Evaluation of frictional forces generated in retrieved aesthetic wires with different ligation methods

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ABSTRACT

Objective: To evaluate frictional forces generated in retrieved aesthetic archwires with different ligation methods.
Materials and Method: A total of 40(20 new and 20 retrieved from the patient's mouth) Teflon coated 019X025 Stainless steel archwires and 40(20 new and 20 retrieved from the patient's mouth) conventional 019X025 Stainless steel archwires were used for the study. The retrieved archwires were cleaned in ultrasonic cleaner for 15 minutes and placed in glutaraldehyde solution for one hour. A jig was formed using ceramic brackets without metal slot and a molar tube for the purpose of evaluation of friction forces. The wires were ligated with either stainless steel ligatures or elastomeric modules. The values obtained were subjected to Mann Whitney and Wilcoxon Sign rank test for statistical analysis.
Results: The frictional values for conventional Stainless steel wires was less than Teflon coated wires in case of new wires. In case of retrieved archwires there was no difference between conventional or Teflon coated wires. The amount of friction for both Teflon coated and conventional wires decreased on retrieved from the patient. In case of Teflon coated wires the friction was greater with ligatures as compared to modules while in case of conventional Stainless steel wires it was vice-versa.
Conclusion: Teflon coated wires when cleaned in ultrasonic cleaner showed reduction in frictional forces with no significant difference in friction generated by both methods of ligation.

Key Words: Frictional Forces, Coated Stainless Steel Wire, Retrieved Wire.

INTRODUCTION

In modern society with more and more emphasis on aesthetics there is an increased demand for orthodontic treatment. Consequently the demand for aesthetic orthodontic appliances is also on the rise, particularly because more and more adult patients are seeking orthodontic treatment.[1] As the demand for aesthetic orthodontic appliance is increasing there is rapid development of materials that present acceptable aesthetics for the patients and an adequate clinical performance for clinicians.[2]
These developments have been in the form of tooth coloured brackets, aesthetic ligation systems, invisalign technology and lingual orthodontics. Over the years various manufacturers have marketed tooth coloured archwires with little success.[2]
The first aesthetic transparent non-metallic orthodontic wire contained a silica core, a silicon resin middle layer and a stain resistant nylon outer layer and was marketed as Optiflex by Ormco. Another research group has also developed a fibre reinforced polymer wire.

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Although these polymer based aesthetic wires have an excellent appearance, they have not been clinically popular because of their brittle character.[1]
To overcome this drawback an alternative route was chosen by some researchers wherein they coated the traditionally available wires with an aesthetic coating.
The coated arch wires which are currently available either have an epoxy resin, Polytetraflouroethylene (Teflon) or a low reflectivity rhodium coating[2] applied to the surface. Teflon or Polytetrafluoroethylene (PTFE) is a material characterized by a completely fluoridated chain. This chain is responsible for its physical and chemical characteristics. From an orthodontic point of view, PTFE is an anti-adherent and aesthetic material that has excellent chemical inertia as well as good mechanical stability.[3] It is made through a sintering process and two forms exist: classical PTFE, not microporous (Teflon) and expanded PTFE (ePTFE), microporous (Gore-Tex). ePTFE is characterized by orientated microfibrils, kept together by solid junctions.[4] Atomized Teflon particles are used to coat the wire using clean compressed air as a transport medium, which is then further heat treated in a chamber furnace. The coating is applied in a depository process that plates the base wire, and its thickness is approximately 0.002 inches as reported by manufacturers. Thus a strong adhesion is achieved between the coating and the wire.[5]
Coating of wires improves aesthetics but creates a modified surface which can affect friction, surface

roughness, bacterial adhesion and mechanical durability of wire and hence may alter the mechanics of orthodontic tooth movement.[6]

The influence of friction between the wires and the bracket during tooth movement in orthodontic treatment is of interest since space closure involves mechanical sliding of the brackets over the wire.[7] During orthodontic mechanotherapy, tooth movement occurs only when applied forces overcome the friction at the bracket-wire interface and apply the so called effective force.[8] Hence the friction will alter the effective force and then the anchorage required during space closure.

One of the problems with coated wires is that their coating layer peeled off in many areas during oral exposure, leaving surface defects. Silva[9] et al evaluated the coating stability of coated Stainless steel after 21 days of oral exposure and concluded that surface coating defects may vary the surface roughness and may then alter the friction at bracket-wire interface.

