Journal of Advances in Medicine and Medical Research

32(24): 307-315, 2020; Article no.JAMMR.64770
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

A Comparative Evaluation of Frictional Resistance of Conventional, Teflon and Epoxy Coated Stainless Steel Archwires in Metal, Ceramic Brackets – An *In vitro* Study

Praveen Katepogu[1], Balagangadhar[2*], Chetan Dilip Patil[2] and Sanjeev V. Jakati[2]

[1]SRM Dental College, Chennai, Tamil Nadu, India.
[2]Yogita Dental College & Hospital, Khed, Maharashtra, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author PK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors Balagangadhar, CDP and SVJ managed the analyses of the study. Author PK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2020/v32i2430783
Editor(s):
(1) Dr. Rui Yu, The University of North Carolina at Chapel Hill, USA.
Reviewers:
(1) Sergio Luiz Mota Júnior, Juiz de Fora Federal University, Brazil.
(2) Erika de Oliveira Dias Macêdo, Federal University of Rio Grande do Sul, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64770

Original Research Article

Received 22 October 2020
Accepted 30 December 2020
Published 31 December 2020

ABSTRACT

Aim and Objectives: To evaluate the frictional resistance of Conventional, Teflon, and Epoxy coated stainless steel archwires in Metal, Ceramic brackets.
Materials and Methods: 0.019" x 0.025" Stainless steel arch wire. (G & H^{TM}) – 30n, 0.019" x 0.025" Teflon coated stainless steel archwire. (D-Tech^{TM}) – 30n, 0.019" x 0.025" Epoxy coated stainless steel archwire. (G & H^{TM}) – 30n, 0.22 MBT Stainless steel (Gemini- 3M Unitek^{TM},) lower incisor brackets – 30n, 0.22 MBT Ceramic (Gemini- 3M Unitek^{TM}), lower incisor brackets – 60n. The wires are cut into 5cm long and are ligated to bracket using 0.010- inch ligature wire. Acrylic block is placed in lower arm of Instron universal testing machine, free end of wire is pulled with upper arm of universal testing machine, at a rate of 10 mm/ min while the wire is placed parallel to long axis of bracket and tooth, and a load of 50 kg was used to measure frictional forces.
Results: Stainless steel bracket combined with Stainless Steel wire showed maximum Friction 2.640N (mean) and minimum was 0.307N (mean) with a SD of ±1.2275 (0.6618). Stainless-steel

**Corresponding author: E-mail: baalagangadhar@gmail.com;*

bracket combined with Epoxy coated SS wire showed maximum Friction of 10.3N and minimum was 5.62N with a SD of ± 7.3513 (1.8975). Stainless steel bracket combined with Teflon coated SS wire maximum Friction noted was 5.59N and minimum was 1.66N with a SD of ± 1.8652 (0.9545). Ceramic brackets combined with Stainless Steel wire showed maximum Friction 10.88N and minimum 4.29N with a SD of ± 6.55529 (1.6081). Ceramic brackets combined with Epoxy coated SS wire showed maximum Friction 14.88N and minimum 5.62 with a SD of ± 9.3305 (2.4077) Ceramic brackets combined with Teflon coated SS wire showed maximum Friction of 6.93N and minimum 4.31N with a SD of ±6.3483 (1.2302)

Conclusions: Stainless steel brackets combined with stainless steel archwires or Teflon coated archwires may be used effectively in sliding mechanics, rather than ceramic brackets and tooth-colored epoxy coated archwires.

Keywords: Orthodontics; friction; esthetic wires; stainless steel brackets; ceramic brackets; epoxy coated; teflon coated.

1. INTRODUCTION

Friction is classically described as a force acting tangentially at surface of two moving bodies in contact. Friction acts parallel to and opposing the movement. Friction can be either static or kinetic. Static friction is force needed to start the movement, whereas kinetic friction is force required to maintain movement once started [1].

Frictional forces in clinical orthodontics are considered as a primary concern since it resists regular tooth movements. During sliding movements of teeth, wire edges contact bracket angles, and a frictional force will develop that compete with normal tooth movements and decrease magnitude of applied orthodontic forces [2].

