Original Article

Friction of Stainless Steel Archwires after Clinical Use in Orthodontic Patient

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Abstract

Background: *Friction is a force that retards or resists the relative motion of the two objects in contact. The friction present during orthodontic sliding mechanics represents a clinical challenge to the orthodontists because high levels of friction may reduce the effectiveness of the mechanics, decrease tooth movement efficiency and further complicate anchorage control. The aim of the study is to investigate the friction of stainless steel archwires after clinical use.*

Objectives: *To evaluate the Friction that occur in SS orthodontic archwires before and after clinical use.*

Place of study: *Department of Orthodontics & Dentofacial Orthopedics of Dhaka Dental College & Hospital, Dhaka. Co-institute-Bangladesh Council of Scientific and Industrial Reserch (BCSIR).*

Method: *Eight patients were randomly selected undergoing regular orthodontic treatment with edgewise brackets. A 0.016×0.022-inch stainless steel round archwire was inserted into the brackets and tied by elastomeric ligatures. Frictional force (by Universal Test Machine) were evaluated as-received and after 8 weeks of intraoral exposure.*

Result: *In this study Frictional force analysis showed a highly significant increase from T0 to T1 (p=0.001).*

Conclusion: *After intraoral use rectangular SS wire shows significant increase in friction .*

Key words: *Friction, Intraoral use, Stainless steel Archwire.*

Introduction

Friction is a force that retards or resists the relative motion of two objectives in contact.[1] The direction of friction is tangential to the common boundary of the two surfaces in contact.[2] As two surfaces in contact slides against each other, two components of total force arise: the frictional force component (F) and the normal force component (N).[3] Frictional force is directly proportional to the normal force, such that $F=\mu N$, where μ= coefficient of friction.[4] The static frictional force is the smallest force needed to start the motion of solid surfaces that was previously at rest with each other, whereas the kinetic frictional force is the force that resists the sliding motion of one solid object over another at a constant speed.[5] As the tooth moves in the direction of the applied force, kinetic friction occurs between the bracket and archwire.[6]

The friction present during orthodontic sliding mechanics represents a clinical challenge to the orthodontists because high levels of friction may reduce the effectiveness of the mechanics, decrease tooth movement efficacy and further complicate anchorage control.[7] When the orthodontic wires slide through the bracket slot and the tubes, some resistance to sliding always takes place at the bracket/wire interface. This phenomenon is observed during leveling and alignment, space closure and even during torque expression at the end of the treatment.[8] A percentage of the orthodontic force applied to the teeth is lost as static friction and the rest is transferred to the tooth and periodontium, generating the actual orthodontic tooth movement. Thus, the biological tissue response to mechanical stimulus takes place only if the force is strong enough to overcome static friction. Therefore, higher levels of friction during sliding mechanics require the application of higher orthodontic forces and may compromise the amount of orthodontic tooth movement.[9]

Studies examining wires as-received from the manufacturer have shown an inverse relationship between the force loss caused by friction, the slot size, and the interbracket distance.[10,11] Direct relationship between the frictional force and the wire section diameter,[10,12-13] as well as the angulation between the bracket and the wire,[10,14] have been reported. Despite some inconsistency in the literature, studies have demonstrated that stainless steel (SS) wire produce less friction than other materials.[10,15,16] SS ligatures creats less friction when compared with elastic ligatures.[10] More recently, studies have demonstrated less friction when self ligating brackets are used during initial sliding mechanics.[13,17,18,] However,when loosened steel ligatures are used, the friction of conventional and self ligating brackets is more or less similar.[12,18] Biological variables causing friction include the presence of saliva, acquired pellicles, corrosion, and plaque.[10]

The major biological factor influencing SF seems to be the presence of saliva, which acts as a lubricant and plays an important role in friction reduction.[19] The influence of saliva in friction reduction may also be relevant when an orthodontists consider the clinical application of in vitro laboratory studies.[2] Some of the studies have shown that when SS wires are used, saliva may not act as a lubricant.[16,20] Instead, saliva may increase the friction and present an adhesive interference, caused by increased surface tension in the archwire.[10]

