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Comparison of frictional resistance, tensile strength and flexural modulus of silica and alumina coated stainless steel archwires with two coated archwires – a randomised controlled trial

Naveen Raj Muthuraman[1], Dilip Srinivasan[2], Poornima Jnaneshwar[3], Ravi Kannan[4]

[1] *Department of Orthodontics and Dentofacial Orthopaedics, SRM Dental College, Ramapuram, Chennai, India.*

[2] *Department of Orthodontics and Dentofacial Orthopaedics, SRM Dental College, Ramapuram, Chennai, India.*

Abstract

To determine the effects of alumina and silica coating on the mechanical properties of orthodontic archwires and compare them with precoated aesthetic archwires. Sample size for the randomised control trial was 40 with 10 subjects in four groups, a control group receiving uncoated 0.019 X0.025" stainless steel archwires, two groups receiving commercially available archwires, fourth group received wires first coated with silica followed by alumina. Frictional resistance, tensile strength and flexural modulus of the archwires were tested for before and after six weeks of intraoral engagement. The three parameters tested were evaluated using ANOVA and posthoc Tukey test for intergroup comparison. Student t test was performed to assess the difference in the parameters in the same wire before and after intraoral engagement. SiO_2 and $_{Al2O3}$ coated wires showed statistically significant reduction in frictional resistance (p=0.000) and increase in tensile strength (p=0.000) when compared to the other wires both in as received and retrieved conditions. SiO_2 and Al_2O_3 coated wires showed increased flexural modulus than the other wires but this finding was not statistically significant after six weeks of intraoral ageing (p=0.131). SiO_2 and Al_2O_3 coated wires exhibited superior mechanical properties when compared to other precoated commercially available archwires even after six weeks of intraoral ageing. This provides promise for better utilisation of coated archwires in the future. Coating will increase mechanical properties of archwires.

Keywords: Aesthetic orthodontic archwires, frictional resistance, tensile strength, flexural modulus.

Full length article **Corresponding Author*, e-mail: **naveenmuthu479@gmail.com**

1. Introduction

Adult patients seeking orthodontic care demand an aesthetically appealing appliance. Ceramic brackets have been in use for more than three decades to meet the aesthetic demands of patients [1]. Aesthetic coating of archwires to impart invisibility of all the components of fixed mechanotherapy is not new. Numerous materials have been used for coating orthodontic archwires; polytetrafluoroethylene (Teflon), epoxy resin2, parylene-polymer [3], rhodium [4,5] palladium to name a few. Functional coating of orthodontic archwires with nanosilver particles has also been reported in the literature [6]. Purpose of such coatings is to prevent biofilm adhesion, antimicrobial towards Streptococcus mutans and other microbes thus aiding in prevention of white spot lesion formation [7]. Though coating the archwires with the above mentioned materials gives a pleasing look, it is prudent to expect alteration in the mechanical properties due to the coating. Delamination occurring in the coated archwires may increase friction and corrosive properties of archwires [8], so development of stable coating over the archwires is essential. Color stability of coated archwires during orthodontic treatment is also clinically important, Arthur et al suggested that changes in the optical properties within a polymer coating in the archwire could be responsible for the color changes seen clinically [9]. Coated Nickel Titanium (NiTi) wires studied by Pop et al revealed minor delamination and coating defects over several areas even before exposure to the intraoral environment. Manufacturing process may introduce some defects on wire surface. The coated wires which were retrieved from oral cavity had inhomogeneous surface [10]. Pop et al concluded that plain NiTi wires also displayed surface flaws brought on by the manufacturing process, whereas wires recovered from orthodontic patients which were exposed to oral environment, showed corrosion symptoms in the form of multiple pitting and cracks10. Friction is complex in nature and can result from mechanical or biological reasons. Mechanical considerations are archwire and bracket characteristics, method of ligation, dimension of archwire and angulation between bracket and archwire [11]. The biological variables that impact the frictional resistance in sliding mechanics include saliva, plaque, and pellicle. Friction between the archwire and bracket should be overcome before any effective biological reaction can be elicited. It would be extremely desirable if the frictional resistance is brought to a minimum. Aluminium (Al), the most abundant metal element on earth, has been widely used as biomedical material. Alumina is chemically inert, possesses increased hardness, low density and transparent. Silica dioxide is commonly used as modification layer due to its superior physiochemical stability and favorable biocompatibility [12]. Silica has a better bonding capacity with stainless steel when compared with alumina. Numerous in vitro experiments were conducted to analyze the mechanical and physical characteristics of coated wires, and findings regarding the clinical effectiveness of the archwire material were made. Takashi Usui et al compared frictional resistance of Hard chrome carbide-plated (HCCP) wires with different commercially available esthetic archwires and uncoated archwires and found that commercially available esthetic wires showed higher friction when compared to uncoated wires [13]. Xin Shi Gang coated aluminum oxide over aluminum alloy using micro-arc oxidation and this coating reduced friction significantly [14]. In vitro experimental models cannot perfectly simulate the contribution of oral environment, saliva, pellicle, plaque on ageing of orthodontic archwires. Effect of intraoral ageing on the archwires needs to be studied extensively, if a complete understanding of the changes in mechanical properties of the wire after intraoral ageing needs to be gained. In orthodontic biomechanics, difficulty in reproducing in vitro the multitude of factors that are present in the oral cavity during treatment impedes the interpretation of biomechanical findings further. There have been numerous studies that have evaluated the in-vitro properties of coated archwires but the evaluation of intraoral ageing on the mechanical properties of orthodontic archwires has not been done yet. Therefore, the purpose of this study was to compare the frictional resistance, tensile strength and flexural modulus of SiO2 and Al2O3 coated SS archwires with two commercially available aesthetic coated SS archwires and uncoated SS archwires before and after intraoral engagement for six weeks.

