Original Article

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Dentistry Section

Frictional Resistance of Non Coated and Epoxy Coated Superelastic NiTi Wires used for Aligning in Three Types of Brackets

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ABSTRACT

Introduction: Coated archwires are preferred in combination with aesthetic orthodontic brackets by orthodontists over non metallic aesthetic archwires. Studies evaluating the frictional properties of epoxy coated round superelastic Nickel Titanium (NiTi) archwires are limited to stainless steel brackets.

Aim: To evaluate and compare the frictional resistance of an epoxy coated 0.016*" superelastic NiTi archwire in stainless steel, composite and ceramic brackets and to compare it with the frictional resistance generated by non coated 0.016*" superelastic NiTi archwire in same brackets.

Materials and Methods: An in-vitro experimental study was conducted in the Department of Orthodontics at SRM Dental College, Ramapuram Chennai, Tamil Nadu, India, from January to February 2020. Frictional resistance of 30 epoxy coated aesthetic 0.016*" upper superelastic NiTi wires (G4™ Nickel Titanium, 0.016*, Upper Trueform™ I, Tooth-Colored) and 30 conventional 0.016*" upper superelastic NiTi wires (G4™ Nickel Titanium, 0.016*, Upper Trueform™) from G&H® orthodontics while sliding across three different types of brackets were evaluated. Twenty stainless steel (Gemini® 3M unitek, Monrovia, California), 20 composite (FLI® RMO, Denver, Colo.), and 20 gemini clear ceramic (Gemini clear ® 3M unitek, Monrovia, California) 0.022×0.028" Slot Roth prescription maxillary first premolar brackets were used. The brackets and archwires were divided into six groups of different bracket and archwire combination with 10 samples in each. An Instron testing machine with a 10 N tension was used to measure the frictional resistance. The obtained values were analysed using One way ANOVA and followed by Post Hoc Tukey's test HSD for multiple comparison.

Results: Coated wires generated significantly high friction in ceramic brackets (136.90±3.79 gms) followed by composite brackets (125.66±3.44 gms) and stainless steel brackets (92.53±8.70 gms). Non coated wires generated significantly high friction with ceramic brackets (89.60±2.90 gms) whereas the friction generated in composite (70.87±5.79 gms) and stainless steel brackets (67.70±2.80 gms) was not significantly different.

Conclusion: Epoxy coating increased the frictional resistance generated by the 0.016* superelastic NiTi archwires irrespective of bracket materials. The coated wires generated less friction in composite brackets compared to ceramic brackets. Further clinical trial are recommended to evaluate the aligning efficacy of these archwires in aesthetic brackets.

Keywords: Ceramic brackets, Coated archwires, Composite brackets, Nickel titanium archwires, Orthodontic friction

INTRODUCTION

There is a constant need for orthodontic brackets and archwires with acceptable aesthetics and adequate clinical performance due to the increasing demand for aesthetic appliances among the orthodontic patients. Non metallic aesthetic brackets made of mono crystalline or polycrystalline ceramic and composite polymers have demonstrated adequate aesthetic and mechanical properties for routine clinical use [1-4]. On contrary, non metallic aesthetic archwires had not demonstrated desirable mechanical properties and coated metallic archwires are preferred by clinicians, in combination with aesthetic brackets [5,6].

Many aesthetic coating material including teflon, epoxy resin, and low reflectivity rhodium have been tried and tested on metallic archwires [7,8]. Archwires coated with low reflectivity rhodium or multi-layered coating of inner silver and platinum and an outer polymer were rougher than the non coated wires [7].

Frictional resistance is encountered whenever sliding occurs between the bracket slot and the archwire during aligning, levelling or space closure [9]. The applied orthodontic force is dissipated by the friction altering the amount of orthodontic force received by the individual tooth, making it important for the clinician to understand the frictional properties of bracket and archwire material [10-12].

The coating processes of aesthetic archwires alter the surface morphology and increases the surface roughness of the wires affecting the frictional resistance generated between the archwire and bracket during sliding [13,14]. Teflon coated aesthetic archwires reduced the frictional resistance considerably but failed to demonstrate an equivocal correlation between the surface roughness and frictional forces [15]. Loss of aesthetic coating, increased surface roughness and reduced unloading force were noted in retrieved coated archwires after clinical use [16].

Due to this, contradictory nature of evidence available in the literature it becomes important to evaluate the frictional resistance of different types of aesthetic archwires available in the market [7-16]. The studies in the literature evaluating the frictional properties of coated superplastic NiTi archwires are limited to the rectangular archwires with only very few studies evaluating the round wires [15-19]. The frictional resistance generated during sliding of epoxy coated round NiTi wires along composite and ceramic brackets had not evaluated so far.

Hence, the present study was designed to evaluate and compare the frictional resistance of an epoxy coated and non coated 0.016*" superelastic NiTi archwire in stainless steel, composite and ceramic orthodontic brackets.