Stainless steel is the most popular and commonly used archwire in fixed mechanotherapy. The role of the orthodontic wire alloys in frictional characteristics of sliding mechanics has

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been extensively studied, and it has been reported that stainless steel offers the least frictional resistance when compared to the other orthodontic alloys.[21] SS archwires are more frequently indicated for sliding mechanics because of their lower friction coefficient. Also, rectangular SS archwires used during sliding mechanics may need to stay in the oral environment for several months.[10]

Dental material science has paid more attention to archwire mechanical properties of as-received material than to changes produced after intraoral exposure.[10] Despite the abundance of evidence produced by orthodontic materials research, the laboratory configurations are strikingly irrelevant to the actual oral environment. The main factor that distinguishes the oral cavity from in vitro media is the presence of complex oral flora and their byproducts, as well as the accumulation of plaque on the material. Thus, it is necessary to examine the changes produced by the oral environment in the friction of orthodontic wire. So this study was conducted to find out the changes of orthodontic archwire after intraoral exposure in which it is intended to function.

Orthodontic tooth movement is caused by the application of a mechanical force to the tooth. This mechanical force induce friction between the archwires and brackets. Therefore tooth movement occurs as the applied force goes beyond the friction induced by an interaction between the archwire and brackets. However the increase in the frictional force between the archwire and brackets is responsible for the decrease in actual bone adaptation to the tooth. These negative correlations lead to a decrease in the efficacy of orthodontic treatment.[22] Orthodontic tooth movement is dependent on the ability of the clinician to use controlled mechanical forces to stimulate biologic responses within the periodontium. Investigators. have indicated that applying the proper magnitude of force during orthodontic treatment will result in optimal tissue response and rapid tooth movement.[23] It is important for the orthodontists to know the exact frictional forces encountered at the bracket-wire interface because we have to apply optimal force in order to elicit the proper biologic response for efficient tooth movement.[24]

There is no study in our country regarding the orthodontic material to reveal their effects on friction after clinical use. The aim of the study was to find out the frictional changes of stainless steel archwires in intraoral environment of our patients to help the orthodontist of our country to apply optimal force and to take measures for efficient tooth movement/ orthodontic treatment.

Materials and Methods

This clinical trial was conducted at Department of Orthodontics & Dentofacial Orthopedics of Dhaka Dental College & Hospital, Dhaka & Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka from September 2017 to March 2018.

Sample collection: 16 preformed rectangular Stainless Steel (0.016x0.022) inch Archwires (ORMCO, GLENDORA, CALIFORNIA) was collected from same manufacturer. Then the samples were divided into two groups, T0 & T1 each comprised of eight samples. Eight pieces were remain intact in the packet and eight were used intra-orally.

Intraoral exposure: Eight patients were randomly selected undergoing regular orthodontic treatment in the Department of Orthodontic and Dentofacial Orthopedics, Dhaka Dental College, Dhaka. The effects of intraoral exposure were examined in these patients who were receiving fixed orthodontic treatment with edgewise technique at final alignment and leveling stage. Rectangular SS wires were inserted into the brackets (Standard edgewise, 0.18 slot, Archist, Seol, Korea) previously bonded for treatment purpose. The wires were tied to the brackets with elastic ligatures (0.120 diameter, Oramco, Mexico). The wires were remain in the oral environment for eight weeks.

After eight weeks the wires were removed from oral cavity and stored in a close container. Within the container a layer of modeling wax was put to keep the wire in upright condition. The container was carried for laboratory examinations. Before laboratory examinations each of the archwires were cut into two pieces, thus obtained 16 samples after clinical use. Then, friction test were done after 48 hours by universal testing machine.

Figure 1.1: Grouping of sample To For control group

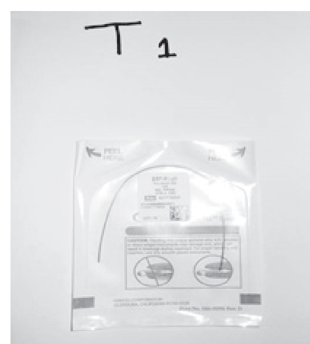

Figure 1.2: Grouping of sample T1 for study group

Fig 2: Stainless Steel Archwires exposed to the oral environment for 8 weeks.