Orthodontic treatment with sliding mechanics involves a relative displacement of wire through bracket slots, and whenever sliding occurs, frictional resistance will arise. During early alignment phase, when all teeth move at same time, low levels of friction is required for the wire to slides through 10 brackets and two tubes [3].

Although more than 70 years have passed since introduction of stainless steel (SS) brackets, these brackets are most used, because of their superior working qualities, their only disadvantage is their lack of aesthetic appearance [4].

Ceramic brackets developed to improve aesthetics during orthodontic treatment. However, they have problems such as brittleness leading to bracket or tie-wing failure, iatrogenic enamel damage during debonding, and high frictional resistance to sliding mechanics. Ceramic brackets with stainless steel slot were recently developed to combine frictional characteristics of stainless steel with aesthetics of ceramics [5].

Orthodontist must apply more force to overcome friction, which results in increased anchorage loading and subsequent anchorage loss. This concept seeked techniques to reduce friction and, consequently, reduce the demand on anchorage and more efficient the system to achieve optimum goals.

1.1 Aims and Objectives

To evaluate frictional resistance of Conventional, Teflon, and Epoxy coated stainless steel arch wires in Metal, Ceramic brackets.

The objectives of the study are to evaluate the frictional resistance of,

A) 0.019" x 0.025" Conventional stainless steel arch wires (G & H™).
B) 0.019" x 0.025" Teflon coated stainless steel arch wire (D-Tech™).
C) 0.019" x 0.025" Epoxy-coated stainless steel arch wire (G & H™).

In

1 Stainless steel brackets (Gemini -3M Unitek™, Monrovia, California, USA),
2 Ceramic brackets (Gemini clear - 3M Unitek™, Monrovia, California, USA).

2. MATERIALS

1) 0.019" x 0.025" Stainless steel arch wire. (G & H™) – 30n
2) 0.019" x 0.025" Teflon coated stainless steel arch wire. (D-Tech™) - 30n

3) 0.019" x 0.025" Epoxy coated stainless steel arch wire. (G & H™) - 30 n
4) 0.22 MBT Stainless steel (Gemini- 3M Unitek™,) lower incisor brackets - 30n
5) 0.22 MBT Ceramic (Gemini- 3M Unitek™) lower incisor brackets - 30n

3. METHODOLOGY

A total of 60 acrylic lower incisor typodont teeth are used in the study. By using silicon rubber impression material (MoldSil 15™), a rectangular mould was prepared, then cold cure acrylic powder and liquid (DPI) is poured into the mould to make rectangular acrylic blocks in which acrylic lower incisor typodont tooth is embedded vertically up to the neck of tooth. These are divided into six groups, and each group consists of 10 acrylic lower incisor typodont tooth samples.

Individual orthodontic lower incisor brackets were bonded to lower incisor acrylic typodont teeth which are mounted in acrylic block using glue adhesive, (Cyanoacrylate™), in a standardized manner, so that long-axis of test bracket slot was parallel to upper arm of Instron universal testing machine (Fig. 1).

3.1 Standardization Protocol Following During Testing

Wires are cut into 5cm long and are ligated to bracket in a regular ligation method using 0.010-inch ligature wire. Acrylic block is placed in lower arm of Instron universal testing machine at an angulation that ensures the arch wire is placed parallel to the bracket slot without contacting the edges of the bracket. The bracket is bonded in such a way that the mesial and distal tie wings are parallel to the incisal edge, and the slot is parallel to the long axis of the lower incisor tooth. Upper arm of universal testing machine have a steel wire which is attached to free end of the archwire.

Free end of wire is pulled with upper arm of universal testing machine, at a rate of 10 mm/ min and wire was pulled up to a distance of 1cm. while the wire is placed parallel to long axis of bracket and tooth, and a load of 50 kg was used to measure frictional forces. Based on line graph obtained from movement of wire in the bracket, average of highest recorded point on line graph was considered as static friction. Total procedure was repeated for all specimens of respective groups. Total number of groups were as follows.