2. Materials and methods

Sample size for this parallel-arm randomised control trial was calculated using G power software version 3.1.9.2 with the power of 90% and alpha error of 0.05, the total sample size was calculated as 2015. Sample size was increased to 40, 10 per group for easier computation. Subjects were randomly allocated by a computer generated blocks with block size of 4 into one of the four groups. Patients who were 18-30 years of age from department of Orthodontics and Dentofacial Orthopaedics, with full complement of permanent teeth excluding third molars, good oral hygiene and those who were treated by non-extraction protocol were included in the study. Patients with multiple missing teeth, those with high caries index, systemic illness like diabetes that would lead to potential xerostomia were excluded from the study.

2.1 Preparation and coating of archwires

After being properly cleaned with distilled water and detergent solution, the specimens (0.019X0.025" SS)(Fig 1) were placed in ethanol for 30 minutes to remove any debris before coating. Coating of SS archwires was done by following the protocol given by S.K.Tiwari et al (12). Silica was coated first for creating a thermodynamically stable silica alumina interface which was followed by alumina coating for aesthetic appearance. Tetraethyl orthosilicate, ethanol, and water were mixed in a 5/5/90% ratio to create the ethanolic silica sol. Before coating, the sol was stored for four days with sporadic stirring. Orthodontic archwires were dipped in silica sol, pulled out at a speed of 0.5 mm/s, and dried at 100°C before being coated with alumina. This procedure was carried out twice to ensure uniform thickness of coating. Nitric acid was added to distilled water and boiled. Aluminium isopropoxide was then added and agitated for evaporation of isopropanol.

Hydrolysis occurred by this reaction

$$2[(CH_3)_2CHO]_3Al+(3+n)H_2O \longrightarrow Al_2O_3.nH_2O+6(CH_3)_2CHOH$$

Concentrated Nitric acid was added to reduce the pH of the above reaction. Alumina (Al_2O_3) was obtained in a fluid form which then was solidified into a colourless gel after cooling to room temperature for proper coating. Before coating the gel was intermittently stirred for four days using magnetic stirrer. The original gel was carefully combined with water to create the proper solution for depositing coatings with 10% Al_2O_3, which was applied using the dip-coating method at a pulling speed of 1 mm/s (Fig 2A). Dip coated samples were air dried before being heated for 15 minutes at 300 °C. The deposition, drying, and heat treatment steps were repeated four times to increase the thickness of coating. The coating was then heated for two hours at 500 °C for proper evaporation of solvents used (Fig 2B).