MATERIALS AND METHODS

The in-vitro experimental study was conducted in the Department of Orthodontics, SRM Dental College, Ramapuram Chennai, Tamil Nadu, India in the months of January to February 2020. The study design was approved by the Institutional Review Board with an IRB Number of SRMDC/IRB/2019/MDS/No.102.

Sample size calculation: The sample size was calculated using G power software and for a power of 80% and p-value of 0.05, the calculated sample size was 60 with 10 in each group [16].

Study Procedure

Thirty epoxy coated aesthetic 0.016*" upper superelastic NiTi wires (G4™ Nickel Titanium, 0.016*, Upper, Trueform™ I, Tooth-coloured) and thirty conventional 0.016*" upper superelastic NiTi wires (G4™ Nickel Titanium, 0.016*, Upper, Trueform™) from G&H® orthodontics were used in the study. Twenty stainless steel (Gemini® 3M unitek, Monrovia, California), twenty composite (FLI® RMO, Denver, Colo.), and 20 gemini clear ceramic (Gemini clear ® 3M unitek, Monrovia, California) 0.022×0.028" slot Roth prescription maxillary first premolar brackets were used in the study.

The brackets and archwires were divided into six groups of 10 bracket and 10 archwire combination each [Table/Fig-1].

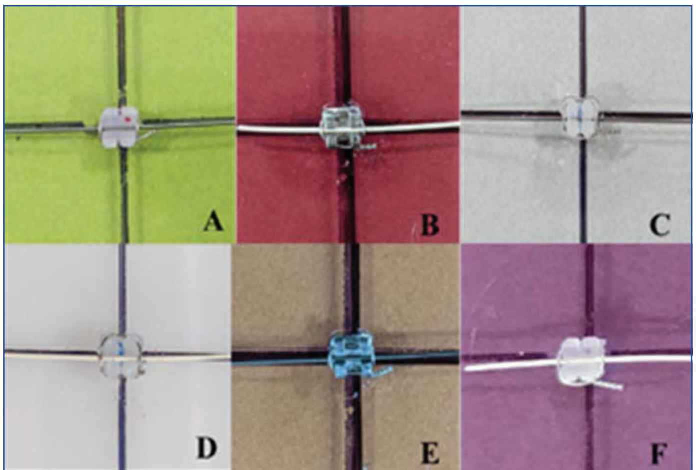
Group	Bracket	Wire
A (n=10)	Composite	0.016*" non coated superelastic NiTi
B (n=10)	Stainless steel	0.016*" coated aesthetic superelastic NiTi
C (n=10)	Ceramic	0.016*" non coated superelastic NiTi
D (n=10)	Ceramic	0.016*" coated aesthetic superelastic NiTi
E (n=10)	Stainless steel	0.016*" non coated superelastic NiTi
F (n=10)	Composite	0.016*" coated aesthetic superelastic NiTi

[Table/Fig-1]: Distribution of archwires and brackets in the six different experimental groups.

Group A, C and E comprised of composite, ceramic and stainless steel brackets respectively with 0.016*" non coated superelastic NiTi. Group B, D, and F comprised of stainless steel, ceramic and composite brackets respectively with coated super elastic NiTi archwires. A total of 60 samples were tested and each bracket archwire combination was tested only once with each wire specimen drawn through each bracket only once to eliminate the influence of wear [17].

Sixty rectangular acrylic sheets of six different colours of 10 each with a 2×2 inch dimension was elected. The colour coded plates were segregated into six groups (Group A, B, C, D, E and F).

Vertical and horizontal reference lines perpendicular to the borders of the acrylic sheets and to each were other were drawn. The allotted brackets were secured to the acrylic plates belonging to different groups with industrial adhesive at the intersection of the reference lines. The buccal segments of the corresponding archwire to each group were cut and fitted to the bracket slot and ligated passively to the tie wings with 0.01" stainless steel ligatures [Table/Fig-2].



[Table/Fig-2]: Archwires ligated in the brackets bonded to acrylic sheets; a) Composite brackets and non coated wire; b) Stainless steel brackets and coated wire; c) ceramic brackets and non coated wire; d) Ceramic brackets and coated wire; e) Stainless steel brackets and non coated wire; f) Composite wire and coated wire.

An Instron testing machine with a 10 N tension load cell, calibrated, that allowed the sliding of a bracket along the orthodontic wire was used in the study. The frictional forces generated were measured at room temperature in dry conditions. The acrylic sheets with the bracket and wire were attached to the crosshead of the testing machine [Table/Fig-3]. The archwire was drawn through the bracket under tension to a distance of 1.25 mm with a constant crosshead speed of 1 mm/minute [18]. The recorded frictional resistance values that were obtained in Newton were converted to grams.