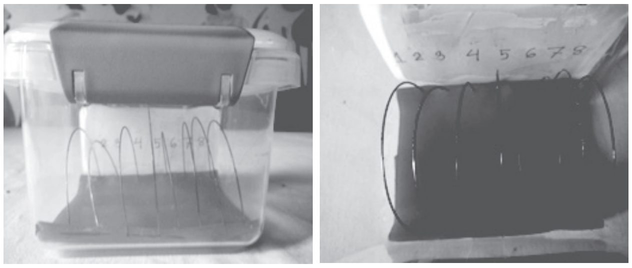

Figure 3: Preservation of the sample in a closed container with a layer of modelling wax

Friction Testing

Friction testing was done using two rectangular acrylic plates (area=4x5.5 cm and thickness=0.5 cm).Two SS edgewise brackets (0.18 slot, Archist, Korea) were bonded on each plate. One SS wire (0.017x0.025 inch) were placed in the bracket slot, providing a full filling for the bracket alignment, and were removed after the composite had cured.

Then, the SS wire for friction test was tied to the bracket slot using a 0.120 inch diameter elastic ligature (Oramco, Mexico).The acrylic plate containing the bent wire segment was fixed in the universal test machine (HOUNSFIELD UNIVERSAL TESTING MACHINE, W10 KS, England) and positioned at a 90° angle relative to the ground. The plates containing the wire end was at the upper grip.

The machine was connected to a computer which contained a software program to record the measurements. The 0.016x0.022 inch SS wire segment's dimensions were transferred in millimeters as 0.41mm x 0.56 mm. The plates moved at the rate of 0.5mm/min for 10 minutes to cover a distance of 5mm.

The upper and the lower grip were tightened to hold the acrylic plates containing the wire segments, and the software programme was started which enabled the machine and the force level were recorded.

The test models was the same for all friction test, so only the wire segments and elastic ligatures were changed. After each friction test, the brackets were cleaned with gauze soaked in alcohol (96%) to eliminate possible debris from the previous wire.

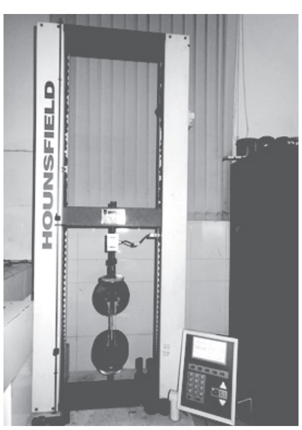

Figure 4: Universal testing machine

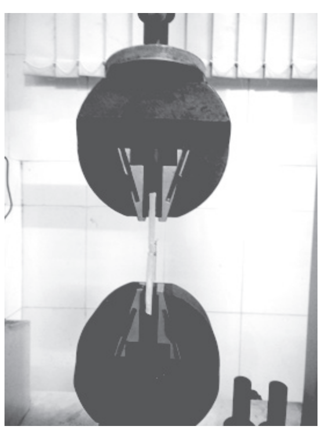

Figure 5: Friction testing in Universal testing Machine

Tensile of Compostes Afroza IUK

Product : *SS wire bracket friction*
Batch :

Specimen	Thick mm	Width mm	Yield MPa	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
P1a	0.4100	0.560	6.53	7.99	1.835	5.77	6.91	6.16	1.415

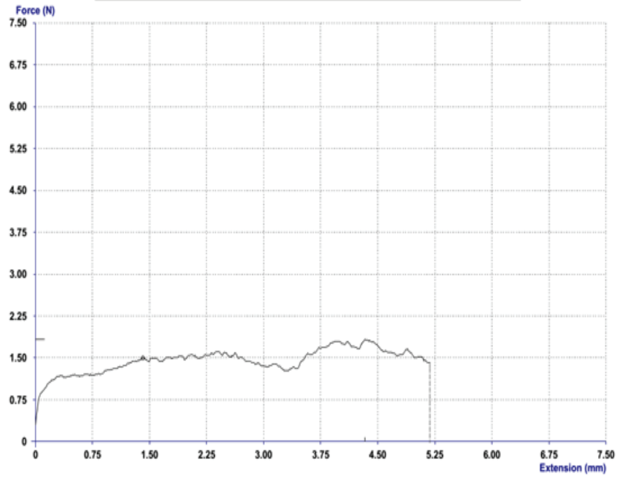

Figure 7: Graphical presentation of Friction test T0 group

Tensile of Compostes Afroza IUK

Product : *SS wire bracket friction*
Batch :