3.2 Composition of Test Groups

- Group 1: Ten Ceramic brackets (Gemini clear - 3M Unitek™, Monrovia, California, USA) with 0.019" x 0.025" Conventional stainless steel (G & H™) arch wires were used for testing. (Fig. 5)
- Group 2: Ten Ceramic brackets (Gemini clear -3M Unitek™, Monrovia, California, USA), = with 0.019" x 0.025" Teflon coated stainless steel arch wire (D-Tech™) were used. (Fig. 7)
- Group 3: Ten Ceramic brackets (Gemini clear -3M Unitek™, Monrovia, California, USA) with 0.019" x 0.025" Epoxy-coated stainless steel arch wire (G & H™) were used. (Fig. 6)
- Group 4: Ten Stainless steel brackets (Gemini -3M Unitek™, Monrovia, California, USA) with 0.019" x 0.025" Conventional stainless steel arch wires (G & H™) were used. (Fig. 2)
- Group 5: Ten Stainless steel brackets (Gemini - 3M Unitek™, Monrovia, California, USA) with 0.019" x 0.025" Epoxy-coated stainless steel arch wires (G & H™) were used. (Fig. 3)
- Group 6: Ten Stainless steel brackets (Gemini -3M Unitek™, Monrovia, California, USA) with 0.019" x 0.025" Teflon coated stainless steel arch wire (D-Tech™) were used. (Fig. 4)