2.2 Bonding procedure

Before bonding, the teeth were dried with water free air source, isolated with cheek retractor, suction and cotton rolls. The buccal surface of all the teeth were etched with 37% orthophosphoric acid (Eazetch gel, Anabond pvt ltd) for 30 seconds following which, the etched surfaces were rinsed with water for 20 seconds. The teeth were then dried using a water free air source and primer adhesive (Transbond XT, 3M Unitek India ltd) was used to coat over the etched surface and light cured for 10 seconds. Composite resin (Transbond XT, 3M Unitek India ltd) was applied over the bracket base and positioned over the buccal surface of the teeth following the MBT bracket positioning protocol and cured for 40 seconds, 10 seconds on each side of the bracket by a LED curing light(MiniS Light cure, Woodpecker). Initial alignment and levelling were done with sequence of archwires 0.016" Heat activated NiTi (HANT), 0.019X0.025" HANT, 0.019X0.025" SS (3M Unitek). The experimental and the control group archwires were inserted into the brackets and ligated with unstretched elastomeric modules. Forty patients recruited were randomly allocated to four groups of ten each with a block size of four. In group 1 uncoated SS wires of dimension 0.019X0.025” were engaged (Fig 3A), in group 2 esthetic archwires from Rabbit force were engaged (Fig 3B), in group 3 esthetic archwires from U orthodontics were engaged (Fig 3C) and in group 4 SiO_2 and Al_2O_3 coated archwires were engaged (Fig 3D). After six weeks of intraoral engagement, all the archwires were retrieved and subjected to testing procedures (Fig 4). New archwires were also tested along with intraorally aged archwires. All the retrieved archwires were stored in an ethanolic storage medium after disinfected with povidine iodine solution.

2.3 Testing procedure

2.3.1 Frictional resistance test

For frictional testing the wire had to be engaged in brackets bonded on prospex sheets with an interbracket span of 8 mm which was then attached to the instron universal testing machine. A length of 6cm of the distal leg of the archform of the wire were cut off from the new wires and wires retrieved after intraoral use for 6 weeks. This sample wires were carefully inserted into the bracket slot using an unstretched elastomeric module after being physically checked for any obvious distortions. The Universal Testing Machine (Instron) is equipped with two jigs, Perspex sheet with orthodontic bracket was securely fastened to the lower jig of the machine. The upper jig was connected to the wire sample that was inserted into the bracket slot. Both the ends of the wires to be tested were thus directly engaged to the upper jig at one end and bracket bonded to the Perspex sheet which was attached to the lower jig. The crosshead speed was established at 5 mm per minute. The upper jig of the Instron machine pulled the 0.019X0.025" SS wire that is attached to it while moving, and the measurements for the frictional resistance encountered were recorded. The lower jig of the machine was stable, whereas the upper jig travelled at a certain predetermined speed (5 mm/min) (Fig 5A). All 40 samples were subjected to this process frictional testing.

2.3.2 Tensile strength

To test the length of the archwires were reduced to 40mm and the two ends of the archwire were secured to the upper and lower jigs directly. While the lower jig was stable the upper jig pulled the wire with a load of 1000N and a crosshead speed of 1 mm/min, till the wire was stretched until the point of fracture, at which time the readings were recorded (Fig 5B). The value for ultimate tensile strength in Mega Pascal was obtained by dividing the load required to break the wire by its cross-sectional area (Mpa). The same procedure was repeated again for each sample.

2.3.3 Modulus of elasticity

Stress-strain curve was generated for every wire in the process of testing the tensile strength and this curve was used to calculate the flexural modulus.

