Vol 9| Issue 2| 2019 | 55-61.

e-ISSN 2248 – 9142
print-ISSN 2248 – 9134

International Journal of
Current Pharmaceutical & Clinical Research

www.ijcpcr.com

COMPARITIVE STUDY OF TENSILE STRENGTH TESTING 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 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 tensile strength of uncoated, polymer-drug coated and Teflon/tooth coloured orthodontic archwires.

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

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 Due to the cost factor, it has been replaced by stainless steel wires, which has improved mechanical and physical properties.More recently, Co -Cr, Ni-Ti, B-TMA and multi stranded stainless archwires have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 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 [1] (orthodontic

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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 TiO_2, with a small amount of NiO on the outermost surface layer.

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 tensile 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 [2].

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

Tensile testing: The completed tensile specimens were tested on a universal testing machine (Shimadzu AG – IS; UTM Autograph) using a cross head speed of 1.0 mm/min under 500 kg load up to the fracture point of the specimens. The specimen was mounted by its ends into the holding grips of the testing apparatus. The tensile testing machine is designed to elongate the specimen at a constant rate continuously until the fracture of the specimen. The specimen was deformed to fracture, with a gradually increasing tensile load that is applied uniaxially along the long axis of the specimen.

The deformation is confined to the narrow center portion, which has a uniform cross section along its length. From the resultant stress-strain curve of each sample, values of Modulus of elasticity, Yield strength, and tensile strength were obtained.

For determining percentage elongation, the fracture parts were repositioned as accurate as possible and the gauge distance between the two marks made earlier was re-measured. The percentage elongation was calculated by dividing the difference between the two measurements with the original length and multiplying with 100.

The orthodontic wires, coated or non-coated, were gripped into a tensile jigs of Universal testing machine (Instron 3366, UK). The machine consisted of a specimen mounting jigs with a load cell capacity of 10kN. The instrument was attached to a computer with Bluehill software which is used to control the testing parameters such as cross head speed and to obtain results of the test such as Maximum tensile strength, maximum load, extension, etc. The wire was stressed at the cross head speed of 0.5mm/min until failure. The tensile strength of the wire and other parameters were noted automatically calculated by the software (n = 5) [3].

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The specimen was mounted by its ends into the holding grips of the testing apparatus as illustrated. The tensile testing machine is designed to elongate the specimen at a constant rate continuously until the fracture of the specimen. The specimen was deformed to fracture, with a gradually increasing tensile load that is applied uniaxial along the long axis of the specimen. The deformation is confined to the narrow center portion, which has a uniform cross section along its length. From the resultant stress-strain curve of each sample, values of Modulus of elasticity, Yield strength (at 0.2 % offset), and tensile strength were obtained.

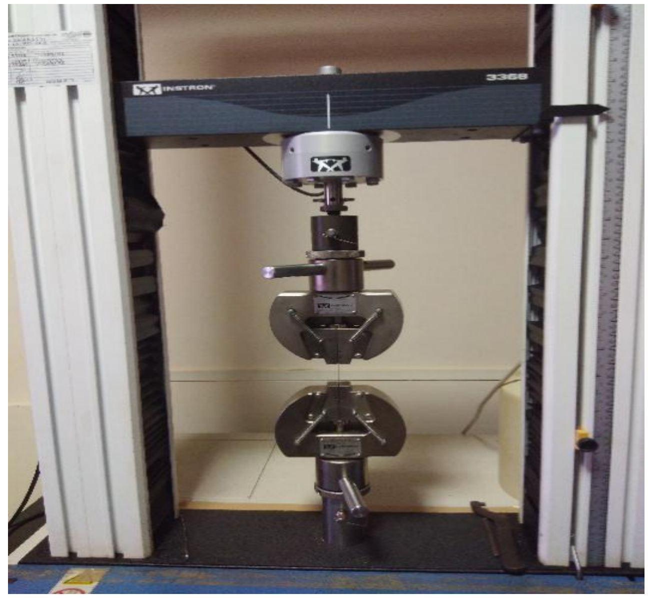
Tensile strength Crosshead speed of 1 mm per minute.

