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Research Article

COMPARITIVE STUDY OF FLEXURAL STRENGTH OF UNCOATED, POLYMER-DRUG COATED & TEFLON/TOOTH COLOURED ORTHODONTIC ARCHWIRES

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ABSTRACT

Archwire alloys are available in various forms and shapes for multiple tooth movements like intrusion and retraction of teeth during orthodontic treatment.Coating on archwires can be done by various methods to improve its mechanical and surface corrosion properties. Chemical and thermal passivation, laser welding, laser melting, surface ion implantation and cathodic electrophoretic deposition of functional materials have been used as surface modification treatment to improve its thermal and mechanical properties. In this study, we are planning to do an in-vitro comparative assessment of the flexural strength of uncoated, polymer-drug coated and Teflon/tooth coloured orthodontic archwires.

Keywords :- Archwire alloys, Orthodontic treatment, Uncoated, Polymer-drug coated and Teflon/tooth.

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INTRODUCTION

Archwire alloys are available in various forms and shapes for multiple tooth movements like intrusion and retraction of teeth during orthodontic treatment. Stainless steel archwires have always been the mainstay for this phase of treatment. Titanium-based archwire is also used for this purpose.In Earlier days gold wires were used for orthodontic treatment. Due to the cost factor, it has been replaced by stainless steel wires, which has improved mechanical and physical properties.

More recently, Co -Cr, Ni-Ti, B-TMA and multi stranded stainless archwires have been developed with a good range of physical and mechanical properties.

Nickel titanium (NiTi) archwires are widely used during the alignment phase of orthodontic straight-wire mechanics. These archwires have unique properties of superelasticity and shape memory which are responsible for their growing use among clinicians.

Titanium molybdenum alloys: Mechanical properties of these wires are generally assessed by tensile, bending, and torsion tests. Although wire characteristics determined by these tests do not necessarily reflect the behavior of the wires

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under clinical conditions, they provide a basis for comparison of these wires. .

Nitinol alloy has been extensively studied as an implant material for biomedical applications (orthodontic wires, self-expanding cardiovascular and urological stents, bone implants and tiny surgery tools). Its good corrosion resistance and biocompatibility with the human body can be attributed to a layer comprised mainly of TiO2, with a small amount of NiO on the outermost surface layer [1].

Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene that has numerous applications. The best known brand name of PTFE-based formulas is Teflon by Chemours. Chemours is a spin-off of DuPont, which originally discovered the compound in 1938.

Coating on archwires can be done by various methods to improve its mechanical and surface corrosion properties. Chemical and thermal passivation, laser welding, laser melting, surface ion implantation and cathodic electrophoretic deposition of functional materials has been used as surface modification treatment to improve its thermal and mechanical properties.

In this study, we are planning to do an in-vitro comparative assessment of the flexural strength of uncoated, polymer-drug coated and Teflon/tooth coloured orthodontic archwires.

MATERIALS AND METHODOLOGY

Nickel titanium wires- Uncoated, Polymer-Nanosilver coated and Teflon/Tooth coloured wires, PTFE, PFA.

Nano laboratory materials :

Planar magnetron sputtering unit (Adulon Polymers, Coimbatore) Scanning electron microscope (Mechanical department, Anna University Chennai)

METHOD OF PREPARATION OF NANO SILVER COATED ORTHODONTIC ARCHWIRES

Surface modification of Nickel titanium orthodontic archwires with Ag nanoparticles was carried out by Adulon polymers laboratory, Coimbatore, by a process of electrodeposition/sputtering.

Sputtering process remove surface atoms or molecular fragment from a solid cathode (target) by bombarding it with positive ions from an inert gas (argon) discharge, and deposit them on the nearby substrate to form a thin film. Substrates are placed in a vacuum chamber and are pumped down to a prescribed process pressure. Sputtering starts when a negative charge is applied to the target material causing a plasma or glow discharge. Positively charged gas ions generated in the plasma region are attracted to the negatively biased target plate at a very high rate of speed. This collision creates a momentum transfer and ejects atomically sized particles from the target. These particles are deposited as a thin film on to the surface of the substrates.

In this study, sputtering was carried out on Niti orthodontic wires (substrates) using silver(ag) as the target. A plasma generated inside the vacuumised chamber ejected surface atoms from the silver target, which were sputtered on to the stainless steel brackets (substrates). The distance between the substrate and the target was kept constant at 7 cm and sputtering was conducted for a period of 10 minutes. All archwires were sputtered at the same time to achieve a thin and uniform coating of silver.

