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RESEARCH ARTICLE

A COMPARATIVE STUDY OF FRICTIONAL RESISTANCE OF DIFFERENT ORTHODONTIC ARCHWIRES ON CERAMIC BRACKETS: AN IN VITRO STUDY

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ABSTRACT

Aim: To assess the frictional resistance of different orthodontic archwires using ceramic brackets.
Material & Methods: This study was conducted using four different orthodontic archwires like Stainless steel, Nickel Titanium, TMA and Teflon coated having 0.019 x 0.025 inch cross-section ligated in a ceramic bracket with 0.022 x 0.028 inch slot with elastomeric modules.
Result: ANOVA was significant ($F= 219.85$, $p< 0.01$) and Turkey's t test assessed that the frictional resistance of the stainless steel wire was the least (185.05, 35.07), followed by Teflon coated wire (217.484, 29.79), followed by NiTi wires (262.55, 30.17), followed by TMA (537.55, 41.14) wires. Result of this study showed Frictional resistance of archwires starts from least friction to high as Stainless Steel< Teflon coated<Niti< TMA.

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INTRODUCTION

Friction is defined as resistance to motion when one object moves tangentially to one another. There are two types of frictional forces. The static frictional forceis the smallest force needed to start the motion of solid surfaces that were previously at rest with each other, whereas the kinetic frictional force is the force that resists the sliding motion of one solid objective over another at a constant speed. (Drescher, 1989) In orthodontics, correction of any malocclusion is achieved by the movement of teeth which is mainly achieved by the sliding mechanics. Sliding mechanics is the term usually applied in orthodontics where the teeth slides along the archwire in a controlled manner. In extraction cases this approach is used in the closure of spaces and also distalize the teeth to obtain increased arch length. When force is applied, bracket slides along the arch wire and friction is developed due to which the movement of the teeth is decreased and henceforth there is reduction in the force required for the movement of the teeth. There are different methods of ligation of wires into the brackets which greatly determines the nature of friction developed whenever a force is applied. In 1930 self-ligating brackets were introduced in the form of the Russell attachment. Advantage of these brackets are reduction in ligation time and improvement in the operator's efficacy. Self-ligating brackets are ligature less bracket systems that have a mechanical device built into the bracket to close off the edgewise slot. (Cacciafesta, 2003) Elastic modules and ligature wire are the different methods of ligation in orthodontics but in this study elastic modules are used to ligate the wire to the bracket. Recently, esthetics have become the prime concern for the adult patients seeking for the Orthodontic treatment due to which various advances in orthodontic materials research have led to the manufacture of ceramic bracket for their use in Orthodontic treatment. Monocrystalline and polycrystalline are the materials used in manufacturing of these brackets which provide excellent colour fidelity and stain resistance. (Tanne, 1991) Thus these study was been done to know the amount of

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friction with different types of archwire with the ceramic bracket system.

MATERIALS AND METHODS

Ceramic bracket of GAC Dentsply and four archwires evaluated in the study were stainless steel, Nickel titanium, Teflon coated and TMA all of Ortho Organizer company (Figure 1). A total of forty arch wire segments of 30 mm length and 0.019x 0.025 inch cross section were taken. Ten of each sample were tested in ceramic brackets. The samples were divided into four groups Group I – stainless steel, Group II – NiTi, Group III – Teflon coated, Group IV – TMA (Figure 2) . The brackets used were maxillary first premolar brackets, 0.022 x 0.028 slot. Archwires were ligated to the bracket with elastomeric modules. Forty color coded acrylic plates of 4 inch x 2 inch dimension to differentiate the four study groups. At one end of the plate horizontal and vertical lines were drawn. The bracket was stabilized by mean of an industrial adhesive at a point of intersection of the two lines.

Fig. 1. Armamentarium used

The archwire segments of about 30mm length was taken and secured into bracket slot with elastomeric module. Immediately acrylic plate was mounted on to the lower grip of Instron testing machine. The free end of the archwire was fixed to the upper grip of the universal testing machine which was connected to the load cell. Before testing each bracket, the wire and modules were cleaned with 95% alcohol and air dried. Each wire was pulled through the bracket slot by a distance of 7 mm at the rate of 5 mm/min and the force levels were recorded from the digital marker. The archwires and brackets were tested such that a new bracket and wire combination was used for every test and then discarded. A fresh ligation was used for each combination. The frictional force was measured with a universal testing machine (Instron Corp. Cantan Mass) during in vitro translatory displacement of bracket relative to archwire. A 500 kg load was used to determine the frictional force levels, the machine was adjusted in the tensile mode and the force levels were measured in grams. The Instron testing machine not only measured the grams of tensile force required to pull the wire through fixed bracket but also gave the tracking distance as a digital read out in mm (Figure 3).