The span of the wire between the grips was standardized at 40 mm. The load taken to break the wire divided by the cross-sectional area of the wire gave the value for UTS. Young' s modulus (E) was then calculated from the load deflection data obtained from the tensile testing.

The specimen was fixed to the grip of the Lloyd machine and pulled in either way at a crosshead speed of 5 mm/minute was used for this test. The maximum tensile load before failure was recorded for each specimen. Tensile bond strength was calculated by the following formula [4].

$$\text{Tensile bond strength} = \frac{\text{Maximum Load (N)}}{\text{Cross Sectional area (mm2)}}$$

The crosshead speed was same for all samples in order to standardize the procedure.



TENSILE TEST DATA

SAMPLE A1	MAX. LOAD (N)	TENSILE STRESS AT MAX.LOAD (MPa)	MODULUS (Gpa)	TENSILE STRESS AT YIELD(off set 0.02mm) (Gpa)
1	107.50	353.85	10.16	0.11
2	134.76	443.58	12.48	0.08
3	279.97	921.58	10.69	0.09
4	296.57	976.19	7.99	
5	251.97	821.40	14.17	0.67
MEAN	226.79	746.52	11.00	0.24
S.D.	83.70	275.50234	2.11515	0.28775
SAMPLE A2				
1	70.12	269.71	6.80	0.14
2	176.65	679.41	4.92	0.58
3	55.43	213.20	5.95	0.17
4	149.46	574.87	8.46	0.05
5	140.60	462.80	9.11	0.07
MEAN	121.48	454.25	7.05	0.25
S.D.	47.79	180.31037	1.55256	0.22206
SAMPLE B1				
1	124.58	943.57	30.80	0.19
2	168.06	1272.91	24.04	0.36
3	90.49	685.41	28.41	0.22
4	158.25	1198.65	15.14	0.99
5	141.84	1074.33	15.13	-----
MEAN	136.64	1034.98	22.70	0.44
S.D.	30.64	232.11222	7.32455	0.37289
SAMPLE B2				
1	268.52	1149.00	11.84	0.87
2	257.33	1101.11	13.03	0.23
3	238.87	1022.12	17.97	0.21
4	234.76	1004.52	12.92	-----
5	124.16	531.28	24.56	0.12
MEAN	224.73	961.61	16.12	0.36
S.D.	57.87	247.61814	5.26894	0.34660

SAMPLE C1				
1	150.53	989.98	23.72	0.19
2	114.84	755.27	18.53	0.15
3	153.41	1008.95	27.97	0.17
4	150.20	987.82	25.79	0.26
5	154.61	1016.80	26.31	0.24
MEAN	144.72	951.76	24.46	0.20
S.D.	16.81	110.53459	3.64749	0.04507
SAMPLE C2				
1	246.62	893.54	21.44	0.12
2	235.65	853.81	15.49	0.14
3	274.27	993.74	10.08	------
4	258.21	935.54	9.48	0.76
5	268.54	972.96	15.64	0.28
MEAN	256.66	929.92	14.42	0.32
S.D.	15.78	57.16871	4.87604	0.29653

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
Sample B1 denotes uncoated 0.016 inch round wire
Sample B2 denotes uncoated 0.016*0.022 inch rectangular wire
Sample C1 denotes tooth coloured/Teflon 0.016 inch round wire
Sample C2 denotes tooth coloured/Teflon 0.016*0.022 inch rectangular wire

Table41 reveals the statistical analysis of tensile bond strength of the group A1,A2,B1,B2,C1 and C2.In this A1 is polymer-drug coated, B1 uncoated and C1 is Teflon coated in round wire dimensions. Group A2, B2, and C2 in which A2 is polymer-drug coated, B2 uncoated and C2 is Teflon coated in rectangular wires.

The mean and standard deviation of the tensile strength test like maximum load, tensile stress at maximum load, modulus in newton, the tensile stress at yield strength at (Gpa), were evaluated.

