COMPARISON OF MECHANICAL PROPERTIES AND SURFACE CHARACTERISTICS OF SPACE CLOSURE ARCH WIRES FOLLOWING FLUORIDE TREATMENT WITH TOPICAL FLUORIDE GELS AND FLUORIDE MOUTHRINSES – AN INVITRO STUDY.

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CERTIFICATE

This is to certify that the dissertation entitled **"Comparison of mechanical properties and surface characteristics of space closure arch wires following fluoride treatment with topical fluoride gels and fluoride mouthrinses – an invitro study"** by **Dr. N. Meiyappan**, post graduate student (M.D.S), Orthodontics and Dentofacial Orthopedics (Branch – V), KSR Institute of Dental Science and Research, Thiruchengode, submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfilment for the M.D.S. degree examination (April 2015) is a bonafide research work carried out by him under my supervision and guidance.

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INTRODUCTION

INTRODUCTION

Orthodontic treatment is vital for improving and maintaining good oral and dental health, as well as creating attractive smile that contributes to the development of self-esteem. The mechanical foundation of orthodontic therapy is based on the principle that stored elastic energy can be converted into mechanical work by tooth movement and that the ideal control of tooth movement requires the application of a system of distinctive forces properly supported by orthodontic wires[1].

Archwire is one of the main parts of a multibracket appliance. It is used to correct the malocclusion through mechanical interaction with the bracket slots.

During orthodontic treatment, knowledge of the mechanical properties of wires is very helpful to the orthodontists in the design and application of optimal force system. While selecting the archwire several properties such as modulus of elasticity (stiffness), elastic limit, resilience, biocompatibility, formability, weldability, friction, springback and characteristics of the acrhwire should be considered.

Until the 1930s, the available orthodontic wires were made of gold. Later it was replaced by stainless steel archwires. It remains popular because of its stiffness, resilience, good balance of environmental stability, formability and low cost. In 1980 Beta titanium alloy was introduced by Charles Burstone and Goldberg into orthodontic applications. It has the advantage of high springback, formability, low stiffness and good corrosion resistance.

The commonly used archwire alloys for the fabrication of orthodontic wires are stainless steel, cobalt-chromium (Co-Cr), nickel-titanium (Ni-Ti), and beta-titanium (β-Ti).

With current orthodontic treatment, superelastic nickel-titanium wire is more often used for leveling and aligning, with beta titanium and stainless steel (SS) wires most frequently used for space closure and finishing and detailing[2]. No archwire is ideal and no single wire is best for all stages.

In fixed orthodontic therapy, teeth can be moved by using retraction archwires, involving minimal friction or sliding mechanics. In sliding mechanics, tooth movement occurs as a result of tipping and uprighting. Resistance to sliding occurs due to the combination of classical friction, bracket-archwire binding, and archwire notching. Tooth movement and biologic tissue response takes place only when the applied forces overcome the friction between the wire and bracket interface. High levels of friction results in little or no tooth movement. During orthodontic tooth movement frictional forces must be eliminated or minimized. Factors influencing the friction may be either mechanical or biologic. Biologic factors include saliva, plaque, acquired pellicle and corrosion[3,4] . Mechanical factors include wire size and morphology, bracket material, slot size, bracket width and angulation, bracket-wire clearance, application of force, type of ligation, torque at the bracket-wire interface, and wire materials[5,6,7,8,9] .

One of the most important components of successful orthodontic treatment is the maintenance of good oral hygiene and caries control. Compromised oral hygiene can lead to enamel demineralization, and decay[10]. During orthodontic treatment, white spot formation around the brackets on the labial surface of bonded or banded teeth have long been considered challenging to the orthodontists while treating their patients.

Daily topical fluoride is commonly prescribed by orthodontists to guard against this complication[11]. Remineralization and reversal of early carious lesion can be achieved by frequent exposure to fluoride through dentifrices, gels, solutions, and varnishes. Arnold M Geiger reported that use of 10ml neutral sodium fluoride rinse during orthodontic treatment resulted in a significant reduction of enamel white spot lesions[12].

Both stainless steel and beta-titanium alloys form corrosion-resistant passivation layer. However, fluoride ions in the prophylactic agents have been reported to cause corrosion, discoloration and alteration of the mechanical properties of wires, particularly when passivated wire surfaces break because of mechanical friction between brackets and wires[13,14].

Mary P. Walker & Richard White have shown that titanium based arch wires particularly NiTi and CuNiTi show occurrence of corrosion, pitting and inclusion bodies on the surface upon exposure to neutral and acidulated fluoride prophylactic agents. Also the wires exhibited deterioration of relevant mechanical properties namely modulus of elasticity and yield strength which may influence effective tooth movement brought about by these wires[15].

It has been reported that fluoride containing prophylactic agents increases the frictional resistance of TMA archwire[13] during orthodontic treatment and it might prolong the treatment period.

The purpose of this study is to evaluate and compare the effects of fluoride prophylactic agents on the mechanical properties of space closure rectangular (TMA and Stainless steel) orthodontic arch wires and to characterize their effects on the surface topography of the wire.

AIM AND OBJECTIVES OF THE STUDY

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AIM:

The aim of the study is to compare the mechanical properties and surface characteristics of the space closure archwires following fluoride treatment with topical fluoride gels and fluoride mouthrinses.

OBJECTIVES

1. To find out whether the mechanical properties and surface characteristics of space closure archwires are affected by topical fluoride treatment with gels and mouthrinses.

2. If so, to find which topical fluoride (gel or mouthrinse) has least adverse effect on the mechanical properties and surface characteristics of space closure archwires.

3. To find out the least affected archwire by fluoride treatment that can be effectively used for space closure during orthodontic treatment.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Charles J. Burstone et al[16] (1980) reviewed the alloys that have been used in the fabrication of orthodontic appliances such as gold based, stainless steel, chrome-cobalt-nickel, nitinol and a new alloy called beta titanium. The beta titanium wire had a wide range of clinical applications because it had a unique balance of low stiffness, high springback, formability, and weldability.

R. P. Kusy[17] (1981) compared the stiffness, strength and range of nickel titanium and beta titanium arch wires with cobalt-chrome or stainless steel wires. With stiffness as the criteria, equivalent force systems were established between the conventional and the new archwire alloys. He concluded that nickel titanium makes superior starting wire, had stiffness similar to multistranded stainless steel wires, with about twice the range and strength in bending. The beta titanium alloy was a good intermediate arch wire. In torsion, stainless steel wire (0.019 by 0.025 inch) had the highest stiffness when compared to nickel-titanium (0.021 by 0.025 inch) or beta titanium (0.019 by 0.025 inch) wire thereby making the finishing wires of choice.

John W. Edie et al[18] (1981) made a study on surface corrosion of nitinol and stainless steel under clinical conditions. He concluded that there was no significant difference between two metals.

Scott R. Drake et al[19] (1983) studied the mechanical properties of three sizes of stainless steel (SS), nickel-titanium (NT), and titanium-molybdenum (TM) orthodontic wires in tension, bending, and torsion. The wires (0.016 inch, 0.017 by 0.025 inch, and 0.019 by 0.025 inch) were tested in the as-received condition. Tensile testing and stiffness testing machines along with a torsional instrument were used. The results showed that, in tension, the titanium-molybdenum wires had the most elastic strain or springback, whereas the stainless steel wires had the least. In bending and torsion, the nickel-titanium wires had the most stored energy at a fixed moment, whereas the stainless steel wires had the least. The results of spring rates in bending and torsion, proved stainless steel wires to be the highest and nickel-titanium wires, the lowest.

Jan G. Stannard et al[9] (1986) measured coefficients of friction for stainless steel, beta-titanium, nickel-titanium, and cobalt-chromium arch wires on a smooth stainless steel or Teflon surface. Coefficients of friction were determined in both dry and wet (artificial saliva) conditions. Stainless steel and beta-titanium wires sliding against stainless steel, and stainless steel wire on Teflon consistently exhibited the lowest dry friction values. Artificial saliva did not increase friction for stainless steel, cobalt chromium sliding against stainless steel, or stainless steel wire on Teflon compared to the dry condition. Beta-titanium and stainless steel wires sliding against stainless steel and stainless steel wire on Teflon showed the lowest friction values for the wet condition.

L.D. Garner et al[8] (1986) conducted a study to evaluate the force required to overcome a simulated canine retraction in one hundred eighty bracket and archwire combinations of nitinol, beta titanium and stainless steel using Instron universal testing machine. The results showed that a significantly larger force is required during canine retraction using beta titanium and nitinol when compared with stainless steel.

Mohammad Kazem Asgharnia et al[20] (1986) compared the bending and conventional tension test for the Stainless steel, cobalt-chromium-nickel (Elgiloy), nitinol, and beta titanium wires with diameters from 0.010 to 0.040 inch and in rectangular sizes from 0.017 x 0.025 to 0.019 x 0.025 inch. The modulus of elasticity (E) and yield strength (YS) of stainless steel and selected Elgiloy wires were obtained with the two mechanical testing procedures as-received and after heat treatment at 900 ° F. Measured values of E and YS in bending were almost higher than the corresponding values obtained in tension.

Robert P. Kusy et al[21] (1988) evaluated the surface roughness of six representative orthodontic archwires using specular reflectance. The results have shown that stainless steel wires were the smoothest, followed by cobalt-chrome, beta-titanium and nickel-titanium.

Sunil Kapila et al[22] (1989) reviewed the clinical applications and mechanical properties of stainless steel, cobalt-chromium, nickel-titanium, beta-titanium, and multistranded wires. Tensile, bending, and torsional tests provide a basis for comparison of mechanical properties of these wires.. Stainless steel wires have remained popular because of their formability, biocompatibility and environmental stability, stiffness, resilience, and low cost. Cobalt-chromium (Co-Cr) wires can be manipulated in a softened state and then subjected to heat treatment. Heat treated Co-Cr wires have properties similar to the stainless steel. Nitinol wires have a good springback, poor formability, joinability and low stiffness. Beta-titanium wires have good springback, average stiffness, good formability, and can be welded to auxiliaries. When compared with stainless steel wires multistranded wires have a high springback and low stiffness.

Dieter Drescher et al[23] (1989) conducted a study about the factors affecting friction in five wire alloys (standard stainless steel, Hi-T stainless steel, Elgiloy blue, nitinol, and TMA) in five wire sizes (0.016, 0.016 x 0.022, 0.017 x 0.025, 0.018, and 0.018 x 0.025 inch) with respect to three bracket widths (2.2, 3.3, and 4.2 mm) at four levels of retarding force (0, 1, 2, and 3 N).The factors affecting friction are in the decreasing order: retarding force (biologic resistance), surface roughness of wire, wire size (vertical dimension), bracket width, and elastic properties of wire. He recommended 0.016 x 0.022 inch stainless steel wire with a medium (3.3 mm) or wide (4.2 mm) bracket for guiding a tooth along a continuous archwire in 0.018 inch slot. The effective force has to increase twice for stainless steel to six times for TMA wire to overcome friction.

