in this study coated the Niti wire with nanosilver without heating and minimal colour change [4]

Niti wire is preferred for alignment of teeth for its property of super elasticity, shape memory and low load deflection rate. The load deflection property is the most important parameter in determining biological nature of tooth movement[37]. The standard method three point bending test (according to ADA specification no 32) is used to evaluate load deflection rate of orthodontic archwire by several authors[18,26,38,39,40,41,,42,43].

The three point bending test was used to accurately differentiate mechanical property of load deflection rate between uncoated and silvercoated Niti wire. In our study, this test was used for its high level of reproducibility, allows comparison with other studies [19,26]and simulate application of wire pressure on teeth in the oral cavity[10].

The elastomeric ligature was used for securing archwire in the bracket slot while testing the load deflection rate of both coated and uncoated wire, as metal ligation over archwire is subjective and it could vary based on orthodontist. [28, 44].

Wire loading deflections of 1mm, 2mm, and 3mm were selected and 0.5mm, 1.5mm, 2.5mm for unloading wire deflections in this study which was similar to the study by Kapooret al[5]. Most other studies used 2mm and 4mm loading deflection [18, 26, 41,45]Thus in our study the tested deflection was within the recommended norm of the oral cavity that is within 4mm of deflection[26,41,45].

When the strain in wire higher than 8 percent of original length, the wire cannot revert back to its initial shape. Graber et al 2005. In the oral cavity the deflection of wire happens to be minimal about 2-3 mm even on an severely malalinged teeth and also stress induced martensitic transformation of superelastic NiTi wire require at least deflection of 2mm over a span of 14 mm[13,17].

Various studies of load defection of uncoated Niti and coated esthetic NiTi wires were evaluated showed a statistically significant difference in loading and unloading hysteresis.[5.20, 29, 30]. Load deflection rate changes between superelastic NiTi and thermal Niti was evaluated and it showed significant difference[26]

In this present study the loading and unloading forces of both 0.016 silver coated and 0.016 uncoated Niti archwire showed less variation. The silver coated 0.016 Niti archwire had mean loading deflection force at 1mm and 2mm very close to the mean force of uncoated 0.016 NiTi archwire and similarly very minimal variation was seen in mean unloading deflection force of both the wires at 0.5 mm. The loading and unloading deflection force of both silvercoated 0.016 x0.022 NiTi wire and uncoated 0.016 x 0.022 NiTi wire also showed a minimal variation.

Load deflection rate comparison of silver coated NiTi versus uncoated superelastic Niti was evaluated first in our present study for wire dimension of 0.016 and 0.016 x 0.022 showed a statistically insignificant difference between them. This result obviously stated to the fact as the coated silver of size 10 nm provided a thin coating layer. This renders no changes in their mechanical property of wire. This result was in contradictory to the study by Raotiwala et al[32] where load deflection rate of uncoated conventional Niti and nanoceramics coated Niti orthodontic wires were compared using three point bending test showed a significant difference, which may be due to manual application of self-lubricant precursor solution resulting in irregular coating over wire.[32]

The surface roughness of orthodontic archwires are measured using several methods like surface profilometer, scanning electron microscope, atomic force microscopy, laser spectroscopy, contact-surface profilometry,3D profilometry etc[20,47,48] The 3D profilometer is an advanced method to evaluate the surface topography which is more advantageous for its non-invasiveness, reliability and accuracy. [49]

Coating of archwire is done for various purposes like to reduce friction, for esthetic purposes and to reduce plaque accumulation. In this study silver coating over on Niti wire was done for the purpose of preventing dental plaque formation and prevention of white spot lesion. A 10nm silver was used for surface coating of Niti archwire by thermal evaporation suggested that smaller size particle provided greater surface-volume ratio which lead to thin uniform coating over the wire and also provided anti-adherent and antimicrobial property to the orthodontic wire[4.].Thus, it would be prudent to determine surface roughness changes over the coated silver Niti wire and to compare the roughness with that of uncoated NiTi wire roughness.

The surface roughness using 3D profilometer is generally expressed as arithmetic average height (S_a) defined as average absolute deviation of the surface.[50] On evaluation of the surface roughness of conventional Niti, it was found to more rough on comparing with other coated NiTi like epoxy coating, Teflon coated, thermal NiTi.[49,50,51]

In present study the S_a value of 0.016 nanosilver coated NiTi and 0.016 uncoated NiTi wires was compared which showed no statistically significant difference. On comparison of surface roughness of 0.016x0.022 nanosilver NiTi wire with 0.016x0.022 uncoated Niti wire it had a significant difference suggesting reduced surface roughness. This result was similar to the study by Krishnan et al were the silver-rhodium coated NiTi arch wire showed reduced surface roughness when compared with the conventional Niti. [49]