2.4 Statistical analysis

Statistical analysis was done using IBM Corp (2013), IBM SPSS Statistics for Windows, version 22.0. Armonk, NY: IBM Corp. The continuous variables were described using mean and standard deviation. Normality of the data was assessed by Kolmogorov-Smirnov test. All the three parameters were analyzed using one way analysis of variance (ANOVA) and post-hoc Bonferroni’s method of multiple comparison to determine the statistical difference and compare effect of coating on the archwires. Student ‘t’ test was used to compare the new wires and intraorally aged wires. A probability value of 0.05 or less was considered statistically significant in all the tests. The P value for frictional resistance, tensile strength and flexural modulus for archwires before and after six weeks of intraoral use were standardized at 0.05.

3. Results and Discussions

Frictional resistance, Tensile strength and Flexural modulus of Al_2O_3 and SiO_2 coated 0.019*0.025” Stainless Steel Orthodontic archwire specimens were compared with the properties of uncoated, rabbit force and U orthodontics wires of same dimension for new wire (T0) and after six weeks of intraoral use (T1). When frictional resistance was compared for all the four groups at both the time intervals (T0 and T1) using ANOVA, it was found that frictional resistance of SiO_2 and Al_2O_3 coated wires was significantly reduced when compared to the other wires (P=0.00) (Table 1,2). When Intergroup comparison was done statistically significant difference was found between SiO2 and Al2O3 coated wires and all the other groups of wires at both time intervals but this result was not found between uncoated wires and wires from U orthodontics (P=0.593) at T0 and (P=0.103) at T1(Table 3). Intraorally aged wires of U orthodontics had frictional resistance similar to uncoated controls whereas SiO_2 and Al_2O_3 coated wires exhibited a reduced friction when compared to control (p=0.001) (Table 3). New coated archwires and uncoated control exhibited increased tensile strength values (Table-1). There was a statistically significant increase in tensile strength in the SiO_2 and Al_2O_3 coated new (T0) and intraoral aged wires(T1) when compared to other two commercially available aesthetic wires (P=0.000) (Table 1,2). No difference was found between control and coated archwires at both the time intervals (p=0.353) at T0 (0.054) at T1 (Table 3). Intraorally aged wires of Rabitt force and U Orthodontics had statistically significant difference in tensile strength when compared with SiO_2 and Al_2O_3 coated wires (p=0.000) and (p=0.11) (Table 3) respectively.

There was statistically significant increase in flexural modulus of SiO_2 and Al_2O_3 coated new wires (T0) (P=0.002) but the same trend was not noticed in intraorally aged wires (T1) (P=0.131) (Table 1, 2). Significant difference in flexural modulus was found only between unused rabbit force and U orthodontics wires (P=0.019) and SiO2 and Al_2O_3 coated wires (P=0.002) (Table 3). Student ‘t’ test showed that frictional resistance was greater after intraoral use in uncoated control(p=0.009), U orthodontics(p=0.001) and SiO_2 and Al_2O_3 coated wires(p=0.00) (Table 4). When tensile strength was compared between new wires (T0) and intraorally aged wires (T1), the new wires(T0) had increased tensile strength than used wires- uncoated control(p=0.002), Rabitt force(p=0.006) and SiO_2 and Al_2O_3 coated(p=0.001) (Table 4). Flexural modulus of new wire was higher than used wires in all the four groups (Table 4).

4. Discussion

Friction between archwire and brackets, tensile strength and flexural modulus of the archwires are the three important mechanical properties which would influence the efficacy of orthodontic treatment [16]. Friction determines the amount of applied force which would be available for effective tooth movement, higher the tensile strength higher will be the fracture resistance, flexural modulus determines the stiffness of the archwires. Sol-gel dip coating method, which is more suitable for coating oxides of metals to orthodontic archwires, was used to coat silica and alumina to the surface of stainless steel wires in the present study [17]. Aim of the present study was to evaluate the changes in mechanical properties of stainless steel archwires that received SiO_2 and Al_2O_3 coating and compare the same with different esthetic wires and uncoated conventional wires. Frictional force is influenced by various factors such as type of the archwire and bracket material used, size of the bracket slot, angulation of brackets, dimension of the archwire used, method of ligation, corrosion, load strength and the presence of biofilm and saliva [18]. When placed in oral cavity, the orthodontic archwires are introduced to various conditions such as temperature, saliva and acidic environment which will result in corrosion of the archwire and leakage of metallic ions into the patient's oral cavity. This corrosion of the archwires would weaken and ultimately cause fracture of the material. The corrosion resistance of metallic implants has been improved by using the sol-gel method to deposit ZrO2, silica, alumina [12].