There is little in the orthodontic literature about the frictional resistance of aesthetic wires after intraoral usage. The purpose of this study was to evaluate the frictional resistance of Teflon coated and plain stainless steel rectangular arch wires ligated with two different methods before and after clinical use.

MATERIALS AND METHOD

For this study a total of 80 Teflon coated stainless steel archwires (019 X 025) and 80 conventional stainless steel archwires (0.019X0.025) were used. Ceramic brackets without metal inserts and stainless steel molar tube MBT 022 slot Brackets were used for evaluation of friction. Ligation was done using elastomeric modules or stainless steel ligature 0.009 inches.(Table 1).

Method to obtain retrieved wires:

For retrieval of arch wires a total of 40 patients were randomly divided into four groups. These patients were used for retrieval of wires to be used in subgroup 1b, subgroup 2b, subgroup 3b and subgroup 4b.

Inclusion criteria for the patients:

1. Undergoing MBT 0.022 slot fixed mechanotherapy.
2. On 0.019 × 0.025 NiTi wire for at least four weeks.
3. Retraction yet to begin.
4. Undergone maxillary first premolars extraction for orthodontic treatment.

Exclusion criteria for the patients:

1. Maxillary anterior tooth extraction/missing.
2. Maxillary anterior spacing present.
3. Proximal stripping done in maxillary anterior region.

A total of 10 teflon coated wires were ligated with modules (for subgroup 1b), 10 teflon coated wires were ligated with SS ligatures (for subgroup 2b), 10 conventional stainless steel archwires were ligated with modules (for subgroup 3b) and 10 conventional stainless steel wires were ligated with SS ligatures (for subgroup 4b). The archwires were placed in each group of patients for four weeks to obtain final alignment. During this stage no retraction force was used.

Cleaning Procedure:

The as-received and retrieved wires were ultrasonically cleaned at 60°C for 15 minutes with distilled water and then immersed in Glutaraldehyde solution for 2 hours and then dried in warm air. Then the wires were used for friction testing.

Friction Testing:

The bracket wire combinations were submitted to mechanical tests with the Computerised Universal Testing Machine (Times-Shijin Group Inc, Banbros; Model no. WDW-5).

Friction testing was performed using two plates, one acrylic (area = 40 × 10 mm^2, thickness = 10 mm) and other metallic (area = 10 × 10 mm^2, thickness = 20 mm). Two ceramic brackets were embedded in acrylic plate - one at 1mm from extremity of the plate and other at 4mm from other bracket. After this a molar tube was placed at a distance of 4 mm from the brackets. One SS wire (0215× 025) was placed in the bracket slot, providing a full filling for bracket alignment before embedding the brackets in the acrylic plate. Acrylic plate was fixed in upper movable clamp of machine. The metallic plate with a flat surface was fixed in lower non movable clamp of machine such that the flat surface was perpendicular to the upper acrylic plate. Clamp was tightened, with no gap between plates. Then upper part of machine was moved upwards so that a 4 mm of gap was present between the plates. Sample wire was placed in brackets so that lower end of wire touches the flat surface of lower plate. Then the upper acrylic plate was moved towards lower plate at a speed of 0.5 mm/minute for a distance of 2.5 mm so that the wire was forced to slide within the bracket slots. The test model was the same for all the test samples and only the wire segments were changed. After each friction test, the brackets were cleaned with gauze soaked in alcohol (96 per cent) to eliminate possible debris from the previous wire. Kinetic frictional force was measured in Newtons (N), using the mean force exerted from the beginning of the movement until the end of the test.

Statistical Analysis

The data distribution for friction between the ligation methods was checked with Mann Whitney test; between new and retrieved wires was checked with Wilcoxon Sign Rank test.

RESULTS

The results revealed higher mean frictional values for as received wires for both Teflon coated and plain stainless steel rectangular wire. But when method of ligation was compared it showed that stainless steel ligature had higher values in case of as received Teflon coated stainless steel wire and lower value for retrieved plain stainless steel wire (Table 2).

When the correlation was made between methods of ligation in Teflon coated wires it showed there was highly significant difference in as received wires but no difference between retrieved wires. Also a significant difference was seen between both methods of ligation in as received and retrieved wires (Table 3).

