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Original Research Article

Comparison of force decay rate and surface roughness characteristics of tear drop loop in aesthetic coated archwires- An invitro study

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A R T I C L E I N F O

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A B S T R A C T

Objective: To compare and evaluate the surface roughness and force decay rate of coated aesthetic stainless steel archwires with the non-coated stainless steel maxillary arch wires.
Materials and M ethods: 4 different groups (non coated, epoxy coated, teflon coated, rhodium coated) of maxillary archwires of 0.019" x 0.025" inch dimension were taken for study keeping the non coated SS wire as the control group. 6 samples from each group were evaluated for surface roughness before and after tear drop loop formation using Optical Profilometer and for force decay rate by Universal testing machine at load of 1mm and 2 mm.
Results: The results obtained were analyzed using paired t test followed by one way ANOVA and post hoc comparison was done between the groups.
Conclusions: The study concluded that force decay rate and surface roughness overall was less for the aesthetic coated SS archwires compared to non coated SS archwires, especially teflon coated archwires showed the least surface roughness and force decay rate while epoxy coated SS archwires showed the highest among all.

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1. Introduction

The constant update in the orthodontic treatment modalities has increased the demand for newer materials and concern for aesthetics. The orthodontic materials have high influence on intensity and extent of tooth movement. There are many aesthetic coated arch wires available in the market and among them the most common are the polytetrafluoroethylene (PTFE) or Teflon and epoxy resin coated archwires which are of synthetic origin while the former comprises of fluoride with carbon and the later is combination of epoxies with other compounds.[1,2] Another emerging wire in the list is rhodium coated wires which are made by plasma immersion ion implantation technique.[3] The availability of different aesthetic coated arch wires in the market has also increased the concern regarding their optimal performance in the patient. Thorough knowledge of brackets and wire properties help in acceleration of the treatment and prevention of the excess force application for the desired treatment outcome. The diverse properties of newer generation arch wires enable us to utilize them in different stages of orthodontic treatment. Force decay rate is one such important property when it comes to study, as it allows choosing the wire that delivers low load per millimeter of deactivation for tooth movement. Earlier it was shown that coated wire execute load less than their uncoated counterparts due to dimensional change in wire due to the coating.[2] However recent studies have shown that there is minimal difference in the force generation between these wires.[2,4] So the main purpose of this study was to differentiate the force decay rate and surface characteristics of epoxy coated, teflon coated and rhodium coated stainless

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steel archwires.

2. Materials and Methods

In this study four different groups of maxillary stainless steel rectangular archwire of 0.019" x 0.025" dimension which were non coated, Epoxy resin coated, Teflon Coated and Rhodium coated stainless steel arch wire were taken. These dimensions were selected as they are well characterized in the orthodontic literature for retraction during space closure.Tear drop shaped loop was made in the wire distal to canine in the archwire, by comparing it with the sym grid in oval arch form (Figure 1) and each specimen was evaluated for the surface roughness by using Optical Profilometer at 3 points which were the initial and the final point of loop and a point on the mid of the loop which was shaded with a marker for reference (Figure 2) (Taylor Hobson Talysurf CCI, Leicester, UK) which has Taly map software (Talysurf, UK).Scanning was done of the same area before and after the tear drop loop was formed. Root Mean square roughness value in microns was recorded and analyzed statistically. The evaluation of load deflection characteristic was done with Instron Universal Testing machine (Figure 3) (ABS Instron3382/66216) at the extension of 1mm and 2mm and was recorded in Newton (N) and analyzed statistically. The mean load deflection at 1mm and 2mm was taken 2.35± 0.05 and 2.55±0.11 respectively from the previous study. With the power of 10% and $\alpha = 0.01$ the required minimum sample was estimated to be 6 in each group with the formula:

$$n \geq \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 \left(\sigma_1^2 + \frac{\sigma_2^2}{r}\right)}{(\mu_1 - \mu_2)^2}$$

FORMULA A : Sample Size Calculation

2.1. Statistical analysis

Mean and standard deviation were estimated from the sample for each study group and the result were statistically analyzed by paired t-test followed by one way analysis of variance (ANOVA). Post hoc comparison test was done for multiple comparisons within the groups to evaluate and determine the statistical significance.