Silver was not enlisted as hazardous heavy metal to public health but it has concentration dependent toxicity. Hence the amount of silver incorporation into the wire was to be done with caution.[52]

The silver coating on the wire is surface based and it may be prone to wear of its coating under clinical conditions. Under oral environment, it is critical to evaluate its surface roughness, its anti-adherent and antimicrobial effect, its effect in prevention of white spot lesion and its changes in its mechanical properties. Therefore further studies in the oral environment are needed.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The study was done for the purpose,

1.To evaluate the load deflection rate of silver coated and uncoated round and rectangular NiTi wire using universal testing machine

2. To evaluate the surface roughness silver coated and uncoated round and rectangular NiTi wire using three dimensional optical profilometer

3.To compare the load deflection rate and surface roughness of silver coated round and rectangular wire with uncoated round and rectangular NiTi wire of same dimension.

Conventional upper super elastic NiTi wires of diameter 0.016 inch -40 numbers and 0.016 × 0.022 inch-40 numberswere used in this study. In 40 numbers of 0.016 inch and 40 numbers of 0.016x0.22 inch NiTi wires, 20 numbers of 0.016 NiTi and 20 numbers of 16 x22 NiTi arch wires randomly selected and silver coating of NiTi wires was done with thermal evaporation method .

The load deflection rate of both silver coated and uncoated Niti archwirewas determined using three point bending test byuniversal testing machine. The wire is fixed to a specially designed fixture with a distance of 14 mm apart. The loading deflection force for1mm, 2 mm, and 3 mm and unloading deflection force for 0.5 mm,1.5 mm and 2.5 mm was recorded for both silver coated and uncoated NiTi archwire (0.016&.016 x 0.022)

The surface roughness of both silver coated anduncoated NiTi archwire of both round and rectangular NiTi was measured using three-dimensional (3D) surface profilometer and surface roughness $S_a$was recorded and statistically evaluated.

In conclusion,

The load deflection rate of 0.016 silver coated and uncoated NiTi archwire showed a statistically insignificant difference that substantiated that on coating silver over round Niti archwire doesnot change its property of load deflection rate, thus maintaining its superelastic nature.

The load deflection rate of 0.016x 0.022silver coated and uncoated NiTi archwire showed a statistically insignificant difference, which evidenced that silver coated rectangular Niti archwire had same mechanical load deflection property as that of uncoated superelastic Niti.

The surface roughness of 0.016 silver coated and uncoated NiTi archwire showed a statistically insignificant difference, which proved that the surface roughness on coating of silver over the round Niti archwire did not produce any significant changes.

The surface roughness of 0.016x0.022 silver coated and uncoated NiTi archwire showed a statistically significant difference, stating reduced surface roughness in rectangular silver coated Niti archwire, which is suggestive of its anti-adherent and antimicrobial effect.

REFERENCES

REFERENCES

1.Corrêa JM, Mori M, Sanches HL, Cruz AD, Poiate E, Poiate IA. Silver nanoparticles in dental biomaterials. International journal of biomaterials. 2015;2015.

2. Espinosa-Cristóbal LF, Martínez-Castañón GA, Martínez-Martínez RE, Loyola-Rodriguez JP, Patino-Marin N, Reyes-Macias JF, Ruiz F. Antibacterial effect of silver nanoparticles against Streptococcus mutans. Materials Letters. 2009;63(29):2603-6.

3. Azarsina M, Kasraei S, Yousefi-Mashouf R, Dehghani N, Shirinzad M. The antibacterial properties of composite resin containing nanosilver against Streptococcus mutans and Lactobacillus. J Contempt Dent Pract. 2013;14(6):1014.

4. Mhask A, et al. Ant adherent and antibacterial properties of stainless steel and NiTi orthodontic wires coated with silver against Lactobacillusacidophilus. Prog Orthod. 2015; 16: 40.

5. Kaphoor AA, Sundareswaran S. Aesthetic nickel titanium wires—how much do they deliver?. Eur J Orthod.. 2012;34(5):603-9.

6. Rego MV, et al.Influence of aesthetic coating on the load-deflection ratio of nickel–titanium archwires Marcus . Braz J Oral Sci. 15(4):293-297

7. Waters NE ,C. D. Stephens & W. J. B. Houston (1975) Physical Characteristics of Orthodontic Wires and Archwires—Part 1, British Journal of Orthodontics, 2:1, 15-24

8. George F. Andreasen, Ray E. Morrow. Laboratory and clinical analyses of nitinol wire. Am J Orthod 1978; 73(2):142-151.