Arici N et al found that wires coated with Aluminium oxide were resistant to corrosion in the intraoral environment and the frictional resistance between metal brackets and NiTi archwires or rectangular SS archwires were decreased by the aluminium oxide coating [8]. Jeyaram et al coated zinc oxide and aluminium oxide over NiTi wires and found that least friction was noted with Zinc oxide coated wires whereas maximum friction was found with uncoated wires[19]. Similarly in the present study aluminium oxide coated wires exhibited lowest friction when compared to uncoated wires. Mochgan Kachoei et al coated ZnO nanoparticles on 0.019X0.025" and 0.016" SS archwires and found that there was a reduction in frictional co-efficient by 51% and 39% respectively [20]. Maryam Karandish et al coated Zincoxide over the Stainless steel wires by Physical vapour deposition and tested for frictional resistance and proved a reduction in frictional resistance of coated archwires [21]. It is evident from present study and the literature that ion coating reduces the frictional resistance of orthodontic archwires which would reduce the unnecessary force dissipation during friction mechanics. Maryam Karandish et al tested for tensile strength and flexural properties of coated SS archwires and found that this coating increased tensile strength and flexural property of the archwires [21]. Pravin Devaprasad et al compared tensile strength of superelastic NiTi archwires from two different manufacturers in three different time periods and concluded that the retrieved wires showed lesser strength when compared to as received wires [22]. Manu Krishnan et al compared corrosional resistance of five surface modified NickelTitanium wires with conventional Niti and concluded that the surface modification of NiTi wires proved to be effective in improving their corrosion resistance and decreasing the surface roughness[23]. Though numerous studies have been done in vitro, very few researchers have evaluated the effect of intraoral ageing on the mechanical properties of orthodontic archwires. Joji Suly Amaya et al compared tensile strength of superelastic NiTi archwires before and after three moths of clinical use and concluded that the retrieved wires showed lesser strength when compared to as received wires [24]. There was a statistically significant increase in tensile strength exhibited by SiO_2 and Al_2O_3 coated archwires (Table1,2). This increase in tensile strength after coating would help to distribute maximum amount of force without fracture, but there was a reduction in tensile strength after six weeks of intraoral use in all the four groups. de Albuquerque et al concluded that flexural strength of coated orthodontic archwires did not depend on the type of coating used [25], which correlates with the results of the present study (Table2). Aruna Dokku et al proved that orthodontic archwires underwent surface degradation after six months of intraoral use [26]. SS wires has more rigidity than other orthodontic archwires, this rigidity is determined by the flexural modulus of that particular wire material. It is evident from the present study that coating the wires did not affect the flexural modulus (Table 1,2). Rabitt force coated wires exhibited significantly reduced flexural modulus.

The marked reduction in the frictional resistance might improve the efficiency of space closure during frictional mechanics, increased tensile strength would increase the toughness of the archwires and this might improve the ability of the archwires to resist fracture, increased flexural modulus would increase the efficiency of the archwires to resist permanent deformation. Though there are various advantages derived from coating the archwires like reduced friction, increased tensile strength and increased flexural modulus, coating of SiO_2 and Al_2O_3 compromised the appearance of the archwires. Dip coating method was used to coat SiO_2 and Al_2O_3 in the present study. After Al_2O_3 coating, there was a significant improvement in esthetic appearance of the wire. The coated wire appeared white till it was cured, curing the coated archwire is an important process for stabilization of coating and evaporation of the solvents. The coated archwire cured at 500°C for two hours. It has been proven by the present research that SiO_2 and Al_2O_3 coated SS archwires exhibited improved mechanical properties when compared to commercially available coated archwires. Future research should focus on improving the coating method to make the wires esthetically more appealing.