3. Results

The resultant data obtained after statistical analysis were further analyzed and tabulated. Root Mean square surface roughness value for all the 6 samples in each group before and after loop formation and the load deflection rate at 1mm and 2 mm for all group are given in Table 1.On comparison between the groups (Table 2), the mean difference between group 1 and group 3 was the least followed by group 2 and group 1.On intergroup comparison using the post hoc test keeping the 'p' value significant at 0.05, the epoxy coated

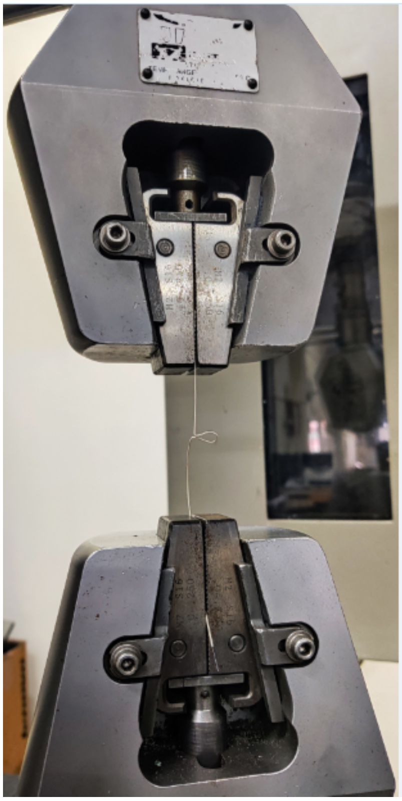

Fig. 1:

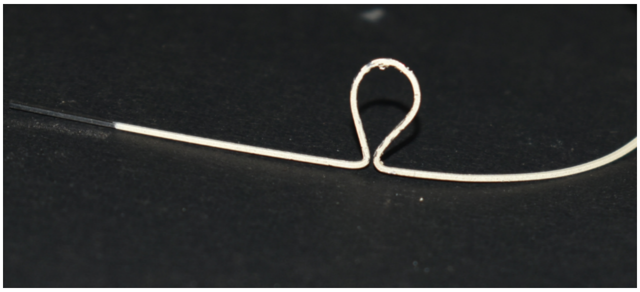

Fig. 2:

Fig. 3:

Table 1: Descriptive data

	Group	N	Mean	Standard deviation	Standard error	95% confidence interval		Minimum	Maximum
						Lower bound	Upper Bound		
Roughness before loop	1	6	.13	.098	.040	.03	.23	0	0
	2	6	.82	.089	.036	.73	.91	1	1
	3	6	.12	.044	.018	.07	.16	0	0
	4	6	.09	.067	.027	.02	.16	0	0
Roughness after loop	1	6	.12	.128	.052	-.01	.26	0	0
	2	6	.99	.263	.107	.71	1.26	1	1
	3	6	.11	.028	.012	.08	.14	0	0
	4	6	.08	.025	.010	.05	.10	0	0
Load deflection at 1 MM	1	6	.86	.151	.062	.70	1.02	1	1
	2	6	.62	.134	.055	.48	.76	0	1
	3	6	.83	.080	.033	.74	.91	1	1
	4	6	.67	.071	.029	.60	.74	1	1
Load deflection at 2MM	1	6	1.78	.443	.181	1.31	2.25	1	2
	2	6	1.44	.282	.115	1.15	1.74	1	2
	3	6	1.86	.257	.105	1.59	2.13	2	2
	4	6	1.59	.220	.090	1.36	1.82	1	2

SS wires showed the most difference compared to the non coated SS wire where as teflon coated SS wire showed the least difference among the study groups.

4. Discussion

In this study, the force decay rate and surface characteristics of epoxy coated, teflon coated and rhodium coated SS wires with keeping the regular SS wires as a control group was evaluated. A tear drop loop was used to assist in assessment of the parameters as they are one of the most commonly used loop and easily reproducible.[5] A multifactorial analysis done by Drescher et al showed that wire material was the decisive factor in space closure compared to wire size and bracket width.[6] Stainless steel wire used in this study had a surface roughness of 0.13 microns before loop formation and 0.12 microns after loop formation. The load deflection rate for these wires was 0.86 N and 1.78N at 1 mm and 2 mm respectively.

4.1. Surface roughness

The surface characteristics were evaluated by subjecting the wire to Optical Profilometry. Surface characteristics evaluate the depth and extent of irregularities present on archwire surface, as they are directly related to the frictional and force characteristics.[7] The root mean square roughness of the wires in the epoxy coated group before and after loop indicated that surface irregularities was higher in the wire when compared with non coated SS wire which affects tooth movements. These results are in accordance with the study conducted by Firas Ellayyan et al,[8] Shiva et al[9] and Silvia Izabella et al.[10] The teflon coated wires results were as near to the control group indicating that the surface roughness of the teflon coated SS wires was the smoothest and will yield better results compared to the other two during space closure as derived by the Ahmed Abdulhussain et al,[11] Giampietro Forronata et al[12] and Vincenzo D'Anto et al.[13] The root mean square roughness of the rhodium coated wires before and after loop were much better compared to the epoxy coated wires and are in relative with the study by Jamal A et al.[14] For surface roughness after the loop formation, the mean difference between group 2 and group 1 showed that epoxy wires had the highest surface roughness among all the 3 groups compared as stated by Cibele Gonsalves et al[15] in his study where he concluded that the epoxy coated arch wires show much serrations and uneven dislodged coatings compared to the uncoated wires. For the group 3 and group 1 the mean results showed that teflon has the least surface irregularities and is more suitable for loop formation during space closure stage, which was in accordance with study by Aruna Dokku et al,[16] Nina Argalji et al.[17] However Neumann P et al[18] in 2002 stated that teflon has a high surface roughness comparatively when tested under a scanning electron microscope, which might be due to the defects on the coating process during the manufacturing by the developers. When group 4 was compared to group 1 the mean it indicated that rhodium Coated wires have much smooth features when compared with epoxy but lesser than teflon and can be used as an alternative to teflon. It is similar to study done by Jamal A et al[11] where the author compared the epoxy, teflon and rhodium coated wires in a non contact 3D profilometry and concluded that the rhodium has the least surface roughness among the three while epoxy has the highest surface roughness. The result of rhodium being much smoother than the teflon is slightly different from this study. However this contradicts with the study done by