9. Charles J. Burstone, John Y. Morton, Chinese NiTi wire- A New Orthodontic Alloy.Am J Orthod. 1985; 87(6):445-52

10. Fujio Miura et al. The superelastic property of the Japanese NiTi alloy wire for use in orthodontics.Am J Orthod Dentofacial Orthop. 1986; 90(1):1-10

11. Schaus JG, Nikolai RJ. Localised , transverse , flexural stiffness of continuous arch wires. Am J Orthod Dentofacial Orthop 1986; 89:407-414

12. Kapila S, Sachdeva R. Mechanical properties and clinical applications of orthodontic wires. Am J Orthod Dentofacial Orthop. 1989; 96(2):100-109.

13. Segner D, r Ibe D, Properties of superelastic wires and their relevance to orthodontic treatment. Eur J Orthod.1995; 17(5):395-402.

14. Robert P.Kusy. A review of contemporary archwires: Their properties and characteristics. Angle Orthod. 1997;67(3):197-207

15.JustinWT.Evans, Malcom L.jones, Robert G.Newcombe. Clinical comparison and performance perspective of three aligning arch wires.Am J Orthod Dentofacial Orthop 1998; 114:32-39

16. Torstein R.Meling, Jan Odegaard . The effect of short term tempearature changes on the mechanical properties of rectangular nickel titanium arch wires tested in torsion. Angle orthod 1998; 68(4): 369-376.

17. Santoro M, Olivier F. Nicolay, Thomas J. Canhialosi. Pseudoelasticity and thermoplasticity of nickel-titanium alloys: A clinically oriented review Part II: Deactivation Forces. Am J Orthod Dentofacial Orthop. 2001; 119(6):594-603

18. Peter D. Wilkinson, PetersS, Dysart, James, Hood, G.PeterHerbison. Load-deflection characteristics of super-elastic nickel-titanium orthodontic wires.Am J Orthod Dentofacial Orthop. 2002; 121(5):483-95.

19.Theodosia N. Bartzela TN, Senn C , Wichelhaus A. Load-Deflection Characteristics of Superelastic Nickel-Titanium Wires. Angle Orthod. 2007; 77(6):991-997.

20.Elayyan F, Nick Silikas, David Bearn. Ex vivo surface and mechanical properties of coated orthodontic archwires.Eur J Orthod 2008; 30:661-667.

21.NadavSegal, Jess Hell, David W. Berzins. Influence of stress and phase on corrosion of a superelastic nickel-titanium orthodontic wireAm J Orthod Dentofacial Orthop. 2009; 135(6):764-770.

22.FirasElayyan, Nick Silikas,David Bearn. Mechanical properties of coated superelastic archwires in conventional amd self-ligating orthodontic brackets. Am J Orthod Dentofacial Orthop 2010; 137(2):213-217.

23.Luca Lombardo et al. Load deflection characteristics force level of nickel titanium initial archwires. Angle ortho.2012;82:507-521.

24.Miguel FS et al.Comparative analysis if load/deflection Fabio Schemann-ratios of conventional and heat-activated rectangular NiTi wires.Dental Press J Orthod 2012; 17(3):1-6.

25. Doshi UH, Mahindra RK. Comparison of the load deflection characteristics of esthetic and metal orthodontic wires on ceramic brackets using three point bending test.J IndOrthodSoc 2013; 47(4):400-404.

26.Gatto E, Matarese G, Di Bella G, Nucera R, Borsellino C, Cordasco G. Load-deflection characteristics of superelastic and thermal nickeltitanium wires. Eur J O rthod. 2013; 35(1):115–23

27. HindDawoodAbaas HD, Al-Huwaizi AF.Load deflection characteristics and force levels of coated nickel titanium orthodontic wires.J Bagh Coll Dentistry 2015; 27(2):154-157

28.Aghili H, Yassaei S, Joshan N, Hosseini N. Comparison of the load-deflection characteristics of aesthetic and conventional super elastic Ni-Ti orthodontic arch wires in conventional and metal-insert ceramic brackets. J ClinDiagn Res. 2016; 10(12): 6-9

29.Gihan H. Waly. Do esthetics contradict with function? In vitro assessment of load deflection and frictional resistance of coated versus uncoated superelastic nickel-titanium archwires. Egyptian Dental Journal2017; 63(4):1623-1633

30. Tang YC, Peh XL, Zakaria NN, Radzi Z. Mechanical and Surface Properties of Initial and Working Aesthetic Orthodontic Archwires,ADUM, University of Malaya, 2017;23 (1): 17-28

31.Argalji N, Silva EM, Cury-Saramago A, Mattos CT Characterization and coating stability evaluation of nickel-titanium orthodontic esthetic wires: an in vivo study. Braz. Oral Res. 2017; 31:68-79.