Specimen	Thick mm	Width mm	Yield MPa	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
TR1a	0.4100	0.560	51.2	75.8	17.40	6.14	6.97	75.3	17.28

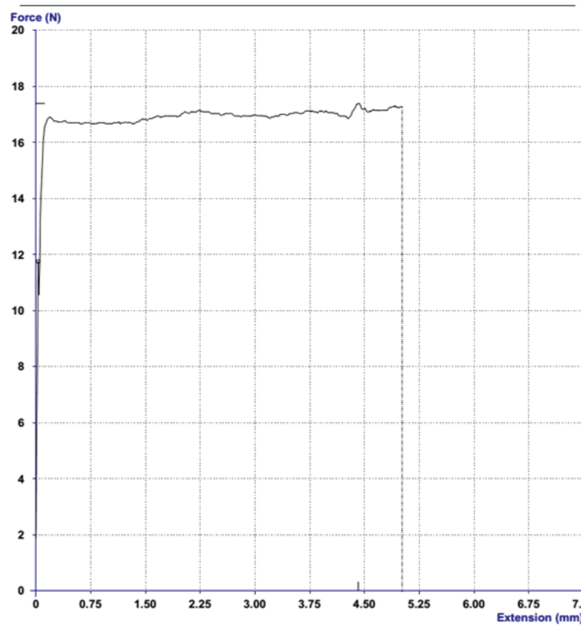

Figure 8: Graphical presentation of Friction test T1 group

A Data collection sheet was used to collect necessary information of the samples. All data was collected from computerized software system. All data were collected and entered in a excel sheet and then the data were transferred to statistical packages for Social Science Software (SPSS) version 20 (IBM Corp, USA).The data analyzed through SPSS. The confidence level was set by 95% and the p value was significant on less then 0.05.Un-paired T test was done to compare the two groups.

Result

Friction analysis

The mean(±SD) Frictional force of as received(T0) wires was 2.70±2.44 N and clinically used (T1) wires was 25.12±8.18N.Statistical analysis showed a highly significant increase from T0 to T1(p<0.001).

Table 1: Descriptive statistics for Friction and P values for Comparisons of as-Received SS Archires (T0) and clinically used SS Archires (T1)

Groups	Friction (N) Mean±SD	P value
As Received (T0) (n=8)	2.70±2.44	<0.001*
Clinically used (T1) (n=16)	25.12±8.18	

Data were expressed as mean±SD

P value reached from Unpaired Student t-test, *significant.

T0: As-received wire

T1: Clinically used wire

n- number of samples.