METHODS

This study was done on 100 specimens of orthodontic archwires for each of the tests. The specimens were divided into 2 test groups. Each group consisted of 25 specimens.

STUDY DESIGN

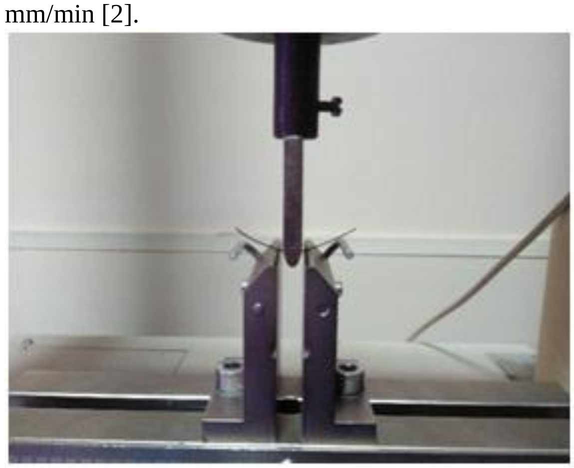
Study was allocated into 2 groups (experimental study)
-25 wires in each control groups (25*2=50)
-25 wires in each experimental group (25*2=50)

MECHANICAL PROPERTIES

Flexural strength: The orthodontic wires were subjected to 3-point bending or flexural strength by placing the specimen and supporting the wire at both the ends at a span length of 12mm. The specimens were stressed in the middle of the wire at a cross head speed of 0.5mm/min to a deflection of 3mm. The flexural strength and modulus were automatically computed by the software (n = 5).

Flexural strength testing

A three-point bending test was carried out for the specimen wires (n = 5). The span size for the wire segments, 12 mm, was chosen in accordance with ANSI/ADA Specification No. 32.11 All samples were loaded to a deflection of 3 mm (loading process) and then unloaded (unloading process) at a rate of 0.5 mm/min [2].



FLEXURAL STRESS MEASUREMENTS

AMPLE B1	MAX. FLEX STRESS (Mpa)	MODULUS (AUTOMATIC) (Mpa)	FLEXURAL STRESS AT YIELD(Mpa)	LOAD AT MAX FLEXURE STRESS (N)
1	1233.01	76823.37	970.9	-2.78
2	1155.35	71683.09	979.6	-2.61
3	1255.11	70288.12	1070.55	-2.83
4	1234.03	74309.72	999.67	-2.78
5	1216.8	72335.9	1025.03	-2.74
MEAN	1218.86	73088.04	1009.15	-2.748
S.D.	34.0064041	2272.634741	35.91175239	0.074672619
SAMPLE B2				
1	821.15	60316	645.63	-4.01
2	884.055	72536.7	726.62	-4.32
3	880.64	68373.78	710.96	-4.31
4	900.64	69627.19	749.93	-4.4
5	900.72	68315.83	696.67	-4.4
MEAN	877.441	67833.9	705.962	-4.288
S.D.	29.33516906	4058.934939	34.96057631	0.144138822
SAMPLE C1				
1	1015.22	54658.68	712.1	-2.83
2	850.67	55939.33	692.5	-2.37
3	567.32	27005.79	441.68	-1.58
4	1013.8	60371.32	676.13	-2.83
5	847.07	58936.77	657.1	-2.36
MEAN	858.816	51382.378	635.902	-2.394
S.D.	163.4970919	12357.89566	98.79200502	0.457060171
SAMPLE C2				
1	704.69	50457.54	577.31	-4.55
2	635.42	46844.19	465.67	-4.1
3	739.46	53720.63	584.07	-4.77
4	658.88	43497.54	505.27	-4.25
5	680.04	45339.82	533.88	-4.39
MEAN	683.698	47971.944	533.24	-4.412
S.D.	36.0836364	3672.758505	44.43937263	0.232929174

SAMPLE A1				
1	491.59	24706.89	414.07	-3.96
2	469.2	25722.64	380.24	-3.78
3	426.3	26023.72	378.1	-3.44
4	478.84	28180.78	381.66	-3.86
5	468.07	25702.31	386.84	-3.77
MEAN	466.8	26067.268	388.182	-3.762
S.D.	21.94141563	1146.422305	13.26083014	0.174859944
SAMPLE A2				
1	741.58	33314.39	626.25	-2.36
2	699.83	31436.33	576.52	-2.23
3	784.5	33857.62	613.05	-2.5
4	627.35	29430.92	513.62	-2
5	629.38	29460.91	533.63	-2
MEAN	696.528	31500.034	572.614	-2.218
S.D.	61.76424254	1859.75359	43.65132694	0.197423403

Sample A1 denotes polymer-drug coated 0.016 inch round Niti arch wire.