Table 2: Post HOC test

	Group	Group	Mean	Standard deviation	Standard error	95% confidence interval	
						Lower bound	Upper Bound
Roughness before loop	2	1	0.691	0.045	0.000	0.58	0.80
	3	1	-0.011	0.045	0.989	-0.12	0.10
	4	1	-0.042	0.045	0.677	-0.15	0.07
Roughness after loop	2	1	0.862	0.085	0.000	0.65	1.08
	3	1	-0.010	0.085	0.999	-0.23	0.21
	4	1	-0.045	0.085	0.910	-0.26	0.17
Load deflection at 1 MM	2	1	-0.247	0.066	0.003	-0.41	-0.08
	3	1	-0.034	0.066	0.915	-0.20	0.13
	4	1	-0.192	0.066	0.023	-0.36	-0.02
Load deflection at 2MM	2	1	-0.337	0.180	0.181	-0.80	0.12
	3	1	0.077	0.180	0.950	-0.38	0.54
	4	1	-0.193	0.180	0.585	-0.65	0.27

Philipa rudge et al[19] and Cibele Gonclaves et al[15] where the roughness of rhodium coated wires were found to be much higher compared to the results obtained in this study.

4.2. Force decay rate

Comparing the load deflection rate at 1 mm between group 2 and group 1 it was evident that the epoxy wires shows the highest load deflection rate among all as stated before by Cibele Gonsalves et al[15],Aruna dokku et al[16] and Silvia Izabella et al.[10] But Elayyan et al[8] stated in his study that the uncoated wires has more load deflection rate than coated epoxy ,this might be due to the smaller wire size used in the study. The teflon coated group had the least decay rate and can be used for a longer period of time as similar to study done by Aruna Dokku et al[16]. But it varies with the study by Hasseinagha et al[20] where teflon was found to exhibit higher forces. Similarly Seong Hu Ryu et al[21] and Hind Dawood et al[22] in their respective studies stated that compared to teflon, epoxy coated wires showed less deflection rate and this finding was due to the thickness of the coating over the SS wire where the Teflon coating was considered to be of minimal thickness than Epoxy. The rhodium coated wires showed better results than epoxy. Murilo Matias et al[23] in his study compared the load deflection of teflon, epoxy and rhodium coated wires using a 3 bend test and concluded that the rhodium coated wires exhibited much less force compared to teflon and epoxy. Based on these values, the teflon coated SS wire can be stated as the wire having least force decay rate, followed by rhodium coated SS wires and epoxy coated SS wires being the highest. Though the values may vary in a minimal rate, all the studies done till now has been in the in vitro set up. This results also supports the evidence that coated wire exhibit much better mechanical properties as compared to their non coated counterparts[12,18] and this comes in contrast with the study done by Bradford Washington[2] and Marccus Vincus[4] where they stated that the coating of a wire does not have much effect on its properties

5. Limitations

The short comings in this study was that the coating process of the wires was not taken into consideration as recent articles shows that a correlation between coating process and mechanical properties, [7,24] thickness of the coating was also not analyzed as they play an important part in the properties of wire [17]. Majority of the studies conducted used nickel titanium arch wires but in this study coated SS wires were used. The future scope of this study can be done by using these SS coated arch wires in the patient during the space closure, further helping in understanding the properties of the wire in detail.

6. Conclusion

Based on this study where the non-coated 0.019"x"0.025"maxillary SS arch wires are compared with the 3 different types of coated SS arch wires of same dimension it can be concluded that:-

1. Epoxy coated wires showed the highest surface roughness and force decay characteristics compared to both teflon coated and Rhodium coated SS wires.
2. Teflon coated wires exhibited the least force decay rate and surface roughness characteristics among the three.
3. Rhodium coated SS wires showed less surface roughness and load deflection when compared to Epoxy coated wires but higher than that of Teflon coated wires.

Therefore Teflon coated SS wires are recommended in clinical situations where the aesthetics are of main concern and can replace the uncoated stainless steel wire during retraction phase, with better mechanical properties, followed by rhodium coated SS wire and Epoxy coated SS wire.

7. Conflicts of Interest

All contributing authors declare no conflicts of interest.

8. Source of Funding

None.

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