D.C. Tidy[24] (1989) investigated the effect of load, bracket width, slot size, arch wire size, and material to measure the frictional resistance along a tooth-archwire interface. He found that friction was proportional to applied load and inversely proportional to bracket width. Arch wire dimension and slot size had little effect on frictional resistance. TMA (beta-titanium) and Nitinol arch wires produced frictional forces five and two times greater than those of stainless steel.

Sunil Kapila et al[25] (1990) made a study to determine the effects of wire size and alloy on frictional force generated between bracket and wire. Several sizes of Stainless steel (SS), cobalt-chromium (Co-Cr), nickel-titanium (NiTi), and β-titanium (β-Ti) wires tested in a narrow single (0.050-inch), medium twin (0.130-inch) and wide twin (0.180-inch) stainless steel brackets in both 0.018- and 0.022-inch slots. Frictional force was measured by compression cell and bracket movement along the wire by mechanical testing machine. He concluded that the levels of frictional forces in 0.018-inch brackets ranged from 49 gms with 0.016-inch SS wires in narrow single brackets to 336 gms with 0.017 x 0.025-inch 13-Ti wires in wide twin brackets. Similarly for 0.022-inch brackets, frictional forces ranged from 40 gms with 0.018-inch SS wires in narrow single brackets to 222 gms with 0.019 x 0.025-inch NiTi wires in wide twin brackets.

Arnold M. Geiger et al[12] (1992) conducted a study to determine the effect of rinsing with a neutral 0.05% sodium fluoride on white spot lesions associated with orthodontic treatment. Patients were instructed to use 10ml of sodium fluoride rinse daily before bedtime. He concluded that sodium fluoride rinse showed reduction in enamel white spot lesions.

Robert L. Boyd[26] (1993) compared the effectiveness of a fluoride toothpaste (1100 ppm**)** used alone, or together with a 0.05% NaF rinse used once daily or a 0.4% SnF_2 gel applied twice daily, in controlling the decalcification during orthodontic treatment. Ninety five patients were examined before and 3 months after the treatment. He concluded that use of 1100 ppm fluoride toothpaste twice daily and either once daily 0.05% NaF rinse or a 0.4% SnF_2 gel twice daily gives additional protection against decalcification than the toothpaste alone.

John P. Klump et al[27] (1994) investigated the ratio of the energy available for tooth movement to the stiffness and flexibility of a wire. Five brands of wire were tested in tension. Two ratios (1) the modulus of resilience/modulus of elasticity (R/E) ratio and (2) the modulus of resilience/elastic compliance (R/C) ratio were measured using three mechanical properties such as the modulus of elasticity (E), modulus of resilience (R), and elastic compliance (C). He concluded that use of two ratios in combination was an effective method to differentiate wire alloys with respect to stored energy.

Niegel G. Taylor et al[28] (1996) made a study to assess frictional forces for three types of 0.022×0.028 inch brackets: Preadjusted stainless steel premolar brackets, Activa brackets and Speed brackets combined with five wire sizes. A model with one attached molar bracket and one or two premolar brackets simulated the buccal segments. The results showed that Activa brackets produced the least friction for all wires tested. Speed brackets with round wires showed little frictional force while rectangular wires gave rise to higher forces, at levels similar to those recorded with two standard straight wire brackets. In all tests, the ratio of static to dynamic friction was remarkably consistent. Different methods of ligation were compared for their effect on static friction. Ligation with loosely placed ligatures or stretched modules reduced frictional forces in standard straight wire brackets, the reduction being greatest for round archwires. Depending on the duration of module in place on the bracket, frictional forces recorded from archwires secured with modules showed a steady reduction over a 3 week period.

Brian P. Loftus et al[29] (1999) conducted a study to evaluate frictional forces during sliding tooth movement in various bracket- archwire combinations on a model. 0.022 inch bracket slot of Conventional and self-ligating stainless steel brackets as well as conventional ceramic brackets, and ceramic brackets with a stainless steel slot were tested with 0.019 × 0.025 inch arch wires of stainless steel, nickel titanium, and beta titanium. Each of the 12 bracket–arch wire combinations was tested 10 times. He concluded that conventional ceramic brackets generated significantly higher friction than the other brackets tested. Beta titanium arch wires produced higher frictional forces than nickel titanium arch wires.

Rupali kumar et al[30] (1999) measured and compared the frictional resistance between the titanium and stainless steel brackets. Edgewise brackets of 0.018 and 0.022 inch slot size were tested with different sized rectangular stainless steel wires in a specially designed apparatus. Instron universal testing machine was used to measure the frictional resistance with a load cell of 10 pound. The specimen population was composed of 180 brackets and 180 wire specimens. He concluded that stainless steel brackets showed higher static and kinetic frictional force as the wire size increased, whereas titanium brackets showed lower static and kinetic frictional force as the wire size increased.

Hera kim et al[31] (1999) made a study to determine the corrosive potential of stainless steel, nitride-coated nickel titanium, nickel titanium, epoxy-coated nickel titanium and titanium orthodontic wires. Wires were immersed in 0.9% NaCl solution with neutral pH and surface changes were measured using scanning electron microscope. The results have shown that epoxy-coated nickel titanium and titanium wires exhibited least corrosive potential and recommends titanium or epoxy coated wires in patients allergic to nickel during orthodontic treatment.

Stanley A. Alexander et al[11] (2000) conducted a study to compare the effectiveness of tooth brushing followed by fluoride gel brushing, fluoride rinsing, or fluoride gel dentifrice brushing alone in controlling the demineralization that often follows orthodontic treatment. Seventy eight patients were divided into 3 groups. Group 1 (control) used a low-potency, high-frequency fluoride rinse; group 2 used a high-potency, high-frequency fluoride brush-on gel; and group 3 used a high-potency, high-frequency fluoride gel dentifrice. He concluded that combination of daily use of a 5000-ppm fluoride gel along with tooth brushing with a fluoride paste or brushing twice daily with a 5000-ppm fluoride dentifrice alone provides better protection than that of brushing with a fluoride paste (1000 ppm) and rinsing with a 0.05% sodium fluoride rinse.

Ikuya Watanabe et al[13] (2003) investigated the effect of fluoride prophylactic agents on the surfaces of titanium-based orthodontic wires. Four types of titanium-based orthodontic wires 2 nickel-titanium alloy wires (nickel-titanium and copper-nickel-titanium) and 2 β-titanium alloy wires (titanium-molybdenum and titanium-niobium), were prepared and immersed in 5 fluoride prophylactic agents (2 acidulated phosphate fluoride agents , 1 neutral agent and 2 stannous fluoride agents) for 5 minutes, 1 hour, and 24 hours. Scanning electron microscope was used to observe the surface changes. The results have shown that titanium – molybdenum wire exhibited higher surface roughness.

Vittorio Cacciafesta et al[32] (2003) measured and compared the level of frictional resistance between stainless steel self-ligating brackets, polycarbonate self-ligating brackets and conventional stainless steel brackets and 3 orthodontic wire alloys: stainless steel, nickel-titanium and beta-titanium. All brackets had a 0.022 slot, whereas the orthodontic wire alloys were tested in 3 different sections: 0.016, 0.017 × 0 .025 and 0.019 × 0.025 inch. Each of the 27 bracket and archwire combinations was tested 10 times and each test was performed with a new bracket-wire sample. Both static and kinetic friction were measured on a custom designed apparatus. The results showed that beta-titanium archwires had higher frictional resistances than stainless steel and nickel-titanium archwires. Stainless steel self-ligating brackets generated significantly lower static and kinetic frictional forces than both conventional stainless steel and polycarbonate self-ligating brackets. All brackets showed higher static and kinetic frictional forces as the wire size increased.

Vinod Krishnan et al[33] (2004) compared the surface characteristics and mechanical properties such as ultimate tensile strength (UTS), 0.02% offset yield strength (YS), and modulus of elasticity (E), load deflection characteristics, frictional properties and elemental analysis for three orthodontic archwire alloys, stainless steel, beta titanium alloy (TMA), and a newly introduced titanium alloy (TiMolium). Scanning electron microscope was used for surface evaluation and an universal testing machine was used for testing mechanical properties. He concluded that Stainless steel was the strongest archwire alloy with high UTS, E, 0.02% offset YS, and less friction at the archwire-bracket interface. TMA wires exhibited better load deflection characteristics with less stiffness than the other two wires. The surface of TMA appeared rough and exhibited very high values for friction at the archwire-bracket interface. TiMolium was intermediate in nature.

Schiff et al[34] (2004) conducted a study to determine the influence of fluoridated mouthwashes on corrosion resistance of orthodontic wires. The titanium based archwires such as TMA, TiNb, NiTi and CuNiTi were tested in three fluoride mouthwashes namely Elmex, Meridol and Acorea as well as in Fusayama Meyer artificial saliva. The wires were classified into two groups. One group contain NiTi based alloys which were subject to strong corrosion in the presence of monofluorophosphate in Acorea solution. The other group were TiNb, which was most resistant to corrosion and TMA, which corroded strongly with the stannous fluoride found in Meridol mouthwash. The results showed that depending on the treatment phase and alloy used, Elmex mouthwash can be prescribed for patients with TMA and NiTi based orthodontic wires.

Robert P. Kusy et al[35] (2004) compared the surface roughness and sliding resistances of 6 titanium based or TMA-type archwires using a scanning electron microscope, an x-ray energy dispersive wavelength analyser, a laser specular reflectometer, and a frictional testing machine. He concluded that the coefficients of friction were independent of surface roughness.

CF Demito et al[36] (2004) made a study to determine the effect of fluoride varnish in reducing demineralization (white spot lesion) adjacent to orthodontic brackets. Extracted bovine incisors, with bonded orthodontic brackets were examined. He concluded that application of fluoride varnish reduce the enamel white spot lesion during fixed orthodontic treatment.

Nicolas Schiff et al[37] (2005) compared the effect of three fluoride mouthwashes (Elmex, Meridol and Acorea) on corrosion resistance of three orthodontic brackets (cobalt–chromium (CoCr), iron–chromium–nickel (FeCrNi) and titanium (Ti) based). A scanning electron microscopic (SEM) study and an analysis of released metal ions confirmed the electrochemical studies. He concluded that Meridol mouthwash should not be used for patients wearing Ti or FeCrNi-based orthodontic brackets because of the risk of corrosion.

Mary P. Walker et al[15] (2005) investigated the effects of fluoride prophylactic agents on the mechanical properties of nickel-titanium (Ni-Ti) and copper-nickel-titanium (Cu-Ni-Ti) orthodontic archwires. Preformed rectangular Ni-Ti and Cu-Ni-Ti wires were immersed in either an acidulated fluoride agent, a neutral fluoride agent, or distilled water (control) for 1.5 hours at 37°C. After immersion, the loading and unloading elastic modulus and yield strength of the wires were measured with a 3-point bend test in a water bath at 37°C. Scanning electron microscopy was used to characterize the wire topography. The results have shown that the functional unloading mechanical properties of the NiTi wire was decreased and surface topography of Cu-Ni-Ti wire was severely affected.