Table 1: Demograhic data

Parameter	Groups	n	Mean	SD	f value	P value
Age	Uncoated	10	24.30	3.743	.031	0.992
	Rabitt force	10	24.30	3.653		
	U Orthodontics	10	24.60	3.950		
	SiO2 and Al2O3 coated	10	24.10	3.414		

Table 2: ANOVA for new wires (T0)

Parameters	Groups	n	Mean	SD	f value	P value
Frictional resistance(N)	Uncoated	10	8.56	2.13	82.817	**0.000**
	Rabitt force	10	21.22	4.31		
	U Orthodontics	10	10.02	0.88		
	SiO_2 and Al_2O_3 coated	10	3.59	1.69		
Tensile strength (Mpa)	Uncoated	10	1747.03	102.95	16.526	**0.000**
	Rabitt force	10	1426.51	153.10		
	U Orthodontics	10	1465.44	270.16		
	SiO_2 and Al_2O_3 coated	10	1873.33	83.90		
Flexural modulus (N/mm^2)	Uncoated	10	1708.25	524.21	6.041	**0.002**
	Rabitt force	10	1329.17	380.46		
	U Orthodontics	10	2044.41	360.71		
	SiO_2 and Al_2O_3 coated	10	2248.69	724.52		

Fig 1: As-Received archwires

Table 3: ANOVA for intraorally used wires (T1)

Paramaters	Groups	n	Mean	SD	f value	P value
Frictional resistance(N)	Uncoated	10	10.46	2.27	149.262	**0.000**
	Rabitt force	10	24.14	2.51		
	U Orthodontics	10	12.52	1.66		
	SiO_2 and Al_2O_3 coated	10	6.70	0.96		
Tensile strength (Mpa)	Uncoated	10	1409.49	191.60	8.282	**0.000**
	Rabitt force	10	1253.85	121.20		
	U Orthodontics	10	1363.64	188.44		
	SiO_2 and Al_2O_3 coated	10	1596.14	107.13		
Flexural modulus (N/mm^2)	Uncoated	10	975.22	123.46	2.006	0.131
	Rabitt force	10	991.83	114.37		
	U Orthodontics	10	1047.60	135.66		
	SiO_2 and Al_2O_3 coated	10	1088.58	85.50		