32. Raotiwala M, Gautam R, Kalia A, Hussain MS. Evaluation of Material Characteristics Of Nano Particle Coated and Uncoated Stainless Steel, Nickel-Titanium and Beta-Titanium Orthodontic Archwire - an In-vitroStudy. Sci J Res Dentistry. 2018; 2(1): 004-011.

33. Borzabadi-Farahani A, Borzabadi E, Lynch E. Nanoparticles in orthodontics, a Review of antimicrobial and anti-caries application. ActaOdontol Scand.2013; 72:413–17.

34. Choi JY, Chung CJ, Oh KT, Choi YJ, Kim KH. Photocatalytic antibacterial effect of TiO2 film of TiAg on Streptococcus mutans. Angle Orthod.2009;79:528–32.

35.Chun MJ, Shim E, Kho EH, Park KJ, Jung J, Kim JM, et al. Surface modification of Orthodontic wires with photocatalytic titanium oxide for its ant adherent and antibacterial properties. Angle Orthod. 2007; 77:483–88.

36. Shah AG, Shetty PC, Ramachandra CS, Bhat NS, Laxmikanth SM. In vitro assessment of photocatalytic titanium oxide surface modified stainless steelorthodontic brackets for antiadherent and antibacterial properties againstlactobacillus acidophilus. Angle Orthod. 2011; 81(6):1028–35.

37. Krishnan V, Kumar K J 2004 Mechanical properties and surface characteristics of three archwire alloys. Angle Orthod;2004; 74(6): 825 – 831.

38. NakanoH, SatohK,Norris R, Jin T, KamegaiT, Ishikawa F, et al. Mechanical properties of several nickel-titanium alloy wires in three point bending tests. Am J Orthod Dentofacial Orthop. 1999; 115:390–395.

39.GurgelJ, KerrS, PowersJM, LeCroneVForce-deflection properties of superelastic nickel-titanium archwires Am J Orthod Dentofacial Orthop 2001; 120: 378-382.

40.IjimaM, OhnoH, Kawashima, EndoK, Mizoguchi Mechanical behaviour at different temperatures and stresses for superelastic nickel-titanium orthodontic wires having different transformation temperatures, Dental Materials.2002 ;18 :88-93

41.ParviziF, Rock WP. The load/deflection characteristics of thermally activated orthodontic archwires, Eur J Orthod, 2003; 25: 417-421

42. KusyRP, WhitleyJQ,Resistance to sliding of orthodontic appliances in the dry and wet states: influence of archwire alloy, interbracket distance, and bracket engagement, Journal of Biomedical Materials Research.2000;52: 797-811

43. KasuyaS, NagasakaS, HanyudaA, IshimuraS, HirashitaA.The effect of ligation on the load-deflection characteristics of nickel-titanium orthodontic wire, Eur J Orthod, 2007;29: 578-582.

44. BednarJR,GrundemanGW,Sandrik JL.A Comparative study of frictional forces between orthodontic brackets and archwires.Am J Orthod Dentofacial Orthop.1991,100(6):512-2

45. SakimaMT, DalstraM, Melsen B. How does temperature influence the properties of rectangular nickel-titanium wires? Eur J Orthod, 2006; 28: 282-291.

46. Doshi UH, Mahindra RK. Comparison of the load deflection characteristics of esthetic and metal orthodontic wires on ceramic brackets using three point bending test. J Indian Orthod Soc. 2013; 47(4): 400-404.

47. Daems J, Celis JP, Willems G. Morphological characterization of as‑received and in vivo orthodontic stainless steel arch wires. Eur J Orthod 2009; 31:260–26

48. YousifAtia and UsmaAbd El-Karim. Microscopic study of surface roughness of four orthodontic arch Wires.Tanta Dental Journal. 20016, 13; 199-207.

49. Krishnan M, Seema S, Tiwari B, Sharma HS, Londhe S, Arora V. Surface characterization of nickel titanium orthodontic arch wires Med J Armed Forces India. 2015;71:340-345.

50. Rudge P, Sherriff M, Bister D. A comparison of roughness parameters and friction coefficients of aesthetic archwires. Eur J Orthod. 2015; 37:149-55.

51.FariborzAmini, VahidRakhshan, MaryamPousti, HajirRahimi, MahsaShariati,and BaharehAghamohamadi .Variations in surface roughness of seven orthodontic archwires: an SEM-profilometry study. Korean J Orthod. 2012; 42(3):129-137

52. Douglas RM, Luiz FG, Aline ST, Adhemar CR, Emerson RC, Debora BB. Thegrowing importance of material that prevent microbial adhesion:antimicrobial effect of medical devices containing silver. Int J Antimicrobial Agents. 2009; 34:103–10.