Fig. 1. Instron universal testing machine

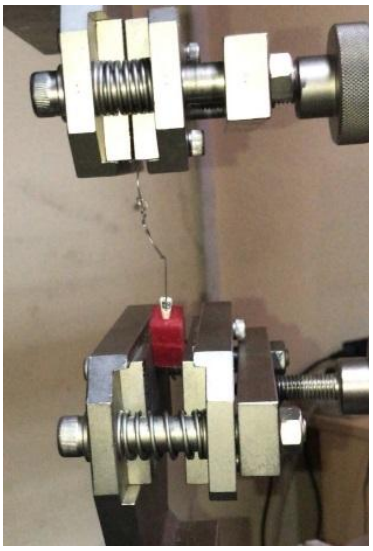

Fig. 2. SS bracket with uncoated0.019" x 0.025" SS arch wire

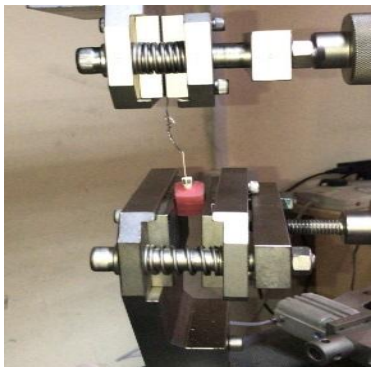

Fig. 3. SS bracket Epoxy coated 0.019" x 0.025" wire

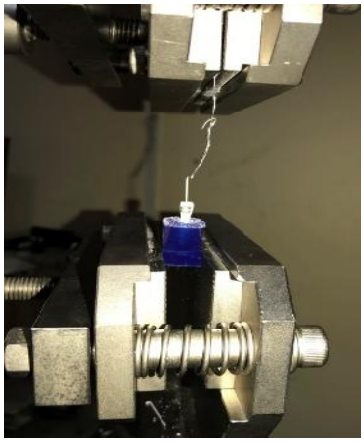

Fig. 4. SS bracket Teflon coated 0.019" x 0.025" SS wire

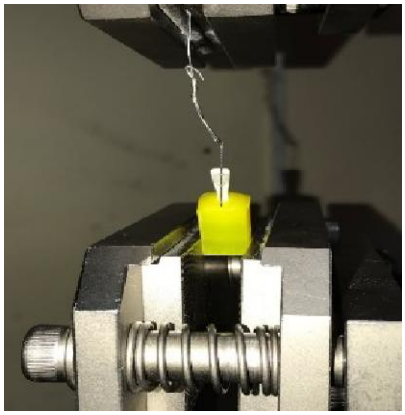

Fig. 5. Ceramic bracket with Uncoated 0.019" x 0.025" SS wire

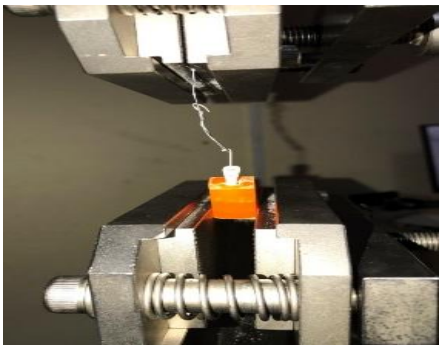

Fig. 6. Ceramic bracket with Epoxy coated 0.019" x 0.025" SS arch wire

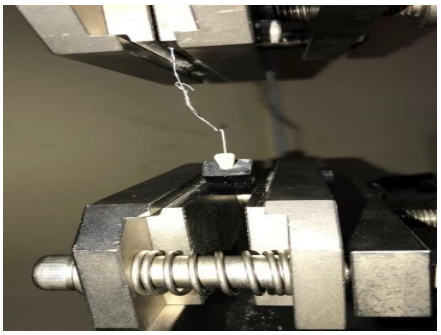

Fig. 7. Ceramic bracket with Teflon coated 0.019" x 0.025" SS arch wire

3.3 Statistical Analysis

Data collected is entered into a computer and analysed using SPSS software. Descriptive and inferential statistical analyses are carried out. Results on continuous measurements are presented on Mean + SD, and results on categorical measurements are presented in number (%). Level of significance is fixed at

p=0.05, and any value equal to or less than or <0.05 is considered to be statistically significant.

One way ANOVA and Tukey test is used to determine significant frictional differences between arch wires and brackets.

4. RESULTS

Group of ceramic bracket with epoxy coated ss arch wire shows the highest frictional resistance, i.e. 14.881N with a SD of ± 9.3305 (2.4077) whereas group of (ss bracket + ss arch wire) shows lowest frictional resistance of 2.640N with a SD of ±1.2275 (0.6618). (Table 1 & Table 2).

5. DISCUSSION

Friction is defined as a force which resists or delays or the relative motion of two objects which are in contact and its direction is tangential to the common interface of the two surfaces. The frictional force is proportional to applied load under normal conditions, depending on the nature of the sliding surfaces and independent of the contact area between the surfaces and the sliding speed. The friction coefficient of a given material couple is the ratio between the tangential force (frictional force) and the normal or perpendicular load applied during the relative motion. [1]

Table 1. Descriptive statistics for groups

Bracket Type	Archwire Type	Mean (Sd)	Minimum	Maximum	95% Ci
Ceramic Bracket	0.019" X 0.025" SS	± 6.55529 (1.6081)	5.622	10.307	6.200-8.501
Ceramic Bracket	0.019" X 0.025" Teflon coated SS	±6.3483 (1.2302)	5.960	10.315	5.173- 9.433
Ceramic Bracket	0.019" X 0.025" Epoxy coated SS	± 9.3305 (2.4077)	5.622	14.881	7.608- 11.052
Metal Bracket	0.019" X 0.025"SS	±1.2275 (0.6618)	0.307	2.640	0.754 - 1.700
Metal Bracket	0.019" X 0.025" Epoxy coated SS Epoxy coated SS	± 7.3513 (1.8975)	4.299	10.881	5.171- 7.886
Metal Bracket	0.019" X 0.025" Teflon coated Teflon coated SS	± 1.8652 (0.9545)	0.265	2.960	1.084-2.450