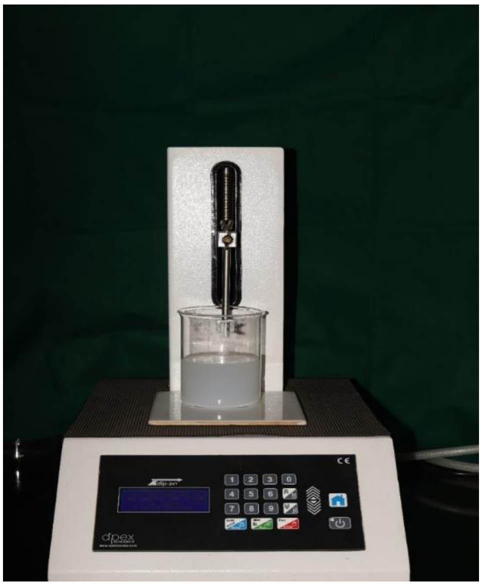

Fig 2A: Dip coating unit

Fig 2B: Furnace

Table 4: Post hoc for T0 and T1

Parametres	Group (I)	Group (J)	Mean Difference (I-J)	p value	95% Confidence Interval	
					Lower Bound	Upper Bound
NEW WIRES (T0)						
Frictinal resistance (N)	Uncoated	Rabitt force	-12.66	**.000**	-15.78	-9.55
		U Orthodontics	-1.45	.593	-4.57	1.66
		SiO_2 , Al_2O_3 coated	4.97	**.001**	1.85	8.09
	Rabitt force	U Orthodontics	11.2	**.000**	8.09	14.32
		SiO_2, Al_2O_3 coated	17.63	**.000**	14.52	20.75
	U Orthodontics	SiO_2, Al_2O_3 coated	6.43	**.000**	3.31	9.54
Tensile strength (Mpa)	Uncoated	Rabitt force	320.52	**.001**	117.13	523.91
		U Orthodontics	281.59	**.004**	78.20	484.98
		SiO_2, Al_2O_3 coated	-126.29	.353	-329.68	77.10
	Rabitt force	U Orthodontics	-38.93	.955	-242.32	164.46
		SiO_2, Al_2O_3 coated	-446.81	**.000**	-650.20	-243.42
	U Orthodontics	SiO_2, Al_2O_3 coated	-407.88	**.000**	-611.27	-204.50
Flexural modulus (N/mm^2)	Uncoated	Rabitt force	379.08	.372	-245.20	1003.35
		U Orthodontics	-336.16	.477	-960.44	288.11
		SiO_2, Al_2O_3 coated	-540.45	.110	-1164.72	83.83
	Rabitt force	U Orthodontics	-715.24	**.019**	-1339.52	-90.96
		SiO_2, Al_2O_3 coated	-919.52	**.002**	-1543.80	-295.25
	U Orthodontics	SiO_2, Al_2O_3 coated	-204.28	.814	-828.56	419.99
INTRAORALLY AGED WIRES (T1)						
Frictinal resistance (N)	Uncoated	Rabitt force	-13.68	**.000**	- 16.03	-11.34
		U Orthodontics	-2.06	.103	-4.40	0.29
		SiO_2, Al_2O_3 coated	3.76	**.001**	1.41	6.10
	Rabitt force	U Orthodontics	11.62	**.000**	9.28	13.97
		SiO_2, Al_2O_3 coated	17.44	**.000**	15.10	19.78
	U Orthodontics	SiO_2, Al_2O_3 coated	5.81	**.000**	3.47	8.16
Tensile strength (Mpa)	Uncoated	Rabitt force	155.64	.137	-33.26	344.53
		U Orthodontics	45.84	.914	-143.05	234.74
		SiO2, Al_2O_3 coated	-186.66	.054	-375.55	2.24
	Rabitt force	U Orthodontics	-109.79	.411	-298.69	79.10
		SiO_2, Al_2O_3 coated	-342.29	**.000**	-531.19	-153.40
	U Orthodontics	SiO_2, Al_2O_3 coated	-232.5	**.011**	-421.39	-43.61

Table 5: Student ‘t’ test

Groups	Parameter	Sub Group	Mean	Std. Deviation	Mean difference	t	p value	95% CI of the Difference	
								Lower	Upper
Uncoated	Frictional resistance(N)	New wires	8.56	2.13	-1.90	-3.346	**.009**	-3.19	-0.62
		Aged wires	10.46	2.27					
	Tensile strength (Mpa)	New wires	1747.03	102.95	337.55	4.330	**.002**	161.18	513.91
		Aged wires	1409.49	191.60					
	Flexural Modulus (N/mm^2)	New wires	1708.25	524.21	733.03	4.502	**.001**	364.67	1101.39
		Aged wires	975.22	123.46					
Rabitt force	Frictional resistance (N)	New wires	21.22	4.31	-2.92	-1.528	.161	-7.24	1.40
		Aged wires	24.14	2.51					
	Tensile strength (Mpa)	New wires	1426.51	153.10	172.66	3.607	**.006**	64.38	280.95
		Aged wires	1253.85	121.20					
	Flexural modulus	New wires	1329.17	380.46	337.33	2.897	**.018**	73.94	600.73
		Aged wires	991.83	114.37					
U Orthodontics	Frictional resistance (N)	New wires	10.02	0.88	-2.50	-5.094	**.001**	-3.61	-1.39
		Aged wires	12.52	1.66					
	Tensile strength (Mpa)	New wires	1465.44	270.16	101.80	1.246	.244	-83.04	286.63
		Aged wires	1363.64	188.44					
	Flexural Modulus (N/mm^2)	New wires	2044.41	360.71	996.81	8.402	**.000**	728.43	1265.19
		Aged wires	1047.60	135.66					
Al2O3 and SiO2	Frictional resistance (N)	New wires	3.59	1.69	-3.11	-5.766	**.000**	-4.34	-1.89
		Aged wires	6.70	0.96					
	Tensile strength (Mpa)	New wires	1873.33	83.90	277.18	7.800	**.001**	196.80	357.56
		Aged wires	1596.14	107.13					
	Flexural Modulus (N/mm^2)	New wires	2248.69	724.52	1160.11	5.027	**.000**	638.02	1682.21
		Aged wires	1088.58	85.50					