The mean of A1 group in tensile strength test like maximum load is 226.79, tensile stress at maximum load is 746.52 modulus in newton is 11, and the tensile stress at yield strength at (Gpa) is0.24

The mean of A2 group in tensile strength test like maximum load is 121.48, tensile stress at maximum load is 454.25 modulus in newton is 7.05, and the tensile stress at yield strength at (Gpa) is0.25

The mean of B1 group of the tensile strength test like maximum load is 136.64, tensile stress at maximum load is 1034.98 modulus in newton is 22.70 and the tensile stress at yield strength at (Gpa) is0.44

The mean of B2 group in the tensile strength test like maximum load is 224.73, tensile stress at maximum load is 961.61 modulus in newton is 16.12 and the tensile stress at yield strength at (Gpa) is0.36

The mean of C1 group in the tensile strength test like maximum load is 144.72, tensile stress at maximum load is 951.76 modulus in newton is 24.46 and the tensile stress at yield strength at (Gpa) is0.20

The mean of C2 group in the tensile strength test like maximum load is 256.66, tensile stress at maximum load is 929.92 modulus in newton is 14.42 and the tensile stress at yield strength at (Gpa) is0.32

The results reveal that Group A1, B1,C1, has higher mean level in the maximum tensile strength load of 226, 136, 144 newton. The mean tensile strength is higher in C1. This reveals the uncoated round wires are having less tensile strength than the Teflon- coated round wires and the lower is polymer coated round wires.

The results reveal that Group A2 B2,C2, has higher mean level in the maximum tensile strength load of 121, 224, 256 newton. The mean tensile strength is higher in C2. This reveals the uncoated rectangular wires are having less tensile strength than the Teflon-coated rectangular wires and the lower is polymer coated rectangular wire.

The results reveal that Group A, B1,C1, has higher mean level in the maximum tensile stress load of 746, 1034, 951 newton. The mean tensile stress is higher in B1. This shows the uncoated round wires are having more tensile strength than the Teflon-coated round wires and the lower is polymer coated round wires.

The results reveal that Group A2 B2,C2, has higher mean level in the maximum tensile stress load of 454, 951, 921 newton. The mean tensile stress is higher in C2. This reveals the uncoated rectangular wires are having high tensile strength than the Teflon- coated rectangular wires and higher than polymer coated rectangular wire.

The results reveal that Group A1, B1,C1, has higher mean level in the maximum Modulus in newton are 11,22, 24 newton respectively. The mean modulus is higher in C2. This reveals the uncoated round wires are having less modulus than Teflon-coated round wires and more than polymer coated round wire.

The results reveal that Group A2 B2,C2, has higher mean level in the maximum Modulus in newton are 7,16, 14 newton respectively. The mean modulus stress is higher in B2. This reveals the uncoated rectangular wires are having high modulus than the Teflon-coated rectangular wires and higher than polymer coated rectangular wire.

The results reveal that Group A1 B1,C1, has higher mean level in the maximum tensile stress at yield of 0.24, 0.44, 0.20 newton. The mean tensile stress at yield is higher in B1. This reveals the uncoated round wires are having high stress at yield than the polymer coated round wires and Teflon-coated/tooth coloured wires.

The results reveal that Group A2 B2,C2, has higher mean level in the maximum tensile stress at yield load of 25, 36, 32 newton. The mean tensile stress at yield is higher in B2. This reveals the uncoated rectangular wires are having high tensile stress at yield than the

Teflon-coated/tooth coloured rectangular wires and the lowest in polymer coated rectangular wires.

The mean of Tensile maximum load is greater in A1 followed by C1 & B1,whereas that of C2 is greater than B2 & A2. The mean of tensile stress at maximum load is greater in B1 than that of A1 &C1, whereas that of B2 is greater than C2 & A2.

Mean modulus of B1, B2 is greater than that of A1, C1 and C2, A2 respectively.

Mean of Tensile stress at yield is greater in B1 when compared to A1 & C1, whereas that of B2 is greater than C2 & A2 respectively.