Astrid Verstrynge et al[38] (2006) compared the material characteristics of contemporary stainless steel (SS) and beta-titanium (β-Ti) wires, also known as titanium-molybdenum alloy (TMA). Twenty two different SS and β-Ti wires of size (0.017 × 0.025 inch) were tested for chemical compositions, bending and tensile properties, and surface characteristics. The results have shown that all β-Ti wires showed high surface roughness. TMA had the highest elastic modulus, and most ductile wire. All SS wires showed high yield strength, lowest elastic modulus and lowest hardness value.

Chia -Tze Kao et al[39] (2006) investigated and compared the frictional resistance of metal brackets and orthodontic wires (TMA, NiTi, and SS) after immersion in 0.2% APF. The results have shown that in the APF immersed group, the static frictional force was greater than the kinetic frictional force. The frictional forces of archwires are in progressive order: TMA, NiTi and SSW. He concluded that frictional forces of orthodontic wires and brackets were influenced by fluoride containing solutions.

Mary P. Walker et al[40] (2007) made a study on mechanical properties and surface characterization of beta titanium and stainless steel orthodontic wire following topical fluoride treatment. Rectangular beta titanium and stainless steel wires were immersed in topical fluoride agent or distilled water (control) for 1.5 hours at 37°C. After immersion, the elastic modulus and yield strength of the wires were measured using a 3-point bend test in a water bath at 37°C. Scanning electron microscopy was used to evaluate the wire topography. He concluded that functional unloading mechanical properties of the wires (stainless steel and beta titanium) has decreased and contributes to prolonged orthodontic treatment.

Julie Daems et al[41] (2009) evaluated the morphological characteristics of stainless steel archwires as received and in the bracket archwire contact surface after in vivo orthodontic use. Twenty four stainless steel archwires of different sizes 0.016 × 0.016, 0.016 × 0.022, and 0.017 × 0.025 inches were examined under scanning electron microscopy (SEM). The results showed that increased surface irregularities were observed after orthodontic use and lesser amount in pretreatment wires due to manufacturing process. Crevice corrosion occurred not only at the surface defects but also at the bracket-archwire interface.

Sabane et al[42] (2009) evaluated the effect of fluoride prophylactic agents on mechanical properties and surface topography of various orthodontic archwires. Five types of archwires such as NiTi, CuNiTi, TMA, stainless steel and Australian stainless steel and three fluoride prophylactic agents were used. Archwires were immersed in fluoride agents followed by mechanical properties and surface topography were measured by universal testing machine and scanning electron microscope respectively. He concluded that acidulated fluoride agents causes greater corrosive effects and affect the unloading mechanical properties of archwires.

Isabella Silva Vieira Marques et al[43] (2010) investigated the degree of debris, roughness, and friction of stainless steel orthodontic archwires before and after clinical use (8 weeks). Scanning electron microscopy was used to measure debris level and surface roughness. He concluded that after 8 weeks of intraoral use stainless steel wires showed increased surface roughness and degree of debris.

Chia-Tze Kao et al[14] (2010) conducted a study to compare the corrosion potential of metal brackets and wires in different environment media and to assess the surface characteristics. Two types of orthodontic wires (stainless steel and nickel titanium) and four brands of metal brackets were investigated. Corrosion potential was assessed by an electrochemical assay in different electrolyte media at 37°C. The test media were acidulated sodium fluoride and pH 4 and pH 6 artificial saliva solutions. The results have shown that NiTi and stainless steel wires were corroded in the artificial saliva and metal brackets were easily corroded in NaF. Scanning electron microscopic study showed that pitting corrosion was observed on the surfaces of brackets and wires.

Shubhaker Rao Juvvadi et al[44] (2010) evaluated the physical, mechanical and flexural properties of three orthodontic wires. Eight properties such as ultimate tensile strength (UTS), modulus of elasticity (E), yield strength (YS), and load deflection characteristics, wire dimension, edge bevel, composition, surface characteristics, frictional characteristics of three types of wires stainless steel, titanium-molybdenum alloy, and beta-titanium alloy were evaluated. Frictional characteristics, tensile strength, and 3 point bending were tested using an universal testing machine. Scanning electron microscope and surface profilometer were used for surface evaluation. He concluded that stainless steel was the smoothest wire and TMA was the roughest wire. The beta-titanium alloy wire delivered gentle forces and greater resistance to fracture.

SR Harish Koushik et al[45] (2011) made a study to determine the effects of fluoride prophylactic agents on the mechanical properties of nickel-titanium (NiTi) and copper-nickel-titanium (Cu-NiTi) orthodontic archwires. Preformed rectangular NiTi and Cu-NiTi wires were immersed in fluoride prophylactic agent, or distilled water (control) for 1.5 hours at 37°C. After immersion, the loading and unloading elastic modulus and yield strength of the wires were measured with a 3-point bend test. Scanning electron microscopy was used to characterize the wire topography. He concluded that unloading mechanical properties of NiTi archwires were decreased with fluoride agents and corrosive changes in surface topography were observed.

Masahiro lijima et al[46] (2011) conducted a study to compare the mechanical properties of wire alloys between nanoindentation test and conventional mechanical tests. Archwires (1 stainless steel, 1 cobalt-chromium- nickel, 1 beta-titanium alloy, and 2 nickel-titanium) of size 0.016×0.022-inch were obtained and subjected to nanoindentation testing along the external surfaces and over polished cross sections to obtain values of hardness and elastic modulus. Other specimens of as-received wires were subjected to Vickers hardness, 3-point bending, and tension tests. All testing was performed at 25°C. He concluded that differences were found in hardness and elastic modulus obtained with the nanoindentation test at the external and cross-sectioned surfaces and with the conventional mechanical-property tests. Mechanical properties obtained with the nanoindentation test generally varied with indentation depth.

Shaza M. Hammad et al[47] (2012) compared the effects of fluoride prophylactic agent on the mechanical properties and surface quality of a round translucent composite archwire with nickel titanium and multistranded stainless steel wires. The wires were immersed in an acidulated phosphate fluoride solution (APF) or in distilled water for 1.5 hours at 37°C. Universal testing machine was used to measure flexural modulus of elasticity (E) and yield strength (YS) using three point bending test. Surface changes were observed with a scanning electron microscope. He concluded that topical fluoride agent decreases the mechanical properties and damage the surface of the translucent composite wire.

MATERIALS AND METHODS

MATERIALS AND METHODS

Two types of commercially available rectangular archwires were investigated in this study. The rectangular archwires were stainless steel (0.019×0.025 inch Libral, Okhla Industrial Area, New Delhi, India) and TMA (0.019×0.025 inch Libral, Okhla Industrial Area, New Delhi, India). These wires were selected because these two wires are most frequently used during orthodontic space closure which leaves them exposed to the oral environment for longer periods.

The fluoride agents selected were as follows,

- Acidulated phosphate fluoride gel (APF gel) containing 1.23% *w/w* sodium fluoride with a pH of 3.5 ± 0.5 Pascal company Inc; Bellevue, WA USA)

- Neutral fluoride gel (2 % *w/w* sodium fluoride with a pH of 7 Pascal company Inc; Bellevue, WA USA)

- Phosflur mouth rinse (1.23% sodium fluoride acidulated phosphate; 0.04% *w/v* sodium fluoride pH = 5-6 Colgate oral pharmaceuticals, Inc., Texas, USA).

- Fluoritop (0.044 % *w/v* sodium fluoride, ICPA HEALTH PRODUCTS LTD. 286/287, GIDC, Ankleshwar. 393002, India)

These fluorides were chosen because of their availability, differences in pH and are commonly prescribed by the Orthodontists to their patients.

Artificial saliva was used as a control solution containing glycerin, cellulose gum, sodium saccharin, and parabens. (ICPA HEALTH PRODUCTS LTD. 286/287, GIDC, Ankleshwar. 393002, India).(figure 1)

Thirty (30) specimens were cut from each type of wire. Each wire specimen was 30 mm in length. For each type of wire, six specimens were incubated in artificial saliva in an individual plastic container. Six specimens from each wire group were incubated in each of four fluoride containing agents in individual plastic container for 90 minutes. The exposure time of 90 minutes would be equivalent to three months of 1 minute daily topical fluoride application or fluoride rinse as stated by Mary Walker and Richard White[15].

MECHANICAL TESTING

Before mechanical testing, the specimens were removed from the respective solutions, rinsed with distilled water and placed in a new, clean containers. Specimens were subjected to three point bending test on a universal testing machine (figure 2) with a load cell of 5 KN. The setup included a 3 point fixture comprising two poles placed 12mm apart (figure 3) and compressive force was applied at a crosshead speed of 1mm/min by means of a steel rod placed midway between two poles. Each specimen was loaded to a deflection of 3.1mm. Deflection in millimeters and load in newtons were recorded.