SD- Standard deviation; C I – Confidence interval for mean

Table 2. Pairwise comparisons between groups, using Post hoc tukey test

Groups			Mean difference	*P*	95% CI
Metal +SS	-	Metal +Epoxy	6.124	P < 0.0001	4.9685 -7.2791
Metal + SS	-	Metal + Teflon	2.567	P < 0.0001	1.6908 to 3.4424
Metal + SS	-	Ceramic + SS	5.302	P < 0.0001	3.9664 to 6.6366
Metal + SS	-	Ceramic + Epoxy	8.103	P < 0.0001	6.4441 to 9.7619
Metal + SS	-	Ceramic + Teflon	4.121	P < 0.0001	3.4677 to 4.7739
metal + Epoxy	-	Metal + Teflon	-3.557	P < 0.0001	-4.8668 to -2.2476
Metal + Epoxy	-	Ceramic + SS	-0.822	P < 0.0011	-2.4748 to 0.8302
Metal + Epoxy	-	Ceramic + Epoxy	1.979	P < 0.0001	0.0556 to 3.9028
Metal + Epoxy	-	Ceramic + Teflon	-2.003	P < 0.0021	-3.1754 to -0.8306
Metal + Teflon	-	Ceramic + SS	2.735	P < 0.0010	1.2642 to 4.2056
Metal + Teflon	-	Ceramic + Epoxy	5.536	P < 0.0001	3.7665 to 7.3063
Metal + Teflon	-	Ceramic + Teflon	1.554	P < 0.0001	0.6559 to 2.4525
Ceramic + SS	-	Ceramic + Epoxy	2.802	P < 0.0001	0.7648 to 4.8382
Ceramic + SS	-	Ceramic+ Teflon	-1.181	P < 0.0002	-2.5307 to 0.1693
Ceramic + Epoxy	-	Ceramic +Teflon	-3.982	P < 0.0001	-5.6531 to -2.3113

**-Statistically significant (p<0.05) ; CI – Confidence interval for mean*

In fixed orthodontic therapy, teeth are moved using sliding mechanics or retraction Arch wires involving minimal friction. Friction is a factor in sliding mechanics in orthodontics, when Arch wire must slide through bracket slots and tubes. [2,3] [f]During sliding mechanics in orthodontics, tissues response and tooth movement occur only when forces that are applied exceeds friction on bracket wire interface. High levels of frictional force will result in debonding of bracket, associated with either a small dental movement or no movement and possibly anchor loss. When friction prevents the movement of teeth to which the bracket is attached, friction can reduce available force almost by 40%, resulting in an anchorage loss [3].

Literature reveals that the friction between bracket and Arch wire is multifactorial and different authors mentioned that the frictional resistance vary by different factors such as bracket material, wire size, difference in wire material, angulation of wire to bracket, method of ligation. However, there are different conflicting views on influence of factors on friction, such as surface roughness, bracket width, lubrication, ligature design, and arch shape.

The results of present study indicate that stainless steel brackets combined with the 0.019"x0.025" Stainless steel wire surfaces represented lowest coefficient of static friction (1.227N). In our study, the highest frictional resistance was recorded with 0.019" x 0.025" Epoxy coated arch wire surface with ceramic brackets (9.33N). This combination resulted in a marked increase in static friction over the most efficient combinations among the study groups. With respect to arch wire alloys, stainless steel arch wires had a significantly lower coefficient of static friction than Epoxy coated and Teflon coated wires in agreement with previous studies.

According to Syed Altaf Khalid et al. [6] round wires generally produced less friction than rectangular wires. Our study calculated the coefficient of static friction, the results from the static frictional coefficients may have a greater significance to the slow and non-continuous tooth movement observed with sliding mechanics. There are numerous factors associated such as arch form, type of arch wire alloy, bracket material, bracket type (self-ligation or conventional) and testing environment that potentially influence frictional resistance.

The influence of arch form plays a very important role in evaluating the frictional forces. A lot of frictional studies has been performed by attaching a single bracket to a rectangular metal frame for measuring frictional properties. This setup does not fully emulate the effect of arch form intraorally at the bracket- arch wire interface.

Zacharias et al [7] compared the effect of dental arch convexity and flat model setup on frictional forces. They explained that frictional forces are higher with convex arch form than with a straight model. Based on classic laws of friction, static coefficient of friction will be larger than corresponding kinetic coefficient of friction [8,9].

So, this is at most important to know the static friction of bracket and arch wire to initiate tooth movement.