Sample A2 denotes polymer-drug coated 0.016*0.022 inch rectangular Niti arch wire

The mean of A2 is higher than the mean A1, in the maximum flexural stress group and the standard deviation of A2 is also higher than A1. This shows group of A2 the rectangular wire of polymer coated are having higher flexural stress than the polymer coated round wire A1.

In the modulus of elasticity the mean of group A1 is 26067 and the mean of A2 is 31500.This shows that A2 has the higher modulus than A1. So the polymer coated rectangular wire has higher flexural modulus than the round wires.

The flexural stress at yield at Mpa values at the mean of A2 is 572.6 higher than the A1 that is 388.18. This shows that the flexural yield is higher in the rectangular wire than the round wire in the polymer coated wires tested.

The load at maximum flexure is higher in the rectangular wire of -2.2 and for the round wire is -3.7, so A2 has higher stress at the maximum load than A1. (Sigma A1=537.75N, A2=1572N)

Sample B1 denotes uncoated 0.016 inch round wire

Sample B2 denotes uncoated 0.016*0.022 inch rectangular wire

The mean of B1 is higher than the mean B2, in the maximum flexural stress group and the standard deviation of B2 is also higher than B1`. This shows group B1 the round wire of uncoated are of higher in flexural strength than the uncoated rectangular wire B2.

In the modulus of elasticity the mean of group B1 is 73088 and the mean of B2 is 67833. This shows that the B1 has the higher modulus than B2. So the uncoated round wire has the higher modulus than uncoated rectangular wire.

The flexural stress at yield at Mpa values at the mean of B1 is 1009.15 higher than the B2 that is 705.96. This shows that the flexural yield is higher in the round wire than the rectangular wire in the uncoated wires tested [3].

The load at maximum flexure is higher in the round uncoated wire of -2.7 and for the rectangular uncoated wire is -4.2, so B1 has higher stress at the maximum load than B2. (Sigma B1=1404N,B2=1981N)

Sample C1 denotes tooth coloured/Teflon 0.016 inch round wire

Sample C2 denotes tooth coloured/Teflon 0.016*0.022 inch rectangular wire.

The mean of C1is higher than the mean C2, in the maximum flexural stress group and the standard deviation of C1 is also higher than C2. This shows group of C1 the round wire of Teflon coated are of higher in flexural strength than the Teflon coated rectangular wire C2.

In the modulus, the mean of group C1 is 51382 and the mean of C2 is 49971. This shows that the C1 has the higher modulus than the C2. So the Teflon coated round wire has the higher modulus than the Teflon coated rectangular wire.

The flexural stress at yield at Mpa values, the mean of C1 is 635.902 higher than the C2 that is 533.24. This shows that the flexural yield is higher in the round wire than the rectangular wire in the Teflon-coated wires tested.

The load at maximum flexure is higher in the round Teflon coated wire of -2.4 and for the rectangular Teflon coated wire is -4.4 so C1 has higher stress at the maximum load than C2. (Sigma C1=989N, C2=1543N)

The results show that mean of maximum flexural stress of B1,B2 is greater than A1,A2 & C1,C2 which indicates uncoated wires have greater stress than polymer-coated and tooth coloured samples of both dimensions.

Also, the mean of modulus and flexural stress at yield follows the same pattern in both round and rectangular dimensions.

Whereas, load at maximum flexural stress is greatest for A1 when compared to B1 & C1 and least for A2 followed by C2 & B2 respectively.

Based on the results rectangular polymer-coated wires have maximum flexural strength when compared to round wires of same category and comparable levels to rectangular Teflon-coated/tooth coloured wire samples [4].

FLEXURAL STRESS MEASUREMENTS

		MAX. FLEX STRESS (Mpa)	
		Mean	SD
Group	Group A1	466.80000	24.53125
	Group A2	696.52800	69.05452
	Group B1	1218.86000	38.02032
	Group B2	877.44100	32.79772
	Group C1	858.81600	182.79531
	Group C2	683.69800	40.34273

The flexural stress measurement the groups of A1,A2,B1,B2,C1 and C2 evaluated and tabulate in tabular form 53.