Figure 1. Materials used in the study

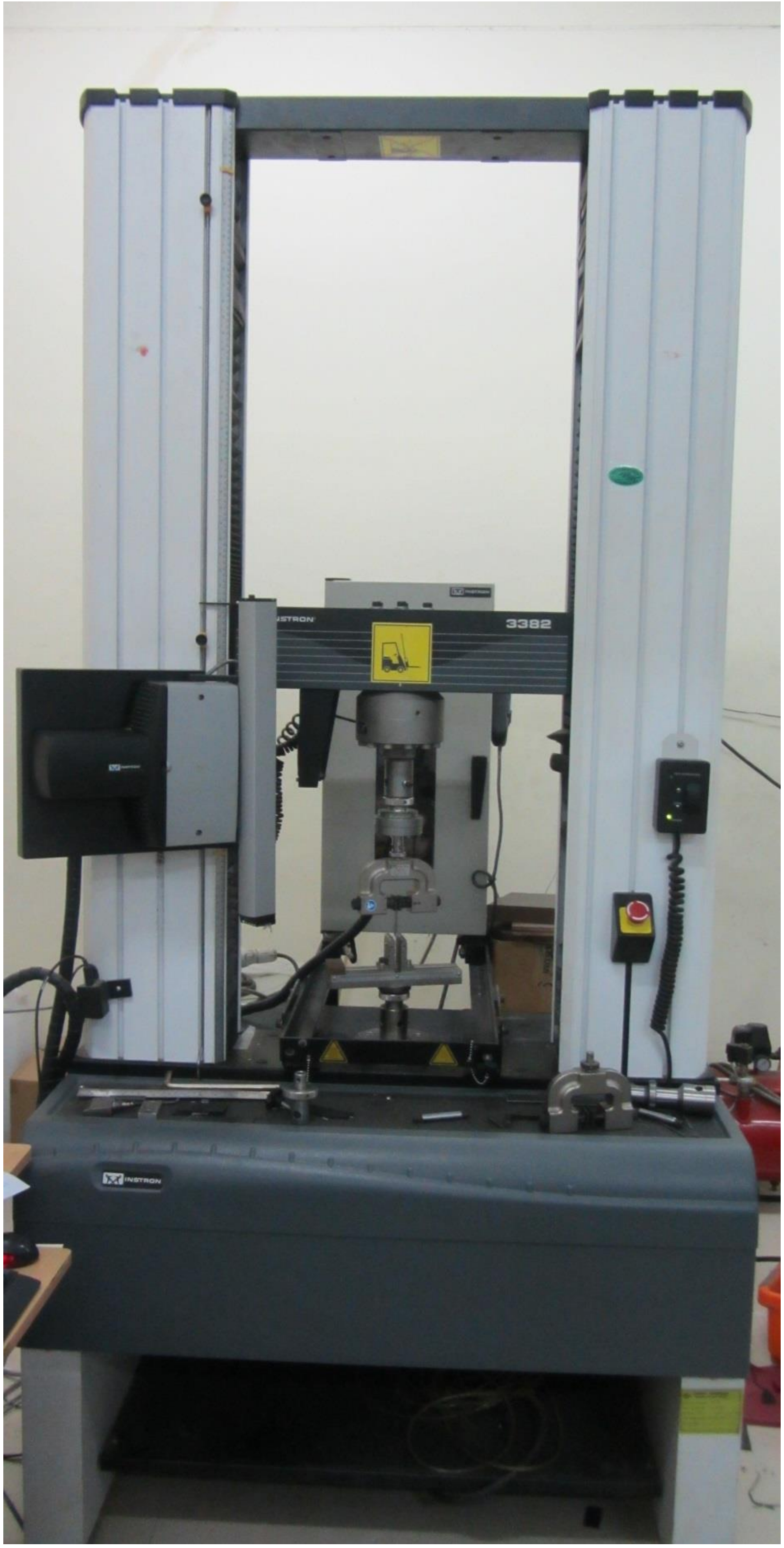


Figure 2. Universal testing machine

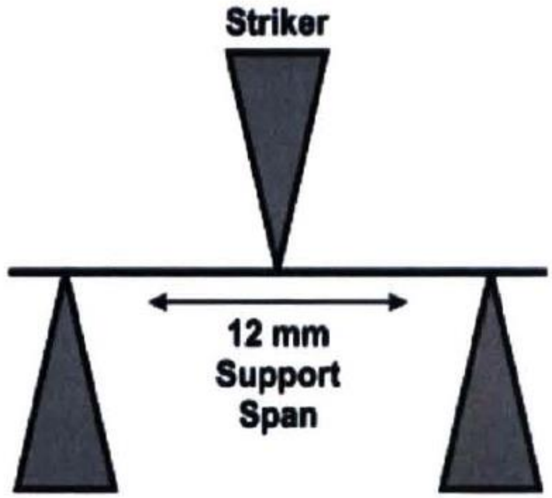


Figure 3.Three point bend fixture configuration

Flexural modulus of elasticity (E) and yield strength (YS) were calculated for each specimen. Springback ratio (YS/E) was calculated for each specimen by dividing yield strength by modulus of elasticity.

WIRE SURFACE CHARACTERIZATION

One representative specimen was selected from each wire group and examined under scanning electron microscope (SEM) (figure 4, 5) at 15 Kv to qualitatively characterize the topography of the wire surface. The specimens were mounted on aluminium SEM stubs and were examined at various magnifications (500X, 1000X, 2500X). This was done to determine whether fluoride prophylactic agents affect the surface topography in the form of pitting, corrosion and inclusion bodies.

Figure 4. Scanning electron microscope setup

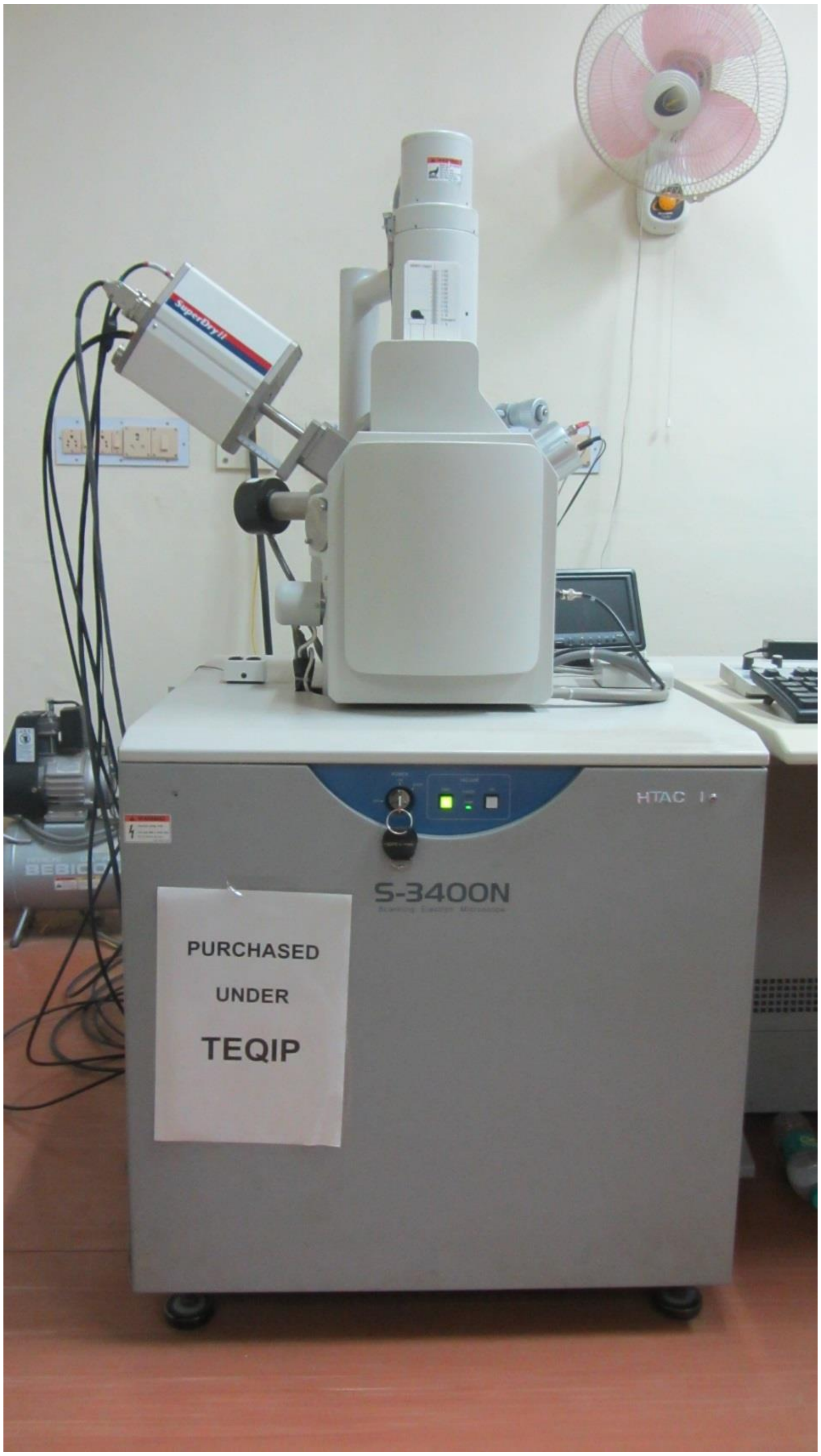


Figure 5. Scanning electron microscope

STATISTICAL ANALYSIS

STATISTICAL ANALYSIS

The mechanical property data were analysed by using a t-test and ANOVA. For each variable, the mean and standard deviation values were calculated. ANOVA (Analysis Of Variance) was used to determine the significance of difference between different groups of fluoride treatment for both Stainless steel and TMA wires. Independent *t*-test was used to determine the significance of difference between control group and different fluoride treatments of both Stainless steel and TMA wires. Level of significance was selected as $P<0.05$ for all tests. All statistical analyses were performed with SPSS software (version 16.0).

The formula used to determine the independent *t*-test was

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

Where

X_1 and X_2 = means for the two groups

S_1 and S_2 = variances of the two groups

n_1 and n_2 = number of participants in each of the two groups

The formula used for the ANOVA analysis was

$$\text{ANOVA} = \frac{\text{BMS} - \text{WMS}}{\text{BMS} + (n-1)\,\text{WMS}}$$

Where

BMS = between subjects mean sum of squares

WMS = within subjects mean sum of squares

n = Number of measurements.

RESULTS

RESULTS

The mechanical properties of the archwire specimens immersed in the prophylactic fluoride agents were compared to the mechanical properties of archwire specimens immersed in artificial saliva (control). The data were analyzed using independent t-test and analysis of variance (ANOVA).

Mean, standard deviation and statistical significance of the mechanical properties of the TMA archwires using independent t-test are shown in table 1 to 4. Mean, standard deviation and statistical significance of the mechanical properties of the stainless steel archwires using independent t-test are shown in table 5 to 8. Mean, standard deviation and statistical significance of the mechanical properties of the TMA archwires using analysis of variance (ANOVA) are shown in table 9. Mean, standard deviation and statistical significance of the mechanical properties of the stainless steel archwires are using analysis of variance (ANOVA) shown in table 10. Mean Values for different Mechanical Properties of TMA Wire in various fluoride prophylactic agents are graphically represented in graph 1 and 2.

The statistical analysis indicated fluoride treatment had no significant effect on mechanical properties of stainless steel and TMA archwires.

SEM observations indicated that surface changes occurred on the surfaces of both wires after immersion in fluoride prophylactic agents.

Representative SEM images of Stainless steel wire exposed to artificial saliva, sodium fluoride rinse, Sodium fluoride gel, APF rinse and APF gel at varying magnifications were shown in figure 6, 8 and 10. The stainless steel wire samples exposed to artificial saliva did not show any alterations in surface topography and no signs of corrosion. Following sodium fluoride rinse and gel treatment, the wire shows almost smooth surface with some bright white spots. Following APF rinse and gel treatment, the surface had a mottled, slightly pitted appearance with some bright white spots which may be due to the action of fluoride.

Representative SEM images of TMA wire exposed to artificial saliva, sodium fluoride rinse, Sodium fluoride gel, APF rinse and APF gel at varying magnifications were shown in figure 7, 9 and 11. As compared to artificial saliva, the exposure to Sodium fluoride rinse, Sodium fluoride gel, APF rinse and APF gel, exhibited rougher surface and the cracks along the wrought structure, indicated more corrosive changes. Especially APF gel showed heavy distortion of the metal surface compared to other fluoride agents.

TABLE 1

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the TMA wires after exposure to Artificial Saliva and Acidulated Phosphate Fluoride gel

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3}± SD
TMA				
	Artificial Saliva(Control)	929.817± 230.02	13.19 ± 3.62	70.88 ± 2.15
	Acidulated Phosphate Fluoride Gel	941.057 ± 210.93	13.49 ± 3.42	70.14 ± 2.39
		t=0.072 P=0.94	t=0.120 P=0.90	t=0.459 P=0.66

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of TMA wire samples following exposure to the acidulated phosphate fluoride gel as compared to the wire samples immersed in artificial saliva.

TABLE 2

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the TMA wires after exposure to Artificial Saliva and Acidulated Phosphate Fluoride rinse.

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3} ± SD
TMA				
	Artificial Saliva(Control)	929.817± 230.02	13.19 ± 3.62	70.88 ± 2.15
	Acidulated Phosphate Fluoride Rinse	851.937 ± 207.68	11.88 ± 3.5	72.37 ± 3.26
		t=0.503 P=0.63	t=0.522 P=0.62	t=0.763 P=0.47

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of TMA wire samples following exposure to the acidulated phosphate fluoride rinse as compared to the wire samples immersed in artificial saliva.