Kinetic friction is irrelevant in orthodontic tooth movement; reason was the continuous motion along an arch wire occurs rarely. In sliding mechanics, we deal with a process called "quasi-static thermodynamic process", that means process of tooth movement occurs slowly, and it goes through a sequence of stages that are close to equilibrium. In sliding mechanics, forces and resistance to tooth movement changes as tooth move, down the Arch wire, it tips and has a biologic response, then uprights. When bone remodels around the root and then again tips, this process occurs cyclically throughout the tooth movement. Our study considered the main friction type as static friction and evaluated their interaction between different arch wire alloys and bracket types elaborately.

The important variables that affect magnitude of frictional force between bracket and arch wire are 1) Arch wire: active torque, vertical dimension, cross-sectional size and shape, surface texture, composition, elastic properties, intrinsic lubrication, abrasive wear resistance and quality of manufacturing. 2) Bracket: type of material, dimension, width, superficial texture and abrasive wear resistance. 3) Ligation: force and ligature type 4) Intraoral variables: saliva, plaque, amount of pellicle, mastication, corrosion, tooth number, bone density, root surface area, anatomic configuration and occlusion. 5) Orthodontic appliance: inter bracket distance, bracket wire angulation, retraction force, level of bracket slot between the adjacent teeth.

Frank and Nikolai [9] found that frictional resistance was increased in a nonlinear manner with increased bracket angulation. This is more attributable to binding rather than friction. Zero degree angulations provide proper frictional characteristics of wire and bracket. Greater angulation between bracket and arch wire yielded greater frictional forces those results in binding and notching. In some cases saliva functions as a lubricant and other times it increases frictional forces. Studies suggest that friction might increase, decrease or no change when tested with artificial saliva. So it was decided to conduct this study in a dry environment rather than using artificial saliva. The major reason for this was, presence of saliva had an inconsistent effect on static frictional resistance.

Stannard et al. [10] reported that saliva increases frictional resistance rather than acting as a lubricant, and many other investigators confirmed this. In study conducted by Pratten DH [11] when ceramic brackets were tested with artificial saliva, friction increased whereas by using human saliva, the friction was decreased.

The influence of bracket material plays a crucial role in friction resistance. Ceramic brackets are an aesthetic alternative to conventional stainless steel brackets. Ceramic brackets were manufactured in two different forms. Polycrystalline alumina and monocrystalline alumina [12]. Major difference between monocrystalline and Polycrystalline brackets is their optical clarity. Single crystal made brackets are clearer than Polycrystalline type brackets, which might be more translucent and more aesthetic.

According to Prattern et al. [11] intrinsic chemical nature, increased roughness and porosity of ceramic surfaces and a sharp bracket slot edge, creates a higher coefficient of friction. Scanning electron microscope studies showed that ceramic brackets display a crystalline structure containing many pores. Still, stainless steel brackets slot are smoother with fewer irregularities.

Saunders and Kusy [12] explained by scanning electron microscopy study that monocrystalline alumina brackets are smoother than polycrystalline brackets. Friction created by polycrystalline bracket was higher than friction produced by monocrystalline brackets. Greater force is required to overcome interlocking of asperities with arch wire.

The arch wire relative to the bracket or bracket relative to arch wire with approximated zero tip and torque does not permit tipping of bracket indicating that no binding interaction at edges of bracket-arch wire interface will occur. This non-binding sliding has demonstrated that frictional resistance generally increases with arch wire selections of stainless steel, Epoxy coated ss, nickel-titanium, and Teflon coated arch wires. Results of present study demonstrated that epoxy-coated arch wire alloy has higher static friction (9.33N). Stainless steel arch wire has least friction (1.227N), for the three arch wires tested, irrespective of the bracket used. The order of static friction has been Epoxy coated > Teflon coated Arch wire> Stainless steel. Surface chemistry and chemical affinity played significant role in overall frictional resistance.