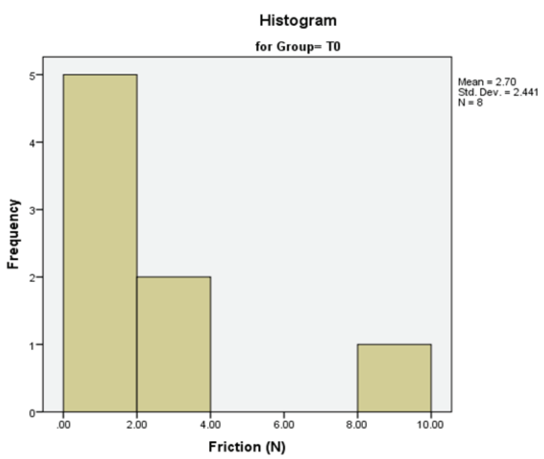

Figure-9: Showing the frequency distribution of Friction (N) in Group T0

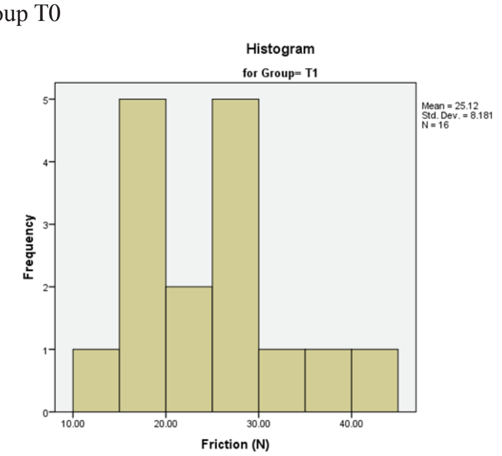

Figure-10: Showing the frequency distribution of Friction (N) in Group T1

Discussion

This study was conducted to evaluate the friction of SS archwire after clinical use. In the present study, the Frictional force of as received (T0) wires was 2.70±2.44 N and clinically used (T1) wires was 25.12±8.18N.The increase in friction of SS archwires after clinical use was highly significant (p<0.001).

The friction of brackets, ligatures and archwires as received from manufacturers has been studied extensively. The effect of aging in the oral environment is an important factor to consider with regard to the efficacy of orthodontic mechanics. Intraoral effects on friction of the archwires have been examined in a few investigations.[10,25] Rectangular SS wires were chosen as these wires are very useful during mechanical sliding because of the lower coefficient of friction. Also, during mechanical incisior retraction, torque expression during final leveling and alignment the wire needs to remain in the oral environment for several months. Edgewise stainless steel brackets were used in the present study because the slots are flat and they can be assembled without any angles or inclination and they are commonly used in clinical practice. The choice of elastic ligatures was made because they are the first choice for most clinical orthodontists. Furthermore it is difficult to standardize the tying strength using SS ligatures. This test setup used linear unidirectional sliding mechanics, while orthodontic tooth movement is dynamic.

In the present study, comparison of frictional forces of SS before and after clinical use showed significant increase in frictional force after clinical use. This result is similar to the previous studies.[10,25]

Resistance to sliding of orthodontic appliances in the dry state may not correspond to actual friction in the oral environment. The major biological factor influencing friction seems to be the presence of saliva, which acts as a lubricant and plays an important role in friction reduction. The adsorption of the intraoral integuments might greatly reduce the coefficient of friction by producing a boundary lubrication effect (i.e. through salivary protein adsorption and plaque accumulation).[26] On the contrary, the presence of saliva seems to cause an increase in friction.[19] The samples were analyzed after 48 hours after removal from the oral environment, which might have caused the drying of residues on the archwire surface. This might have influenced the friction level; however the dryness can also occur during the clinical use of orthodontic wire, since the orthodontist usually removes the archwire from the mouth and replaces it after a short period of time.

The magnitude of force loss caused by friction generated in the bracket-wire interface seems to be an important factor to be considered when the force to be applied is calculated. Tooth movement occurred most effectively at an optimal range of forces. When sliding mechanics are used, a proportion of the applied force is dissipated as friction and much of the remainder is transferred to supporting structures of the tooth to cause tooth movement. This implies that in order to achieve efficient tooth movement in the presence of bracket/archwire friction, the total force applied to the tooth will be determined by the optimal force necessary to move the tooth, as well as by the magnitude of bracket/archwire friction. It seems evident from the present study that the force used to move a tooth is insufficient to generate appropriate movement in rectangular archwires after 8 weeks of clinical use. So it is necessary to take measures to prevent an increase in friction during mechanical sliding.

Conclusion

This study concludes that rectangular SS wire exposed to the oral environment for 8 weeks shows a highly significant increase in friction between the wire and bracket during the mechanics of sliding. It indicates that intraoral use of stainless steel archwires reduces the effectiveness of the archwires and increased the amount of required force to achieve desired tooth movement.

Recommendation

We have to take measures to reduce friction such as archwire cleaning at each visit during orthodontic treatment. Further studies should be carried out to find out factors contributing in increasing friction among the orthodontic materials used in our country and take measures accordingly to reduce friction thus providing efficient treatment for our patients. Further study can be carried out with different bracket-archwire combinations, techniques and in different stages of orthodontic treatment in our patients to evaluate the friction and to provide cost effective alternatives aimed at reducing friction.

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