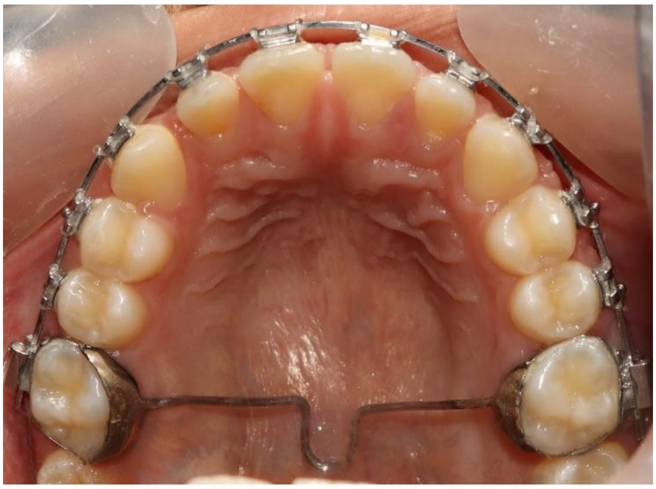

Fig 3A: Uncoated 0.019X0.025” SS

Fig 3B: Rabbit force 0.019X0.025”SS

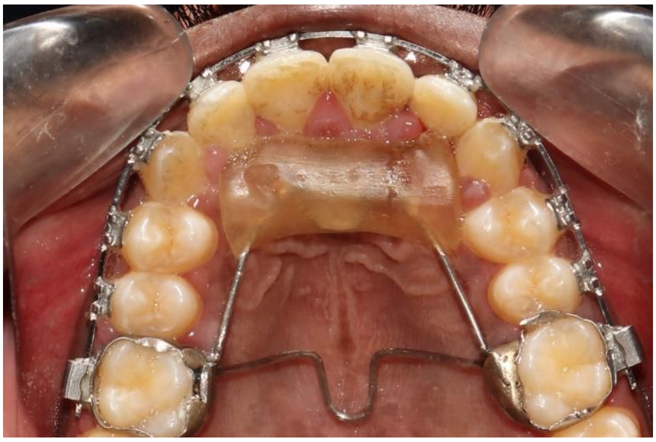

Fig 3C: U Orthodontics 0.019X0.025 SS”

Fig3: D-SiO_2 and Al_2O_3 coated 0.019X0.025"SS

Fig 4: Retrieved archwires were cut into segment of 40mm each after intraoral engagement in orthodontic brackets for six weeks.

Fig 5A: Universal testing machine (Friction)

Fig 5B: Universal testing machine (Tensile strength and Flexural modulus)

4. Conclusions

This study provides the following conclusions

1. SiO_2 and Al_2O_3 dip coating of stainless steel orthodontic archwire reduced frictional resistance, increased tensile strength and no statistically significant difference in flexural modulus of archwires.
2. After exposure to intraoral environment frictional resistance of archwires increased, tensile strength and flexural modulus decreased in all the groups.
3. After exposure to intraoral environment for a period of six weeks, frictional resistance of archwires increased, tensile strength and flexural modulus decreased in all the groups.
4. Regardless of intraoral ageing, silica- alumina coated archwires exhibited decreased.

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