When the correlation was made between methods of ligation in plain stainless steel wires it showed there was highly significant difference in both as received wires and retrieved wires. Also a significant difference was also seen between both methods of ligation in as received and retrieved wires (Table 4).

Now when comparison was made between the two wires with only module as ligation method only the as received Teflon coated and plain stainless steel wires showed highly significant difference (Table 5). There was no difference in case of retrieved archwires.

When comparison was made between the two wires with only stainless steel ligature as ligation method both as received and retrieved Teflon coated and plain stainless steel wires showed highly significant difference (Table 6).

Table 1: Distribution of samples in various groups and subgroups was as follows

Group	Wires used	Subgroup a	Subgroup b
Group 1 n= 20	Teflon coated stainless steel wires ligated with modules	As Supplied by manufacturer (n= 10)	Retrieved from patients (n= 10)
Group 2 n= 20	Teflon coated stainless steel wires ligated with SS ligatures	As Supplied by manufacturer (n= 10)	Retrieved from patients (n= 10)
Group 3 n= 20	Conventional stainless steel wires ligated with modules	As Supplied by manufacturer (n= 10)	Retrieved from patients (n= 10)
Group 4 n= 20	Conventional stainless steel wires ligated with SS ligatures	As Supplied by manufacturer (n= 10)	Retrieved from patients (n= 10)

Table 2: Mean values with standard deviation

	Ligation Method / As received or retrieved wire	Mean	Standard Deviation	Maximum	Minimum
Teflon Coated Stainless Steel	Module /As Received	31.24	2.34	36.2	28.1
	Module / Retrieved	5.16	1.9	8.1	2.8
	Ligature / As Received	36.65	3.03	40.7	32.1
	Ligature / Retrieved	5.49	2.11	9.5	3
Plain Stainless Steel	Module / As Received	12.22	1.36	13.6	9.8
	Module / Retrieved	4.78	2.42	8.6	1.7
	Ligature / As Received	8.12	0.5959	9.4	7.5
	Ligature / Retrieved	1.49	0.7264	3.2	0.8

Table 3: Correlation between methods of ligation using Teflon coated wire

		New		Retrieved			
		Mean	SD	Mean	SD	Wilcoxon Sign Rank Test	p - Value
Teflon	Module	31.240	2.3391	5.160	1.9039	-2.807	0.005
	Ligature	36.650	3.0369	5.490	2.1184	-2.803	0.005
	Mann Whitney U	7.500		44.500			
	p – Value	0.001		0.677			

p=< 0.001 – Very Highly Significant; 0.001 – 0.01 – Highly Significant

Table 4: Correlation between methods of ligation using plain stainless steel wire

		New		Retrieved			
		Mean	SD	Mean	SD	Wilcoxon Sign Rank Test	p - Value
SS	Module	12.220	1.3677	4.780	2.4252	-2.803	0.005
	Ligature	8.120	0.5959	1.490	0.7264	-2.805	0.005
	Mann Whitney U	0.000		4.500			
	p – Value	< 0.001		0.001			

p=< 0.001 – Very Highly Significant; 0.001 – 0.01 – Highly Significant

Table 5: Correlation between Teflon coated and plain stainless steel wire with module as ligation method

		New		Retrieved	
		Mean	**SD**	**Mean**	**SD**
Module	Teflon	31.240	2.3391	5.160	1.9039
	SS	12.220	1.3677	4.780	2.4252
	Mann Whitney U	0.000		45.500	
	p - Value	< 0.001		0.734	

p=< 0.001 – Very Highly Significant; > 0.05 – Not Significant

Table 6: Correlation between Teflon coated and plain stainless steel wire with stainless steel ligature as ligation method

		New		Retrieved	
		Mean	**SD**	**Mean**	**SD**
Ligature	Teflon	36.650	3.0369	5.490	2.1184
	SS	8.120	0.5959	1.490	0.7264
	Mann Whitney U	0.000		1.000	
	p - Value	< 0.001		< 0.001	

p= < 0.001 – Very Highly Significant

DISCUSSION

During orthodontic treatment, friction between the bracket and wire is present from the early stages of alignment and levelling up to the finishing phase. Thus, the resistance to sliding of the bracket along the orthodontic wire is important in clinical practice since a lower friction of orthodontic mechanics can be directly related to a reduction in treatment time.[10]