According to Khambay et al. [13] another parameter in understanding Orthodontic frictional forces is wire stiffness. It is generally accepted that larger diameter wires have a higher coefficient of friction than smaller diameter wires. However, if one compares wires of same diameter but different compositions, it can be seen that they will exhibit different stiffness values. A less stiff wire, given same inter bracket distance, will deflect more. As the wire can deflect more, it would exhibit a higher angle of attack relative to bracket slot. This greater angle of attack means that it is easier to reach critical angle and that binding is more likely to occur. Resultant friction would increase significantly. This phenomenon explains why stainless steel wires of same diameter as Epoxy coated and Nickel-Titanium wires would produce lower friction.

Ceramic Brackets during initial alignment stage [14]. Results shown that there is no difference in rate of alignment between the two. Sliding mechanics during Orthodontic tooth movement, majority of the force is lost due to friction. Approximately 12-60% of applied force in fixed orthodontics is lost in friction. A finite element analysis shows that 60-80% of applied orthodontic force is lost during retraction of canine along a rectangular arch wire by sliding mechanics. Iwasaki et al. [14] calculated that 31-54% of total frictional force generated by a premolar bracket moving along 0.019×0.025 stainless steel arch wire was due to friction of ligation and remaining 46-69% was due to elastic binding. So ligation is considered as an

established parameter affecting the resistance to applied forces.

An *in vitro* study by Redlich et al [15] on five different brands of "reduced friction" claiming brackets showed that there was no such "reduced friction" as claimed by the manufacturers. Friction between bracket and wire is present from early stages of alignment and levelling up to finishing phase. Thus, resistance to sliding of bracket along the orthodontic wire is important in clinical practice since lower friction of orthodontic mechanics can be directly related to a reduction in treatment time.

In our study, static frictional forces are measured instead of kinetic frictional force since the static friction is more appropriate in clinical orthodontic as movement of teeth is not continues. In present study, ligature wire is used instead of elastomeric ligatures in order to standardize the force magnitude. Maximum static friction appeared with coated wires than uncoated wires since they have larger width due to additional coating layer which is 1 to 1.4 mm. [16]

Some researchers have investigated that frictional forces of aesthetic orthodontic wires focused on link with surface roughness of coating layer of coated arch wires. Rhodium and Teflon coating materials are most common surface treatment used to coat stainless steel and nickel-titanium orthodontic arch wires and rhodium coated types have increased surface roughness and consequently increased friction while Teflon coated wires have a smoother surface and therefore showing least amount of friction thus improved sliding movements will be obtained.

In this study results shows that ceramic bracket with epoxy coated ss arch wire shows the highest frictional resistance, i.e. 9.330N, whereas ss bracket + SS arch wire shows lowest frictional resistance of 1.227N, followed by the Metal Bracket combined with 0.019” X 0.025” Teflon coated SS showed the least friction of 1.8652.

The sequence of the mean values from high friction to lowest friction as follows, ceramic bracket with epoxy coated arch wire (9.3305N), SS bracket with epoxy coated arch wire (7.3513N), ceramic bracket with Teflon coated arch wire, (6.3483N) ceramic bracket with SS arch wire (6.55529N), SS bracket with Teflon coated arch wire, (1.8652N) and SS bracket with SS arch wire (1.2275N).

Clinically, when SS brackets are used on posterior teeth, with ceramic brackets on anterior teeth, difference in friction between steel and the ceramic brackets result in faster movement of posterior teeth; this would cause an undesired anchorage loss. [17] Therefore, to reduce unwanted effects of frictional force, authors suggest developing ceramic brackets with smoother slot surfaces to decrease possible effects of static friction.

6. SUMMARY

In the present study, highest static frictional resistance among test groups was observed in ceramic bracket combined with Epoxy coated stainless steel (9.33N) and when it comes to arch wires, Epoxy coated SS arch wire showed highest frictional resistance among the test groups. Lowest frictional resistance was observed in two groups, i.e. Stainless steel bracket with Stainless steel arch wire (1.227N), Stainless steel brackets with Teflon coated SS arch wire (3.79N), which indicates that Stainless steel bracket showed less frictional resistance when compared to that of ceramic bracket. Whereas, Stainless steel arch wire showed less frictional resistance than that of Teflon coated SS arch wire followed by Epoxy-coated stainless steel arch wire. The comparison of mean, the standard deviation of nine groups showed a p-value of <0.001, which were statistically highly significant.