[Table/Fig-3]: Sample mounted on the LLOYD Universal testing machine.

STATISTICAL ANALYSIS

The obtained values were analysed using One way ANOVA and followed by Post Hoc Tukey's test HSD for multiple comparison using IBM Statistical Package for the Social Sciences (SPSS) statistics tool version 26.0. A p-value less than 0.05 was considered as the level of statistical significance.

RESULTS

The descriptive statistics for the frictional resistance between the archwire and bracket samples belonging to the six experimental group (Group A, B, C, D, E and F) is presented in the [Table/Fig-4].

Group	N	Mean	Standard deviation	Standard error	95% confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
Group A	10	70.87	5.79	1.83	66.73	75.01	61.60	79.40
Group B	10	92.53	8.69	2.75	86.30	98.74	83.40	113.27
Group C	10	89.59	2.89	.92	87.52	91.66	86.20	76.20
Group D	10	136.90	3.79	1.20	134.18	139.61	131.20	143.10
Group E	10	67.70	2.80	.89	65.69	69.71	62.60	71.30
Group F	10	125.66	3.44	1.09	123.19	128.12	120.00	130.10

[Table/Fig-4]: Descriptive statistics for mean frictional resistance in grams for each group.

The mean frictional resistance of the Group E samples with stainless steel bracket and non coated superelastic NiTi archwire was the least among the six experimental groups evaluated with a value of 67.7±2.80 gms. The group D samples with ceramic brackets and coated archwire reported the highest mean frictional resistance of 136.90±3.79 gms which was approximately twice that of the stainless steel bracket and non coated archwire group and significantly different from other groups (p-value of <0.01).

One way ANOVA revealed that the difference among the mean frictional resistance of the six groups was statistically significant with a p-value <0.01 [Table/Fig-5].

The results of the multiple comparisons indicate that the bracket archwire combination of non coated wire in each bracket had lesser

Groups	Sum of squares	df	Mean square	F	Sig.
Between groups	40293.292	5	8059.658	318.821	<0.01*
Within groups	1364.930	54	25.276		
Total	41658.221	59			

[Table/Fig-5]: ANOVA for comparison of frictional resistance among the experimental groups.
*Highly significant with p<0.01

frictional resistance than the coated archwire in their respective counterparts. Ranking frictional resistance from least to highest frictional resistance is stainless steel brackets in non coated wire, composite brackets with non coated wire, ceramic bracket with non coated wire, stainless steel brackets with a coated archwire, composite bracket with coated wire, and ceramic bracket with coated wire.

Post Hoc Tukey's test HSD revealed that there was no significant difference between the frictional resistance generated by non coated wire in the stainless steel bracket and composite bracket [Table/Fig-6]. The frictional resistance generated by the non coated archwires in stainless steel brackets (group E samples) was significantly lower than that of other groups with a p-value of <0.01 except group A samples comprising composite brackets and non coated archwire which reported a mean value of 70.87±5.79 gms. The frictional resistance generated by coated wires in stainless steel brackets (group B samples) with a value of 92.53±8.69 gms was not significantly different from the forces generated by the non coated wire in ceramic brackets (89.59±2.89 gms).

(I) Group (J) Group	Mean difference (I-J)	Standard error	Significance	95% Confidence interval	
				Lower bound	Upper bound
Group A					
Group B	-21.65700*	2.2480	<0.01*	-28.2998	-15.0142
Group C	-18.72000*	2.2480	<0.01*	-25.3628	-12.0772
Group D	-66.03000*	2.2480	<0.01	-72.6728	-59.3872
Group E	3.17000	2.2480	0.721	-3.4728	9.8128
Group F	-54.7000*	2.2480	<0.01*	-61.4328	-48.1472
Group B					
Group A	21.65700*	2.2480	<0.01*	15.0142	28.2998
Group C	2.93700	2.2480	0.780	-3.7058	9.5798
Group D	-44.37300*	2.2480	<0.01*	-51.0158	-37.7302
Group E	24.82700*	2.2480	<0.01*	18.1842	31.4698
Group F	-33.13300*	2.2480	<0.01*	-39.7758	-26.4902
Group C					
Group A	18.72000*	2.2480	<0.01*	12.0772	25.3628
Group B	-2.9300	2.2480	0.780	-9.5798	3.7058
Group D	-47.31000*	2.2480	<0.01*	-53.9528	-40.6672
Group E	21.89000*	2.2480	<0.01*	15.2472	28.5328
Group F	-36.07000*	2.2480	<0.01*	-42.7128	-29.4272
Group D					
Group A	66.03000*	2.2480	<0.01*	59.3872	72.6728
Group B	44.37300*	2.2480	<0.01*	37.7302	51.0158
Group C	47.31000*	2.2480	<0.01*	40.6672	53.9528
Group E	69.20000*	2.2480	<0.01*	62.5572	75.8428
Group F	11.24000*	2.2480	<0.01*	4.5972	17.8828
Group E					
Group A	-3.17000	2.2480	0.721	-0.8128	3.4728
Group B	-24.82700*	2.2480	<0.01*	-31.4698	-18.1842
Group C	-21.89000*	2.2480	<0.01*	-28.5328	-15.2472
Group D	-69.20000*	2.2480	<0.01*	-75.8428	-62.5572
Group F	-57.96000*	2.2480	<0.01*	-64.6028	-51.3172
Group F					
Group A	54.79000*	2.2480	<0.01*	48.1472	61.4328
Group B	33.13300*	2.2480	<0.01*	26.4902	39.7758
Group C	36.07000*	2.2480	<0.01*	29.4272	42.7128
Group D	-11.24000*	2.2480	<0.01*	-17.8828	-4.5972
Group E	57.96000*	2.2480	<0.01*	51.3172	64.6028