The effect of aging in the oral environment is an important factor to consider with regard to the efficacy of orthodontic mechanics. Aging effects on surface archwire roughness, surface topography, fracture and friction have been examined in only a few investigations on NiTi archwires.[10]

There are few studies on intraoral ageing of orthodontic archwires and its effects on mechanical properties.[11] A recent study done by Marques[12] et al demonstrated that Stainless Steel rectangular archwires, when exposed to the intraoral environment for 8 weeks, showed a significant increase in the degree of debris and surface roughness, causing an increase in friction. As there are no studies on Teflon coated stainless steel rectangular wires studying its frictional resistance, so this present study was conducted to evaluate and compare friction produced by Teflon coated and plain stainless steel rectangular wire before and after clinical use with two different methods of ligation.

In the present study, the as received Teflon coated stainless steel rectangular wire showed higher friction value when ligated with stainless steel ligature 36.65± 3.03 (Table 2) but when as received plain stainless steel wire was used, higher friction value was shown by ligation with module (12.22±1.36). The reason for this may be that as the ligature wire was tied it may get embedded into the coating creating an irregular surface and hence friction increases.

When frictional values were compared between Teflon coated wires, as received wires showed higher values with both the methods of ligation. A study conducted by Marques[12] et al revealed that there was a significant increase in the surface roughness and friction in stainless steel rectangular wires after clinical use. Conversely in our study, retrieved Teflon coated wires showed much less values with both the methods of ligation as debris and calculus deposited on the wires was removed during the cleaning procedure. This finding has been previously reported by Normando[13] et al in which he proved that amount of friction is reduced after archwire cleaning. Also it was found that coating was removed from the edges of wire contributing to lower frictional values. He used stainless steel wool sponge for cleaning the archwires for 1 minute and the friction values returned to values similar to those of as-received archwires. In addition, the use of stainless steel wool sponge was shown to be more efficient for the removal of debris accumulated on the orthodontic wire surface; this method has the advantage that it can be clinically applied in a shorter period of time (1 minute)[13] but as this method cannot be used for coated archwires so in the present study archwires were ultrasonically cleaned at 60°C for 15 minutes with distilled water and then immersed in Glutaraldehyde solution for 2 hours.

The ligation between bracket and wire is another variable that could influence the frictional force level. Authors are unanimous in reporting that the force used through stainless steel ligature is subjective, varying according to the orthodontist and it can fracture ceramic brackets.[14-18] On the other hand, elastomeric ligature loses elasticity with time and can alter the frictional force values (same).[19] In stainless steel wires, as received wires ligated with module showed higher frictional values (12.22±1.36) because there is more tendency of debris accumulation around a module as compared to ligature wire as seen in studies done by Berdner, Gruendeman and Sandrik.[20] Also a higher frictional value was seen with module ligation in retrieved SS wires (4.78±2.4).

In the retrieved Teflon coated stainless steel wire both the methods of ligation showed similar friction values (table 2) as the coating was removed from the edges of the brackets during sliding. In retrieved plain stainless steel wires, module ligation still showed higher values (4.72±2.42). Retrieved wires showed less friction values because debris collected on wires was effectively removed by immersion in ultrasonic cleaner for 15 min and then immersed in glutaraldehyde for two hours.

CONCLUSION

As the demand for esthetic orthodontic appliances is increasing, there is rapid development of materials with acceptable esthetics. So Teflon coated stainless steel rectangular archwires are one of these new inventions. But as friction plays an important role in sliding mechanics it is important for orthodontists to know about the amount of friction produced by such wires. So this study was conducted and it can be concluded that-

1. As received Teflon coated stainless steel wires ligated with SS ligature showed higher mean frictional values as compared to plain stainless steel rectangular wire.
2. Retrieved Teflon coated wires ligated with SS ligature still showed higher frictional values but they were very less as compared to as received wires.
3. As received and retrieved stainless steel wires showed higher frictional values with elastomeric module as ligation method but the frictional values were significantly reduced in retrieved wires.
4. Between the two wires, Teflon coated arch wires showed higher friction values with both the methods of ligation.

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