TABLE 3

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the TMA wires after exposure to Artificial Saliva and Sodium Fluoride rinse

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3} ± SD
TMA				
	Artificial Saliva(Control)	929.817± 230.02	13.19 ± 3.62	70.88 ± 2.15
	Sodium Fluoride Rinse	833.395 ± 204.65	12.00 ± 3.29	69.79 ± 2.27
		t=0.626 P=0.55	t=0.488 P=0.64	t=0.691 P=0.51

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of TMA wire samples following exposure to the sodium fluoride rinse as compared to the wire samples immersed in artificial saliva.

TABLE 4

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the TMA wires after exposure to Artificial Saliva and Sodium Fluoride gel

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3}± SD
	Artificial Saliva(Control)	929.817± 230.02	13.19 ± 3.62	70.88 ± 2.15
TMA				
	Sodium Fluoride Gel	920.202 ± 243.41	13.25 ± 3.66	69.61 ± 1.46
		t=0.057 P=0.95	t=0.023 P=0.98	t=0.974 P=0.36

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of TMA wire samples following exposure to the sodium fluoride gel as compared to the wire samples immersed in artificial saliva.

TABLE 5

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the Stainless steel wires after exposure to Artificial Saliva and Acidulated Phosphate Fluoride gel

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3} ± SD
Stainless Steel				
	Artificial Saliva(Control)	2231.57 ± 314.73	47.68 ± 16	46.80 ± 7.38
	Acidulated Phosphate Fluoride Gel	1954.24 ± 292.94	36.73 ± 7.84	53.92 ± 4.54
		t=1.290 P=0.24	t=1.228 P=0.26	t=1.220 P=0.26

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of stainless steel wire samples following exposure to the acidulated phosphate fluoride gel as compared to the wire samples immersed in artificial saliva.

TABLE 6

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the Stainless steel wires after exposure to Artificial Saliva and Acidulated Phosphate Fluoride rinse

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3}± SD
Stainless Steel				
	Artificial Saliva(Control)	2231.57 ± 314.73	47.68 ± 16	46.80 ± 7.38
	Acidulated Phosphate Fluoride Rinse	1901.24 ± 264.69	35.60 ± 6.7	53.92 ± 4.33
		t=2.782 P=0.32	t=2.314 P=0.16	t=2.864 P=0.29

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of stainless steel wire samples following exposure to the acidulated phosphate fluoride rinse as compared to the wire samples immersed in artificial saliva.

TABLE 7

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the Stainless steel wires after exposure to Artificial Saliva and Sodium Fluoride rinse

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3} ± SD
Stainless Steel				
	Artificial Saliva(Control)	2231.57 ± 314.73	47.68 ± 16	46.80 ± 7.38
	Sodium Fluoride Rinse	1895.57 ± 257.44	39.14 ± 4.68	48.43 ± 2.76
		t=4.611 P=0.21	t=2.937 P=0.26	t=3.670 P=0.16

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of stainless steel wire samples following exposure to the sodium fluoride rinse as compared to the wire samples immersed in artificial saliva.

TABLE 8

Comparison of Mean, Standard Deviations and Results of t-Tests of Mechanical Properties of the Stainless steel wires after exposure to Artificial Saliva and Sodium Fluoride gel.

Wire	Treatment	Yield Strength Mpa ± SD	Elastic Modulus Gpa ± SD	Springback Ratio 10^{-3}± SD
Stainless Steel				
	Artificial Saliva(Control)	2231.57 ± 314.73	47.68 ± 16	46.80 ± 7.38
	Sodium Fluoride Gel	2019.53 ± 300.88	41.71 ± 7.57	58.41 ± 4.09
		t=2.732 P=0.14	t=2.196 P=0.09	t=2.408 P=0.18

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of stainless steel wire samples following exposure to the sodium fluoride gel as compared to the wire samples immersed in artificial saliva.

TABLE 9

Mean comparison of mechanical properties of TMA archwires between different fluoride treatment groups

TMA	Sum Of Squares	df	Mean Square	F Value	P-Value
Yield strength					
Between groups	38471.500	4	9617. 875	0.199	0.935
Within groups	725003. 883	15	48333.592		
Total	763475.383	19			
Elastic modulus					
Between groups	9.305	4	2.326	0.189	0.940
Within groups	184.313	15	12.288		
Total	193.619	19			
Springback ratio					
Between groups	20.207	4	5.052	0. 890	0.494
Within groups	85.157	15	5.677		
Total	105.363	19			

The values in the table suggested that there is no significant difference (P>0.05) in the mechanical properties (elastic modulus, yield strength) of TMA wire between different fluoride treatment groups.

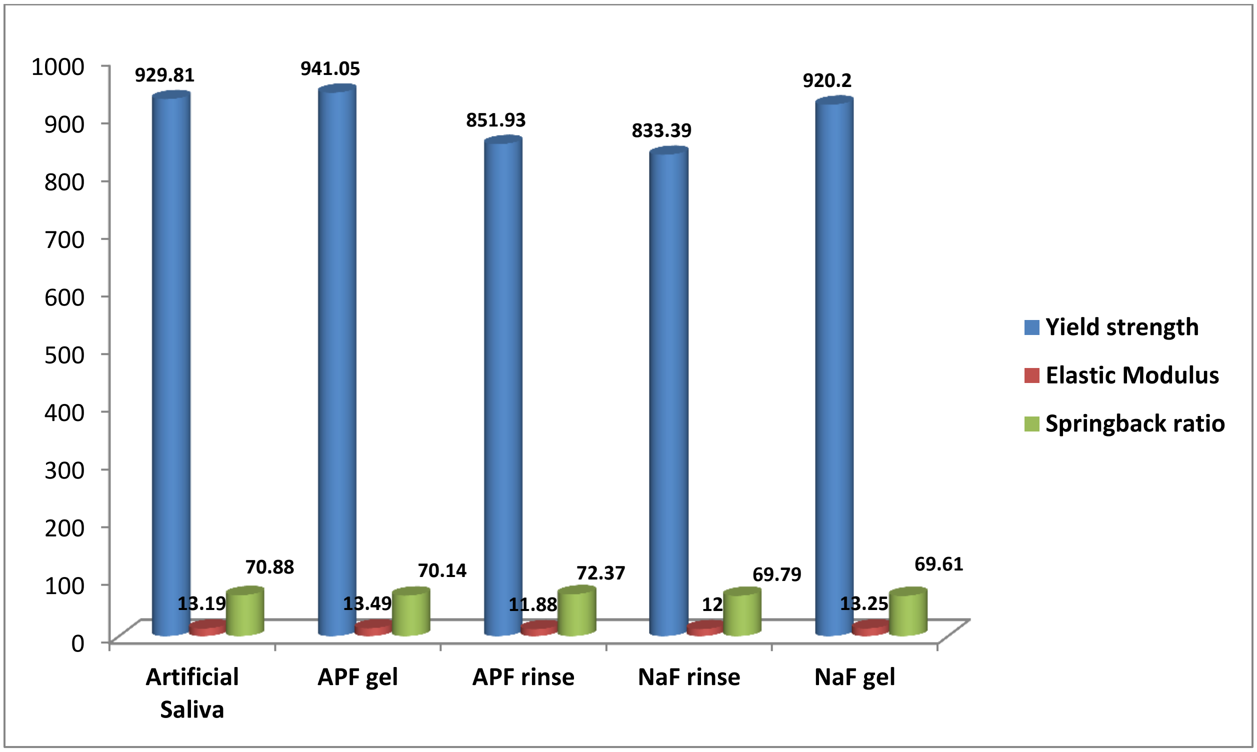
TABLE 10

Mean comparison of mechanical properties of Stainless steel archwires between different fluoride treatment groups

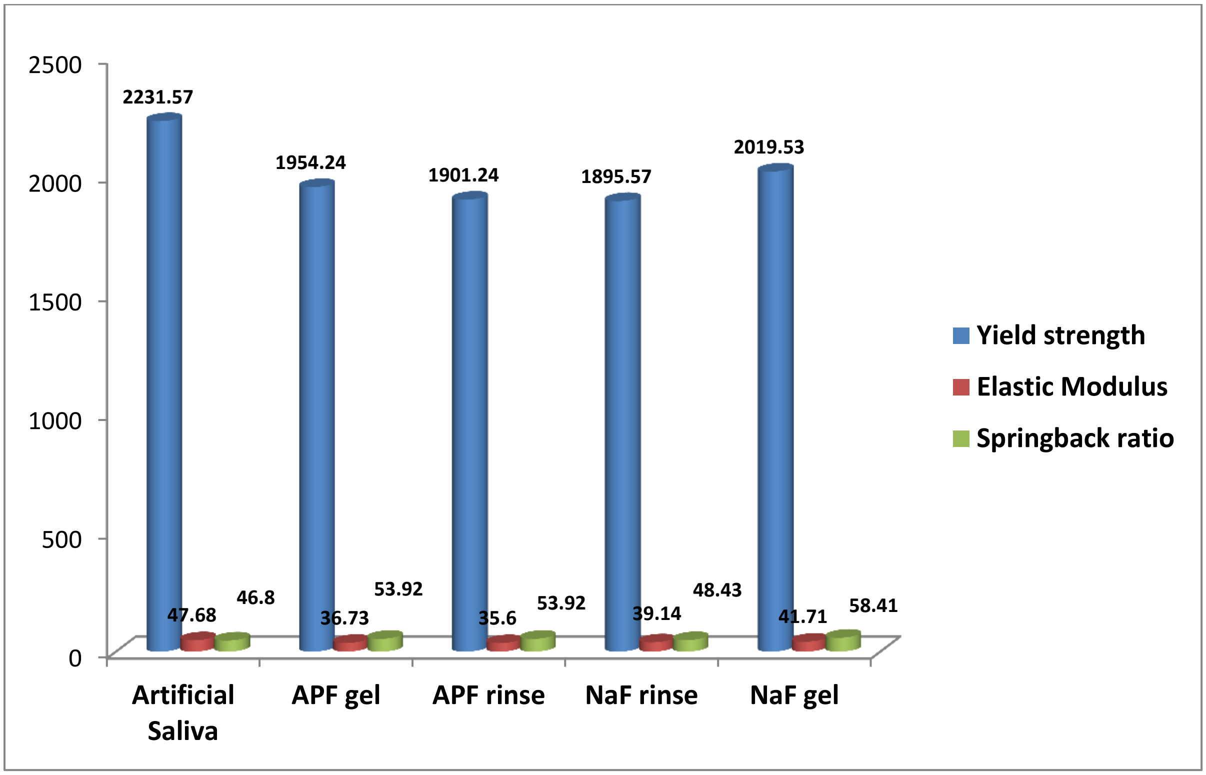
Stainless steel	Sum of squares	df	Mean square	F value	P-value
Yield strength					
Between Groups	1374172.234	4	343543.059	4.968	0.093
Within Groups	1037275.399	15	69151.693		
Total	2411447.634	19			
Elastic modulus					
Between Groups	1438.747	4	359.687	4.275	0.176
Within Groups	1261.947	15	84.130		
Total	2700.694	19			
Springback ratio					
Between Groups	505.485	4	126.371	5.642	0.061
Within Groups	335.969	15	22.398		
Total	841.454	19			

The values in the table suggested that there is no significant difference ($P>0.05$) in the mechanical properties (elastic modulus, yield strength) of stainless steel wire between different fluoride treatment groups.