Ultimate tensile strength of the polymer-coated round wires are at a comparable levels of the Teflon-coated/tooth coloured wires, whereas that of rectangular wires of same category have the least values, which indicates that rectangular polymer-coated wires have the least ultimate tensile strength when compared to uncoated and Teflon-coated/tooth coloured samples.

T-TestGroup Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Max. Load (N)	Group A1	5	214.1540	86.93773	38.87973
	Group A2	5	118.4520	52.78918	23.60804
Tensile Stress at Max Load (MPa)	Group A1	5	704.9200	286.16996	127.9791 0
	Group A2	5	439.9980	197.77754	88.44881
Modulus	Group A1	5	11.0980	2.34804	1.05007
	Group A2	5	7.0480	1.73501	.77592
Tensile Stress at Yield	Group A1	4	.2375	.28860	.14430
	Group A2	5	.2020	.21696	.09703

The T-test on group statistics were calculated for all the four tests and it was analysed between the groups A1 and A2. In all the four tests, the polymer coated round wires have the best mean values than the rectangular wires.

T-TestGroup Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Max. Load (N)	Group B1	5	136.6440	30.64521	13.704 95
	Group B2	5	224.7280	57.86879	25.879 71
Tensile Stress at Max Load (MPa)	Group B1	5	1034.9740	232.1109 4	103.80 317
	Group B2	5	961.6060	247.6196 2	110.73 886
Modulus	Group B1	5	22.7040	7.32237	3.2746 6
	Group B2	5	16.0640	5.30912	2.3743 1
Tensile Stress at Yield	Group B1	4	.4400	.37408	.18704
	Group B2	4	.3575	.34500	.17250

The T-test on group statistics were calculated for all the four tests and it was analysed between the groups B1 and B2. In all the four tests the uncoated round wires have the best mean values in tensile stress& modulus. Max load and for tensile stress at yield, the uncoated rectangular wire have higher values.

T-TestGroup Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Max. Load (N)	Group C1	5	144.71 80	16.80721	7.5164 1
	Group C2	5	256.65 80	15.77871	7.0564 5
Tensile Stress at Max Load (MPa)	Group C1	5	951.76 40	110.5331 5	49.431 93
	Group C2	5	929.91 80	57.16917	25.566 83
Modulus	Group C1	5	24.464 0	3.64774	1.6313 2
	Group C2	5	14.426 0	4.87731	2.1812 0
Tensile Stress at Yield	Group C1	5	.2020	.04658	.02083
	Group C2	4	.3250	.29861	.14930

The T-test on group statistics were calculated for all the four tests and it was analysed between the groupsC1 and C2. In all the four tests the Teflon coated round wires have the best mean values in tensile stress and modulus. And the max load, and for tensile yield stress the Teflon coated rectangular wire have the higher value.

One way Anova

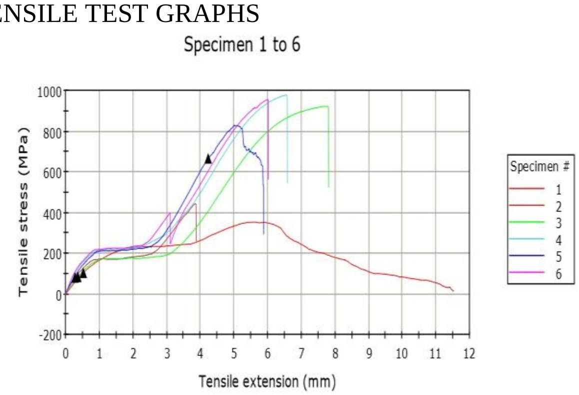
		Sum of Squa res	Df	Mean Square	F	Sig.
Max. Load (N)	Between Groups	1815 7.24 6	2	9078.6 23	3.10 2	.082
	Within Groups	3511 9.11 9	12	2926.5 93		
	Total	5327 6.36 5	14			
Tensile Stress at Max Load (MPa)	Between Groups	2946 52.5 12	2	147326 .256	2.98 7	.089
	Within Groups	5919 45.2 38	12	49328. 770		
	Total	8865 97.7 50	14			
Modulus	Between Groups	527. 411	2	263.70 6	10.9 22	.002
	Within Groups	289. 745	12	24.145		
	Total	817.	14			