In this the uncoated round wire has the maximum flexural stress values 1218 Mpa and then comes the uncoated rectangular wire of value 877 Mpa. Among the test materials Teflon coated round wires has the maximum mean value of 858 Mpa and the next value closest to the high flexural stress is polymer coated rectangular wire of 696 Mpa

One way ANOVA

MAX. FLEX STRESS (Mpa)

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	160077 1.073	5	320154.21 5	44.742	.000
Within Groups	171732. 815	24	7155.534		
Total	177250 3.887	29			

The one way Anova test statistically implies that the F. value is 44.742 and the significant level of .000.

T-Test - Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
MAX. FLEX STRESS (Mpa)	Group A1	5	466.8000000	24.53124844	10.97070782
	Group A2	5	696.5280000	69.05452244	30.88212127

In this polymer-coated round wire has the maximum flexural stress values 466.800 Mpa and then comes the polymer coated rectangular wire of value 696.528Mpa. This shows polymer-coated rectangular wire has more flexural values.

T-Test

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
MAX. FLEX STRESS (Mpa)	Group B1	5	1218.8600000	38.02031562	17.00320205
	Group B2	5	877.4410000	32.79771608	14.66758453

In this uncoated round wire has the maximum flexural stress values 1218.86. Mpa and then comes uncoated rectangular wire of value 877.441Mpa. This shows Uncoated round wire has more flexural values.

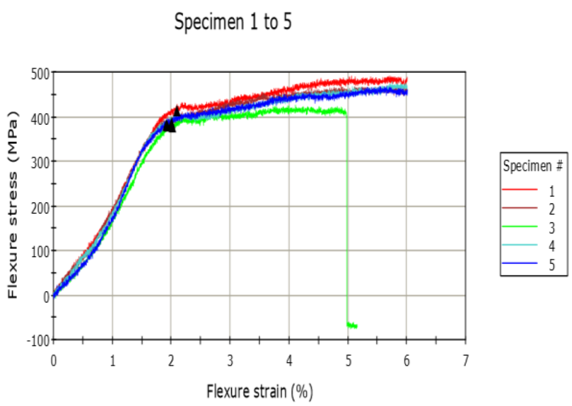
T-Test

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
MAX. FLEX STRESS (Mpa)	Group C1	5	858.8166000	182.79530582	81.74854596
	Group C2	5	683.6980000	40.34273194	18.04181820

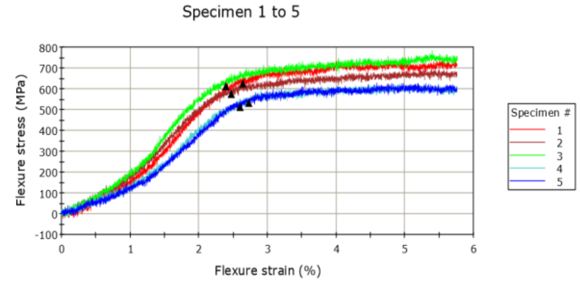
In this Teflon coated round wire has the maximum flexural stress values 858.8166Mpa and then comes the Teflon-coated rectangular wire of value 683.698Mpa. This shows Teflon- coated round wire has more flexural values when compared to rectangular wires.

FLEXURAL TEST GRAPHS



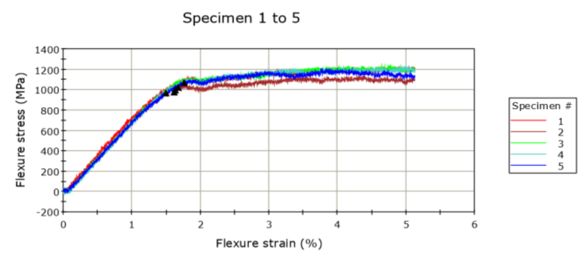
Sample A1

	Maximum Flexure stress (MPa)	Modulus (Automatic) (MPa)	Flexure stress at Yield (Offset 0.2 %) (MPa)	Load at Maximum Flexure stress (N)
1	491.59	24706.89	414.07	-3.96
2	469.20	25722.64	380.24	-3.78
3	426.30	26023.72	378.10	-3.44
4	478.84	28180.78	381.66	-3.86
5	468.07	25702.31	386.85	-3.77