Graph 1: Mean Values for different Mechanical Properties of TMA Wire in various fluoride prophylactic agents



Graph 2: Mean Values for different Mechanical Properties of Stainless Wire in various fluoride prophylactic agents



Scanning electron microscope (SEM)

The results of scanning electron microscopic images of the stainless steel and TMA wire specimens at varying magnifications are as follows:

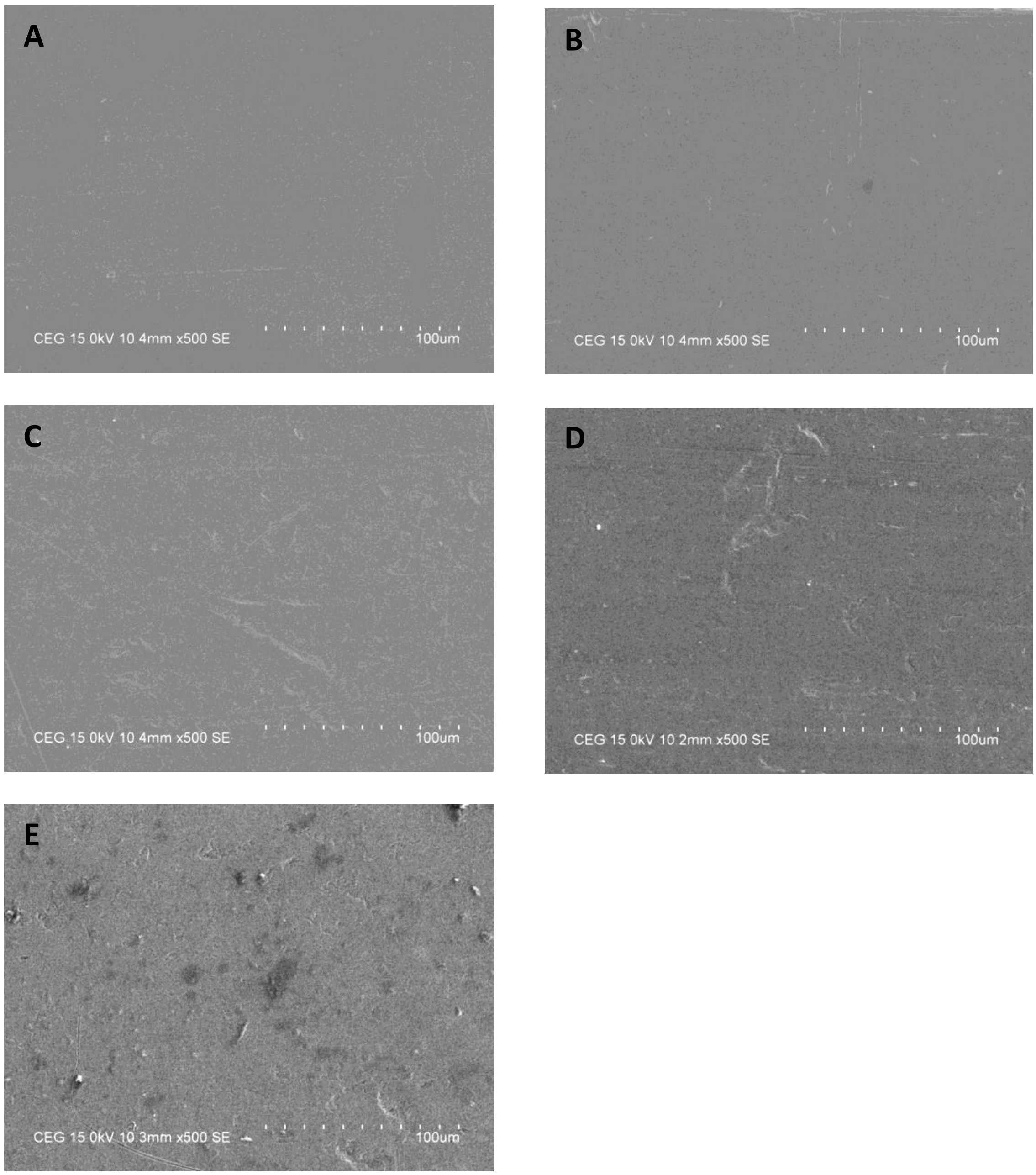


Figure 6. Representative SEM images of Stainless steel wires exposed to (A) Artificial saliva (B) Sodium fluoride rinse (C) Sodium fluoride gel (D) APF rinse (E) APF gel (500x magnification)

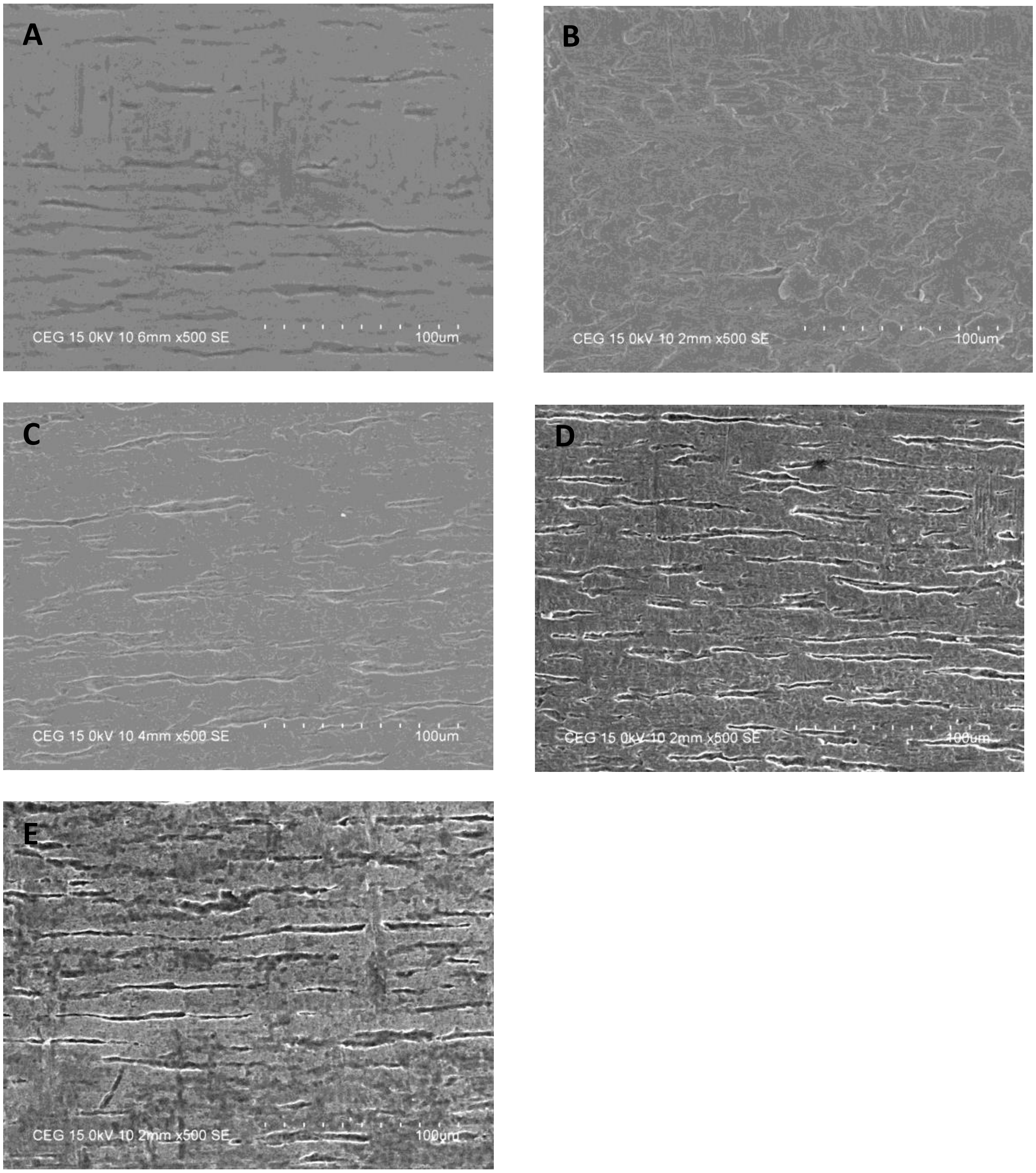


Figure 7. Representative SEM images of TMA wires exposed to (A) Artificial saliva (B) Sodium fluoride rinse (C) Sodium fluoride gel (D) APF rinse (E) APF gel (500x magnification)