		156				
Tensile Stress at Yield	Between Groups	.140	2	.070	1.029	.392
	Within Groups	.678	10	.068		
	Total	.818	12			

Max. Load (N)	Between Groups	52358.353	2	26179.176	12.301	.001
	Within Groups	25537.852	12	2128.154		
	Total	77896.205	14			
Tensile Stress at Max Load (MPa)	Between Groups	855167.736	2	427583.868	12.370	.001
	Within Groups	414798.983	12	34566.582		
	Total	1269966.719	14			
Modulus	Between Groups	230.677	2	115.338	6.293	.014
	Within Groups	219.941	12	18.328		
	Total	450.618	14			
Tensile Stress at Yield	Between Groups	.062	2	.031	.380	.693
	Within Groups	.813	10	.081		
	Total	.875	12			

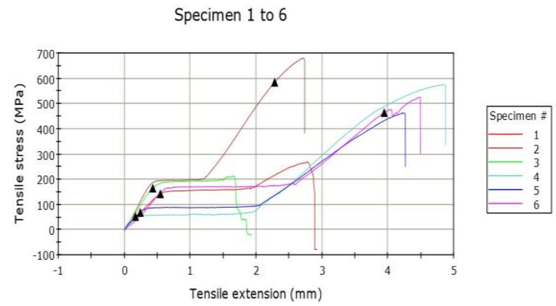
The one way anova test conducted within the groups and between the groups shows more significant values.

TENSILE TEST GRAPHS



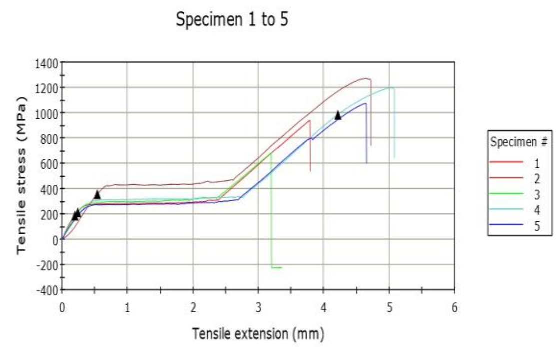
	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Modulus (Automatic) (GPa)	Tensile stress at Yield (Offset 0.02 mm) (GPa)
1	107.50	353.85	10.16	0.11
2	134.76	443.58	12.48	0.08
3	279.97	921.58	10.69	0.09
4	296.57	976.19	7.99	-----
5	251.97	829.40	14.17	0.67
6	290.00	954.56	10.49	-----
Mean	226.79	746.52	11.00	0.24
Standard Deviation	83.70	275.50234	2.11515	0.28775

SAMPLE A1



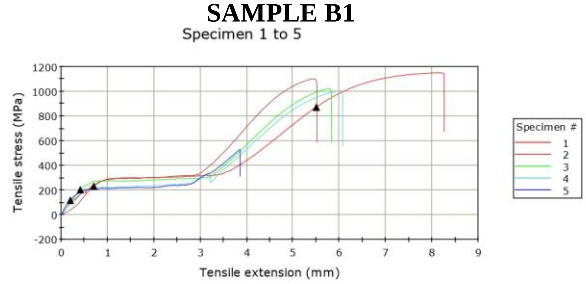
	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Modulus (Automatic) (GPa)	Tensile stress at Yield (Offset 0.02 mm) (GPa)
1	70.12	269.71	6.80	0.14
2	176.65	679.41	4.92	0.58
3	55.43	213.20	5.95	0.17
4	149.46	574.87	8.46	0.05
5	140.60	462.80	9.11	0.07
6	136.63	525.52	7.05	0.47
Mean	121.48	454.25	7.05	0.25
Standard Deviation	47.79	180.31037	1.55256	0.22206