7. CONCLUSION

Within the limitations of present study, the following conclusions can be drawn.

1. Among all test groups, Ceramic bracket combined with epoxy coated arch wire exhibited highest frictional resistance.
2. Stainless steel bracket showed significantly lower frictional resistance when compared to other groups.
3. 0.019" x 0.025" Epoxy coated SS arch wire showed highest friction whereas 0.019" x 0.025" stainless steel arch wire showed lowest friction.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Omana HM, Moore RN, Bagby MD et al. Frictional properties of metal and ceramic brackets. Journal of Clinical Orthod. 1992; 26:425-32.
2. Avinash Kumar, Arifa Khanam, Hajra Ghafoor et al, Effects of intraoral aging of arch-wires on frictional forces: An ex vivo study. Journal of Orthodontic Science. 2016;5(4):109-116.
3. Nadeem Husain, Avinash Kumar et al Frictional resistance between orthodontic brackets and archwire: An in vitro Study. The Journal of Contemporary Dental Practice. 2011;12(2):91-99.
4. Ariana Pulido Guerrero, Odilon Guariza Filho, Orlando Tanaka et al. Evaluation of frictional forces between ceramic brackets and archwires of different alloys compared with metal brackets. Brazil Oral Res. 2010; 24(1):40-5.
5. Tiziano Baccetti, Lorenzo Franchi, Matteo Camporesi. Forces in the Presence of Ceramic vers Syed Altaf Khalid, Vadivel Kumar, Prithviraj Jayaram. The comparison of frictional resistance in titanium, self-ligating stainless steel, and stainless steel brackets using stainless steel and TMA archwires: An in vitro study. 2012;4(6):203-211.
6. Us Stainless Steel Brackets with Unconventional vs Conventional Ligatures. The Angle Orthodontist. 2008;78(1):120-124.
7. Zacharias Fourie et al. Effect of dental arch convexity and type of archwire on frictional forces. AJODO. 2009;136(1): 14.e1–14.e7.
8. Nanda RS, Ghosh J. Biomedical considerations in sliding mechanics. In: Nanda R (Ed).Biomechanics in Clinical Orthodontics. Philadelphia, PA, WB Saunders. 1997;188-217.
9. Frank Charles A, Robert J Nikolai. A comparative study of frictional resistances in orthodontic bracket and arch wire. AJODO. 1980;78(6):593.
10. Jan G Stannard, Jeanne M Gau, Milford A Hanna, Ph.D. Comparative friction of orthodontic wires under dry and wet conditions. AJODO. 1986;89(6):485–491.
11. DMD MS, Don H, Pratten BS Kris Poplib, DMD Nicholas Germanec,1, DDS, MS, Frictional resistance of ceramic and stainless steel orthodontic brackets, AJODO. 1990;98(5):398–403.
12. Saunders CR, Kusy RP. Surface Topography and Frictional Characteristics of Ceramic Brackets. Am J Orthod Dentofacial Orthop. 1994;106:76-87?
13. Khambay B, Millett D, McHugh S. Archwire seating forces produced by different ligation methods and their effect on frictional resistance. Eur J Orthod. 2005;27(3):302-8.
14. Iwasaki Laura R. et al. Clinical ligation forces and intraoral friction during sliding on a stainless steel archwire. American Journal of Orthodontics and Dentofacial Orthopedics. 123;(4)408 – 415.
15. Meir Redlich, DMD, MSc, Yaniv Mayer, DMD Doron Harari, DMD et al In vitro study of frictional forces during sliding mechanics of “reduced-friction” brackets AJODO. 2003;124(1):69–73.
16. Rudge Philippa, Martyn Sherriff et al. A comparison of roughness parameters and friction coefficients of aesthetic archwires. European Journal of Orthodontics. 2014;37(1):49-55.
17. Dieter Drescher DMD, Christoph Bourauel et al. Frictional forces between bracket and arch wire. AJODO. 1989;96(5):397–10.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/64770