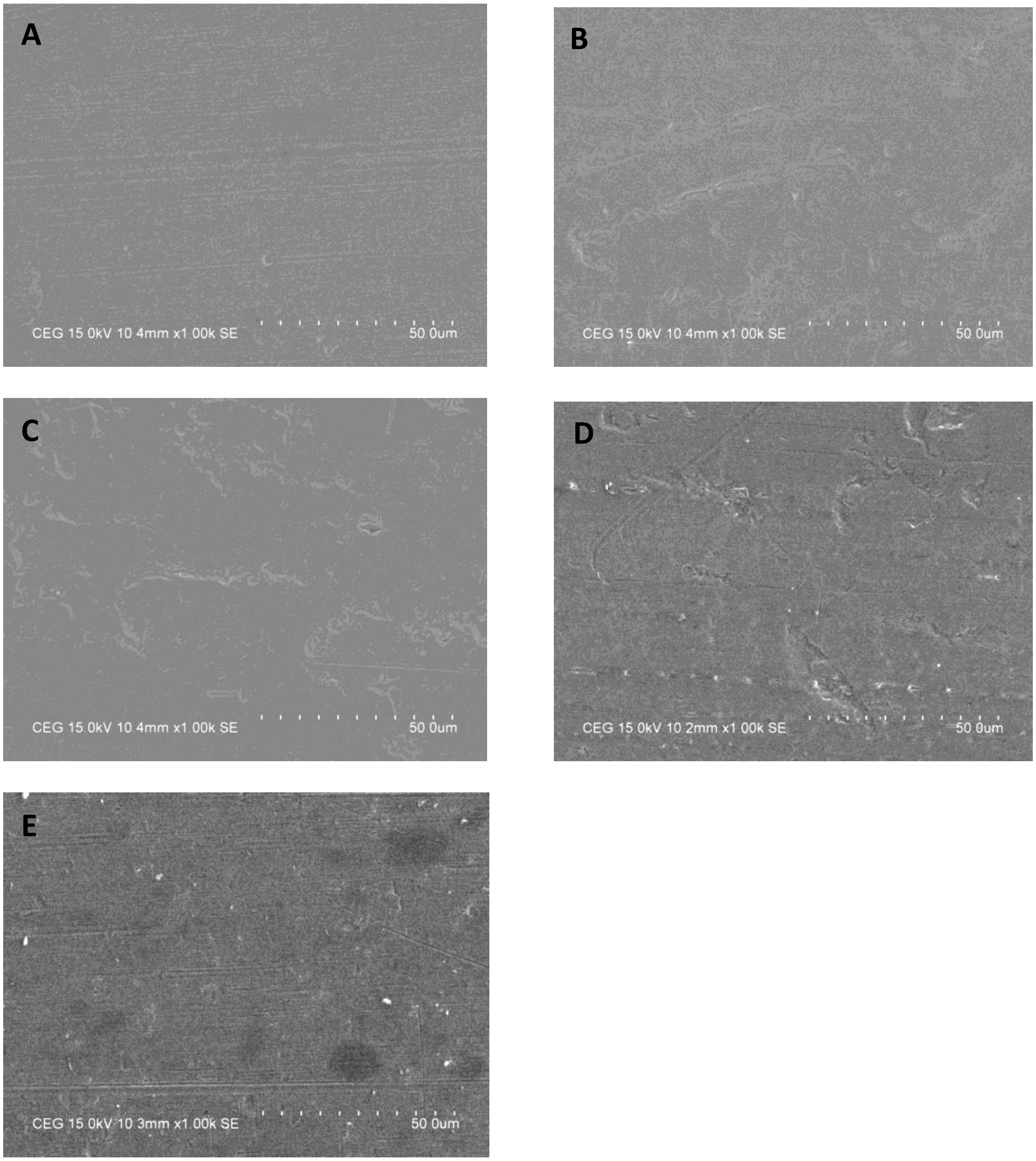


Figure 8. Representative SEM images of Stainless steel wires exposed to (A) Artificial saliva (B) Sodium fluoride rinse (C) Sodium fluoride gel (D) APF rinse (E) APF gel (1000x magnification)

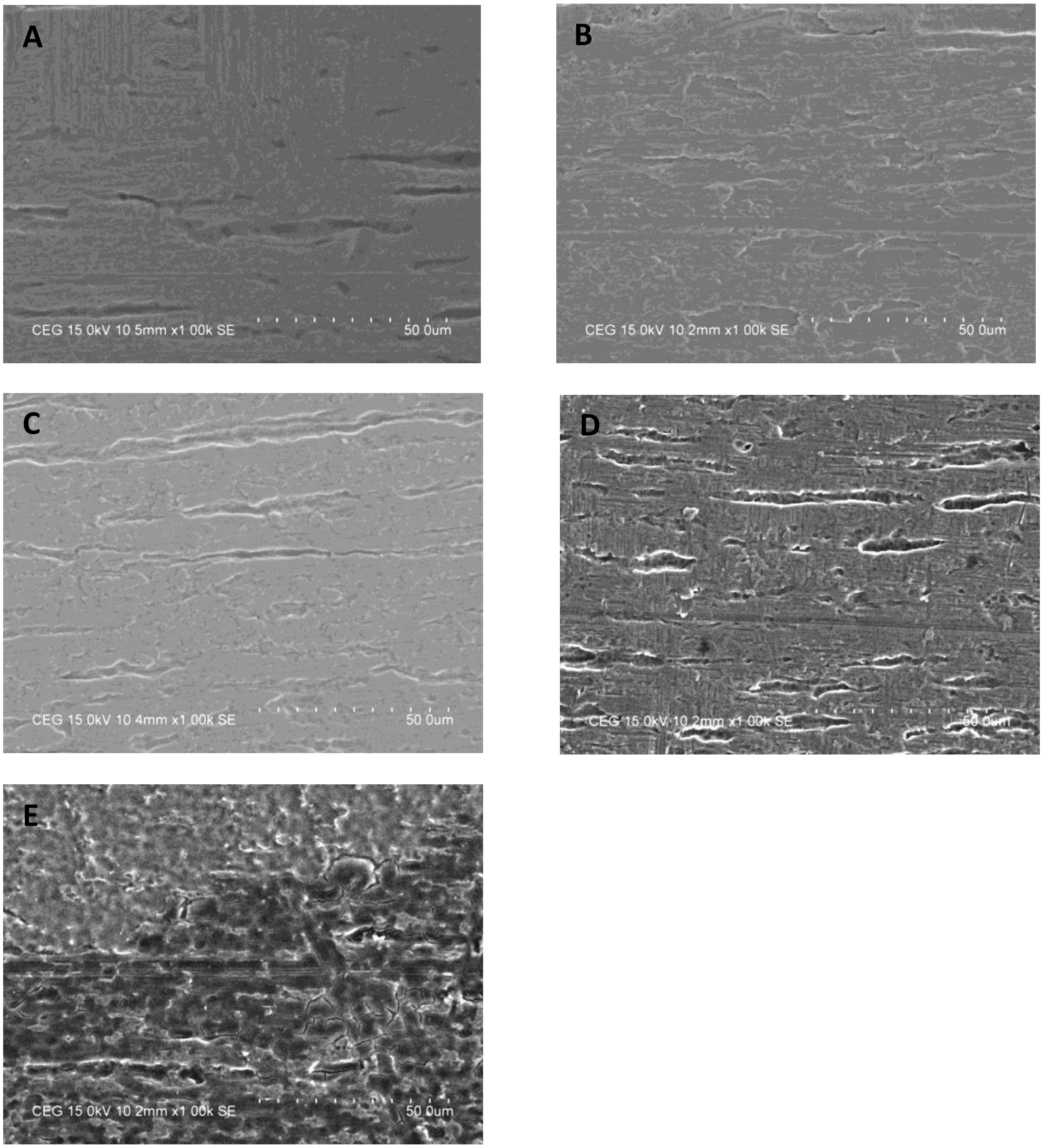


Figure 9. Representative SEM images of TMA wires exposed to (A) Artificial saliva (B) Sodium fluoride rinse (C) Sodium fluoride gel (D) APF rinse (E) APF gel (1000x magnification)

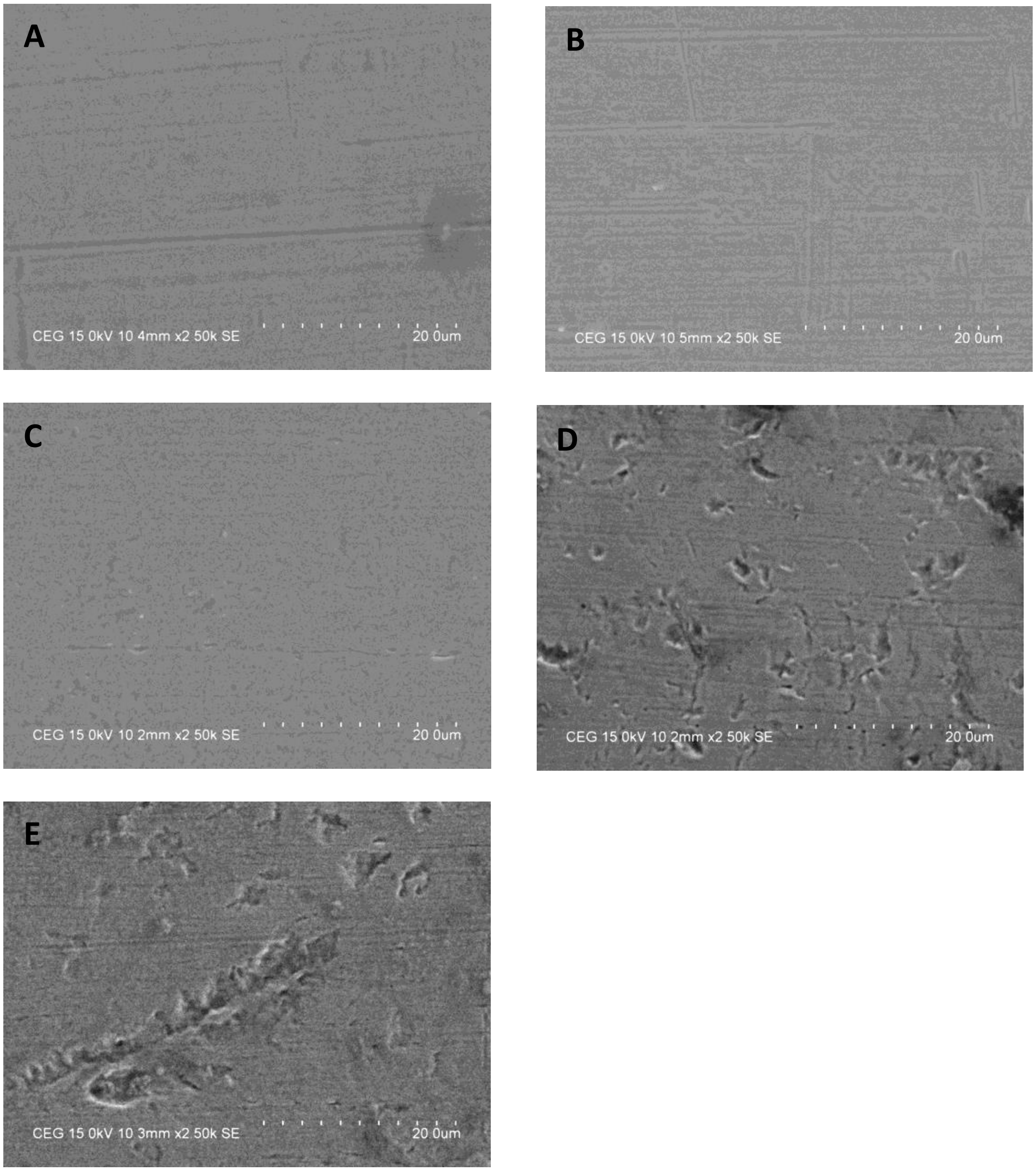


Figure 10. Representative SEM images of Stainless steel wires exposed to (A) Artificial saliva (B) Sodium fluoride rinse (C) Sodium fluoride gel (D) APF rinse (E) APF gel (2500x magnification)