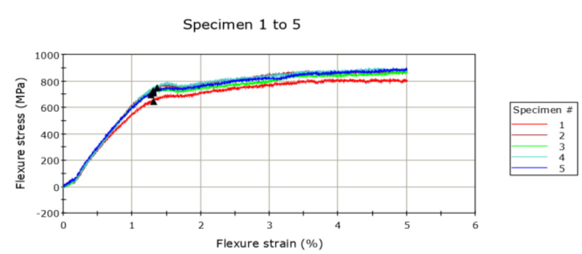
Sample A2

	Maximum Flexure stress (MPa)	Modulus (Automatic) (MPa)	Flexure stress at Yield (Offset 0.2 %) (MPa)	Load at Maximum Flexure stress (N)
1	741.58	33314.39	626.25	-2.36
2	699.83	31436.33	576.52	-2.23
3	784.50	33857.62	613.05	-2.50
4	627.35	29430.92	513.62	-2.00
5	629.38	29460.91	533.63	-2.00



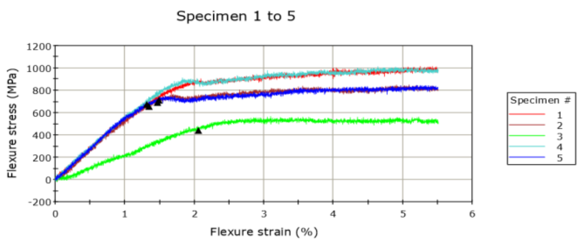
Sample B1

	Maximum Flexure stress (MPa)	Modulus (Automatic) (MPa)	Flexure stress at Yield (Offset 0.2 %) (MPa)	Load at Maximum Flexure stress (N)
1	1233.01	76823.37	970.90	-2.78
2	1155.35	71683.09	979.60	-2.61
3	1255.11	70288.12	1070.55	-2.83
4	1234.03	74309.72	999.67	-2.78
5	1216.80	72335.90	1025.03	-2.74



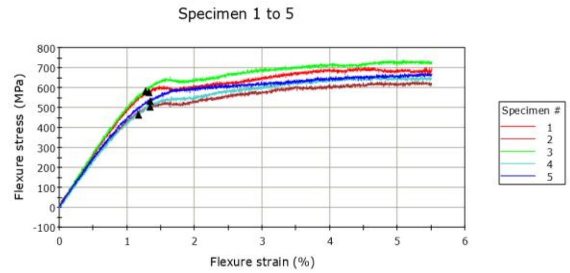
Sample B2

	Maximum Flexure stress (MPa)	Modulus (Automatic) (MPa)	Flexure stress at Yield (Offset 0.2 %) (MPa)	Load at Maximum Flexure stress (N)
1	821.15	60316.00	645.63	-4.01
2	884.55	72536.70	726.62	-4.32
3	880.64	68373.78	710.96	-4.31
4	900.64	69627.19	749.93	-4.40
5	900.72	68315.83	696.67	-4.40



Sample C1

	Maximum Flexure stress (MPa)	Modulus (Automatic) (MPa)	Flexure stress at Yield (Offset 0.2 %) (MPa)	Load at Maximum Flexure stress (N)
1	1015.22	54658.68	712.10	-2.83
2	850.67	55939.33	692.50	-2.37
3	567.32	27005.79	441.68	-1.58
4	1013.80	60371.32	676.13	-2.83
5	847.07	58936.77	657.10	-2.36



Sample C2

	Maximum Flexure stress (MPa)	Modulus (Automatic) (MPa)	Flexure stress at Yield (Offset 0.2 %) (MPa)	Load at Maximum Flexure stress (N)
1	704.69	50457.54	577.31	-4.55
2	635.42	46844.19	465.67	-4.10
3	739.46	53720.63	584.07	-4.77
4	658.88	43497.54	505.27	-4.25
5	680.04	45339.82	533.88	-4.39

RESULTS :

The results show that mean of maximum flexural stress of B1,B2 is greater than A1,A2 & C1,C2 which indicates uncoated wires have greater stress than polymer-coated and tooth coloured samples of both dimensions.

Also, the mean of modulus and flexural stress at yield follows the same pattern in both round and rectangular dimensions.

Whereas, load at maximum flexural stress is greatest for A1 when compared to B1 & C1 and least for A2 followed by C2 & B2 respectively [5,6].

CONCLUSION :

Based on the results rectangular polymer-coated wires have maximum flexural strength when compared to round wires of same category and comparable levels to rectangular uncoated and Teflon-coated/tooth coloured wire samples.

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