SAMPLE A2



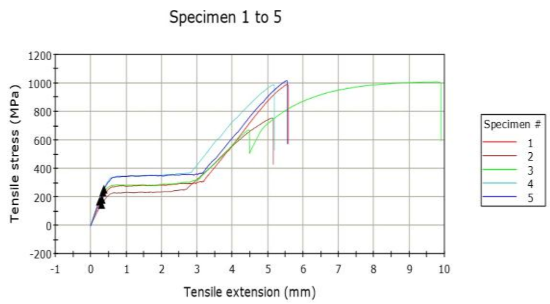
	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Modulus (Automatic) (GPa)	Tensile stress at Yield (Offset 0.02 mm) (GPa)
1	124.58	943.57	30.80	0.19
2	168.06	1272.91	24.04	0.36
3	90.49	685.41	28.41	0.22
4	158.25	1198.65	15.14	0.99
5	141.84	1074.33	15.13	-----
Mean	136.64	1034.98	22.70	0.44
Standard Deviation	30.64	232.11222	7.32455	0.37289

SAMPLE B1



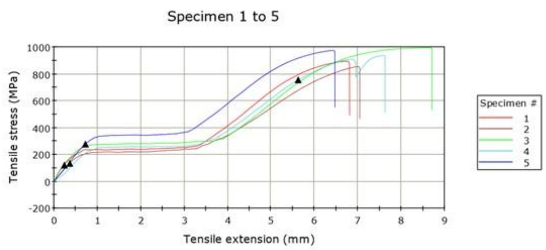
	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Modulus (Automatic) (GPa)	Tensile stress at Yield (Offset 0.02 mm) (GPa)
1	268.52	1149.00	11.84	0.87
2	257.33	1101.11	13.33	0.23
3	238.87	1022.12	17.97	0.21
4	234.76	1004.52	12.92	-----
5	124.16	531.28	24.56	0.12
Mean	224.73	961.61	16.12	0.36
Standard Deviation	57.87	247.61814	5.26894	0.34660

SAMPLE B2



	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Modulus (Automatic) (GPa)	Tensile stress at Yield (Offset 0.02 mm) (GPa)
1	150.53	989.98	23.72	0.19
2	114.84	755.27	18.53	0.15
3	153.41	1008.95	27.97	0.17
4	150.20	987.82	25.79	0.26
5	154.61	1016.80	26.31	0.24
Mean	144.72	951.76	24.46	0.20
Standard Deviation	16.81	110.53459	3.64749	0.04507

SAMPLE C1



	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Modulus (Automatic) (GPa)	Tensile stress at Yield (Offset 0.02 mm) (GPa)
1	246.62	893.54	21.44	0.12
2	235.65	853.81	15.49	0.14
3	274.27	993.74	10.08	-----
4	258.21	935.54	9.48	0.76
5	268.54	972.96	15.64	0.28
Mean	256.66	929.92	14.42	0.32
Standard Deviation	15.78	57.16871	4.87604	0.29653

SAMPLE C2

RESULTS

Tensile bond strength tests were carried out with a universal testing machine named Lloyd Instron Instrument. The tensile bond strength was recorded. All data were tabulated and statistical comparisons were made by one way ANOVA variance and student t-Tests. The test conducted between the groups A1, A2, B1, B2 and C1, C2.

The mean of Tensile maximum load is greater in A1 followed by C1 & B1,whereas that of C2 is greater than B2 & A2. The mean of tensile stress at maximum load is greater in B1 than that of A1 &C1, whereas that of B2 is greater than C2 & A2.

Mean modulus of B1, B2 is greater than that of A1, C1 and C2, A2 respectively.

Mean of Tensile stress at yield is greater in B1 when compared to A1 & C1, whereas that of B2 is greater than C2 & A2 respectively [5].

CONCLUSION

Results shows that Ultimate Tensile Strength(UTS) of the polymer-coated round wires are at a comparable levels of the Teflon-coated/tooth coloured wires, whereas that of rectangular wires of same category have the least values, which indicates that rectangular polymer-coated wires have the least ultimate tensile strength when compared to uncoated and Teflon-coated/tooth coloured samples.

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