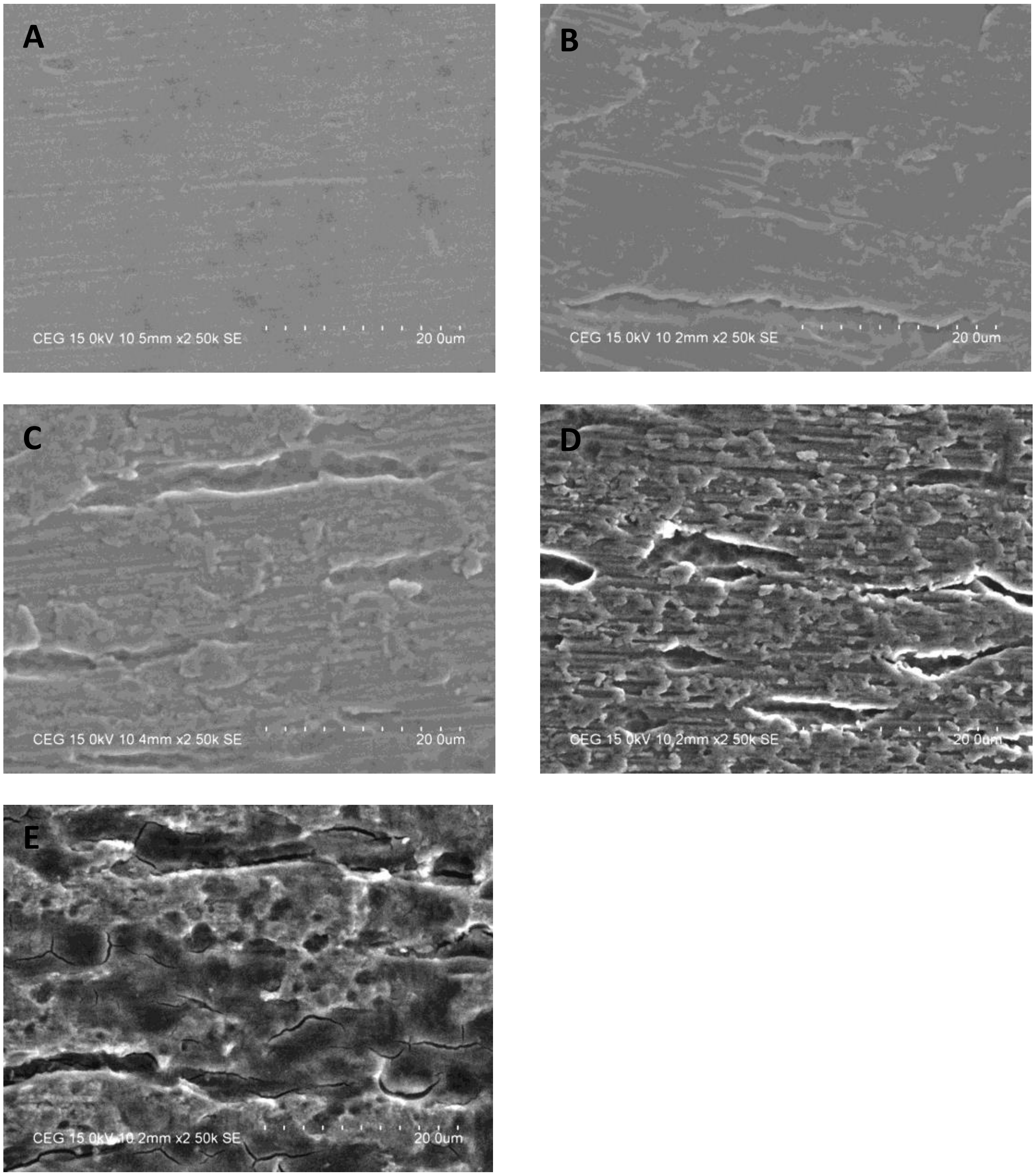


Figure 11. Representative SEM images of TMA wires exposed to (A) Artificial saliva (B) Sodium fluoride rinse (C) Sodium fluoride gel (D) APF rinse (E) APF gel (2500x magnification)

DISCUSSION

DISCUSSION

One of the main disadvantage of direct bonding system is enamel demineralization (white spot lesion) that can occur around orthodontic brackets. It promotes more retention of dental plaque and makes oral hygiene more difficult. Alteration of microbial environment around the bracket area due to poor oral hygiene leads to the cariogenic condition. The prevalence of white spot lesions in patients who seek orthodontic treatment is in the range of 50–96%[12,48,49,50] .

Enamel lesions can occur rapidly (around 4 weeks) after the appliance placement. This suggests that substantial mineral loss around bracket peripheries can occur without being observed clinically. Scanning electron micrographs have demonstrated that although enamel translucency appeared normal, a physical lack of mineral can be observed in the immediate area of the bracket[51].

The clinical advantage of fluoride as an anticariogenic agent has been well documented and topical fluorides have been used extensively in the prevention of demineralization around orthodontic brackets. Geiger et al reported a 25% reduction in the number of patients exhibiting white spot lesions using a home fluoride rinse program[10]. Several meritorious effects of fluorides have been documented with little concern over the deleterious effect of the fluorides on the orthodontic arch wire materials.

The surfaces of all the metals react with oxygen to form a surface oxide layer, which inhibits an attacking substance from reaching the metal surface. The corrosion resistance of beta-titanium, and stainless steel wires depends on the formation of a passivation layer, an oxide film[31,52].

Titanium-based alloys form a passive film of primarily titanium oxides, with titanium dioxide (TiO_2) being the most prevalent and the stainless steel passivation layer is very complex, the protective character is due to chromium oxide (Cr_2O_3). These passivation layer prevents further oxygen diffusion, resulting in corrosion resistance. The archwires become susceptible to corrosion if the passivation layer gets disrupted.

Unlike the previous studies using only acidulated phosphate fluoride agents, this present study used various commercially available topical fluoride gels and mouthrinses and showed their effects on the mechanical properties and surface changes of rectangular archwires used during orthodontic space closure treatment.

In the present study, the effect of fluoride prophylactic agents on the mechanical properties and surface characteristics of stainless steel and TMA archwires were evaluated because of prolonged use during orthodontic space closure.

The mechanical properties evaluated were elastic modulus that refers to the stiffness or flexibility of a material within the elastic range, yield strength (the point on the load deflection curve where permanent deformation is first noticed) and springback ratio. Springback ratio is a very useful index to indicate the clinical performance of the wire in terms of working range, stiffness, resilience and load deflection rate.

Zucchi et al[53] reported that stainless steel archwire undergoes corrosion in physiologic solutions as well as fluoride agents. Studies by Watanabe et al[13], Walker et al[15] and other studies[54,55,56] reported topical fluorides to cause corrosion of titanium based archwires.

SEM images suggested that both sodium fluoride and APF agents produced qualitative surface topography changes on beta-Ti and SS wires that might be the result of fluoride-related disruption of the passive layer. Previous studies showed that when titanium based archwires are exposed to neutral and acidulated topical fluoride agents, hydrofluoric acid is produced according to the equation[15]

$$H_3PO_4 + 3NaF \rightarrow Na_3PO_4 + 3HF$$

The hydrofluoric acid (HF) dissolves the passive oxide layer on the surface of titanium and its alloys according to the following equations

$$TiO_2 + 4HF \rightarrow TiF_4 + 2H_2O$$

$$TiO_2 + 2HF \rightarrow TiOF_2 + H_2O.$$

Once the degradation and loss of the oxide film occurs, it exposes the underlying alloy leading to corrosion and absorption of hydrogen ions because of the high affinity of titanium for hydrogen.

Fluoride containing agents which causes corrosion of these wires may have clinical implication of increased frictional resistance during tooth movement and also the corrosion of wire surfaces may affect the mechanical properties of the archwire because of the phenomenon of hydrogen embrittlement[56].

There are many studies which evaluated and compared the effect of topical fluoride agents on the mechanical properties of titanium based archwies. Toumelin-chemla et al[54] showed that hydrogen embrittlement and increased fracture susceptibility of titanium based orthodontic wires in fluoride solutions.

Hydrogen absorption and its associated embrittlement of titanium based wires have been explained by the diffusion of hydrogen through interstitial sites, grain boundaries and dislocations reacting with lattice atoms to form titanium hydride. This titanium hydride forms a body-centered tetragonal structure, considered to be the cause of related degradation of the mechanical properties.

Mary P Walker et al[15] conducted a study to evaluate the effect of fluoride prophylactic agents on the mechanical properties of nickel-titanium based orthodontic wires and concluded that surface topography and mechanical properties of nickel titanium wire was affected and it could contribute to prolonged orthodontic treatment.

Studies by Kaneko et al[57,58] and Ogawa et al[59] showed that hydrogen absorption of beta-titanium treated with APF solutions cause decreased tensile strength and increased brittle fracture.

In contrast to the previous studies, the present study shows that there is no significant difference in the mechanical properties of TMA archwire following exposure to the topical fluoride agents. This may be due to addition of molybdenum and zirconium to the titanium because of which the titanium based alloy can maintain its body centered cubic lattice referred to as the Beta phase[16]. This may interfere with the formation of titanium hydride and prevent hydrogen embrittlement of the alloy.

Stainless steel orthodontic wires are susceptible to corrosion in experimental fluoride solutions[57]. Similar to the titanium based alloys, once protective oxide layer degradation occurs, hydrogen absorption leading to embrittlement and cause stress corrosion and cracking[60,61]. In contrast to the previous studies, this phenomenon did not occur in the present study as there is no significant difference in the mechanical properties of stainless steel archwire following exposure to the topical fluoride agents.

Both Stainless steel and TMA archwires produced qualitative surface topography changes on exposure to all the experimental topical fluoride agents.

The surface topography of stainless steel wire on exposure to sodium fluoride rinse and gel, shows almost smooth surface and APF rinse and gel cause little corrosive changes like mottled, pitted appearance with white spots. This is similar to the results of previous studies by Walker et al[40] and Kaneko et al[57] conducted on stainless steel and TMA acrhwires following exposure to topical fluoride agents.

The surface topography of TMA wire on exposure to topical fluoride agents shows more corrosive changes and the cracks along the wrought structure. The APF gel particularly showed heavy distortion of the metal surface as compared to other fluoride agents. This is similar to the results of previous studies by Walker et al[40] and Kaneko et al[57] conducted on stainless steel and TMA acrhwires following exposure to topical fluoride agents.

In clinical situations these surface changes may increase the friction at the bracket-wire interface and thereby interfere with effective tooth movement during retraction and contributes to prolonged treatment period.

As with any in vitro investigation, the protocol of the present study cannot exactly simulate clinical conditions. In this study the archwires were exposed to fluoride agent continuously for 1.5 hours. In the clinical application, fluoride exposure would consist of repeated, shorter exposures rather than continuous exposure. Therefore, a future study is needed to address the effects of cumulative, shorter treatments on the mechanical properties of the archwire.

SUMMARY AND CONCLUSION

SUMMARY

The present study has been done

1. To find out whether the mechanical properties and surface characteristics of space closure archwires are affected by topical fluoride treatment with gels and mouthrinses.

2. If so, to find which topical fluoride (gel or mouthrinse) has least adverse effect on the mechanical properties and surface characteristics of space closure archwires.

3. To find out the least affected archwire by fluoride treatment that can be effectively used for space closure during orthodontic treatment.

Rectangular (0.019×0.025) stainless steel and TMA wires were immersed in the artificial saliva and topical fluoride agents for 1.5 hour. The mechanical properties were tested by three point bent test using universal testing machine. The surface changes were examined with the scanning electron microscope.

The results of this in vitro study indicated that, after exposure to prophylactic fluoride agents there was no statistical difference in the mechanical properties of both the beta-titanium and stainless steel wires. SEM images suggested that both the wires are affected and showed corrosive changes following exposure to the topical fluoride agents which may increase the friction at the bracket-wire interface, thereby interfering with effective tooth movement.

CONCLUSION

The following conclusions are drawn from the study:

- Topical fluoride gels and mouthrinses showed no significant differences in the mechanical properties of stainless steel and TMA archwires.
- Both stainless steel and TMA archwires exhibited qualitative surface changes following exposure to topical fluoride gels and mouthrinses.
- Compared to the gels, mouthrinses showed less corrosive changes on the surface of the archwires. Particularly sodium fluoride mouthrinse showed lesser changes on the stainless steel archwire.

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