[Table/Fig-6]: Post Hoc for comparison of frictional resistance between each experimental group.
*highly significant with p<0.01

DISCUSSION

In the current study, the epoxy coated archwires demonstrated significantly more frictional resistance than the non coated wires in all the three bracket materials. Stainless steel brackets produced significantly lesser friction and ceramic brackets produced the maximum friction with both coated and non coated archwires.

When an non coated arch wire was used the frictional resistance generated was similar in stainless steel bracket and composite bracket. The forces generated by non coated wires in ceramic brackets were similar to the friction generated by the coated wires in stainless steel brackets. Other groups showed highly significant differences in the frictional resistance generated between the bracket and archwire during sliding.

The fact that stainless steel brackets producing lesser friction than composite and ceramic brackets may be due to the polished surface and lower surface roughness of the stainless steel [19-21]. Researches evaluating the frictional properties of ceramic brackets have found that ceramic brackets have greater resistance than stainless steel brackets and composite brackets with polycrystalline ceramic brackets producing more friction than the monocrystalline brackets [22-28].

Studies evaluating the effect of aesthetic coating on frictional resistance generated by archwires mostly have evaluated the rectangular archwires and only few studies have evaluated the aligning archwires but, none of them have evaluated the effect of epoxy coating in round NiTi wires in three different type of bracket material [20-26, 29-32].

A study conducted by Farronato G et al., evaluating the frictional resistance generated by round and rectangular archwires in self-ligating brackets showed that teflon coating reduced the frictional resistance generated by the orthodontic archwires [29].

Al-groosh D et al., compared the static frictional resistance of fiber-reinforced polymer composite archwire with teflon coated, epoxy coated and a conventional NiTi archwires in ceramic brackets and concluded that composite wires showed higher friction value when used with ceramic brackets compared to other coated and non coated archwires. Contrary to the findings of the previous study teflon coated archwires demonstrated more frictional resistance than epoxy coated wires and non coated wires [30].

In experimental research evaluating polycrystalline ceramic brackets with and without metal slot and monocrystalline brackets with teflon coated, epoxy coated, and rhodium coated stainless steel wires epoxy coated wires produced more friction than teflon coated archwires [31].

Studies have shown that the surface roughness in as received epoxy coated wires are higher compared to other aesthetic arch wires and it may due to the difference in the coating methods. The epoxy coating of the G and H archwire evaluated in the study is carried out by electrostatic coating where atomized liquid epoxy particles are air sprayed over the archwires wire resulting in 0.002″ thick epoxy covering around the wire. Aesthetic wires coated by embedding methods or micro layering process have been reported to provide durable coating which accounts for its lowered surface roughness [31,32].

The frictional forces generated by the archwires are not exclusively dependent on the surface coating and the surface roughness but also on the cross-section, inner core dimension and elastic modulus of wires and this could be the probable explanation for the contradictory finding observed in the previous studies [33,34].

In the current study, it was observed, that, the epoxy coated 0.016* NiTi wires generated significantly less friction in composite brackets compared to ceramic brackets and based on this finding composite brackets could be a choice of aesthetic brackets along with epoxy coated NiTi archwires.

Limitation(s)

The limitation of the study evaluating the frictional resistance in experimental set-up, is that, the friction magnitude recorded is substantially different type of friction generated during orthodontic tooth movement. The difference is, due the fact that the values are measured in dry conditions and the lubricant effect of saliva which is major influencing factor is missing.

CONCLUSION(S)

Epoxy coated of the 0.016* superelastic NiTi archwires significantly increased the friction during sliding in all the three types of brackets. The coated wires generated less friction in composite brackets compared to ceramic brackets. The friction may reduce the aligning efficacy of the archwire when used along with aesthetic brackets and increase the treatment period. Further clinical trials are recommended to evaluate the aligning efficacy of these archwires in aesthetic brackets.

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