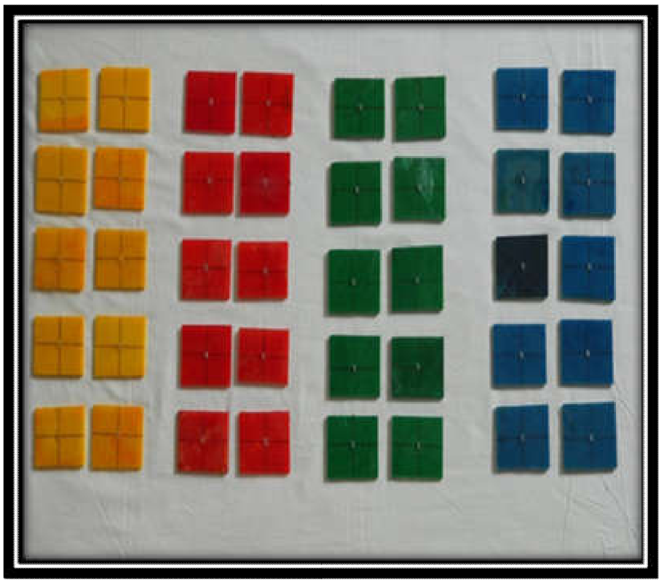

Fig. 2. Color coded acrylic plates

Fig. 3. Instron testing machine

The recorded values that represented the frictional resistance in Newton was converted into grams. The kinetic frictional force generated by all four types of archwires were shown. A statistical comparison of these observations was also provided.

In order to compare the frictional resistance between the four different types of wires, we considered One way ANOVA test and in case the results were significant we further conducted the turkey's t test to assess the variability amongst the different wires.

RESULTS

Mean and standard deviation were estimated for each study group. Mean value was compared by one way ANOVA. Multiple range tests by Turkey t test. In the present study p<0.01. In order to compare the frictional resistance between the four types of archwires, we shall consider a one way ANOVA test and in case the results are significant, we shall further conduct a Turkey‘s t test to assess the variability amongst the different wires. The present study was conducted to evaluate the frictional resistance of different orthodontic archwires using ceramic brackets. The result was obtained presented as table:

Table 1 -. From the result of ANOVA test we can see that the ANOVA test is significant (F = 219.85, P<0.01). From the Turkey's t test result was assessed and found that the frictional resistance of Stainless Steel archwire (Group I) is the least (185.05, 35.17) while TMA archwire (Group III) exhibits the greatest while the Teflon coated archwire (Group IV) exhibits the frictional resistance comparable to that of Stainless steel. Alternatively we can say that frictional resistance of following archwires can be arranged as Stainless Steel < Teflon coated <Niti< TMA.

Table 1. Frictional resistance in gms

	GROUP I	GROUP II	GROUP III	GROUP IV
SNO.	Stainless steel	NiTi	TMA	Teflon coated
1	160.359	280.508	490.431	220.381
2	240.509	290.342	500.166	210.509
3	140.509	260.961	560.633	230.662
4	190.673	310.351	520.895	170.408
5	220.530	270.827	580.933	180.819
6	170.515	230.527	590.369	190.181
7	185.385	280.789	570.780	220.758
8	150.759	210.004	560.079	240.445
9	160.264	240.600	530.976	260.215
10	230.998	250.596	470.504	250.457
Mean	185.050	262.550	537.550	217.484

Table 2 – In this the calculation of sum, average and variance between the groups was evaluated by the ANOVA test which also shows that the frictional resistance between the Teflon coated archwire and stainless was comparable. Thus these results shows that the Teflon coated archwires can be used in place of stainless steel in high esthetic demanding cases.

Table 2. Calculation of sum, average and variance between the groups anova: single factor

GROUPS	COUNT	SUM	AVERAGE	VARIANCE
Stainless steel	10.000	1,850.501	185.050	1230.279
NiTi	10.000	2,625.550	262.555	910.613
TMA	10.000	5,375.496	537.550	1,693.077
Teflon Coated	10.000	2,174.835	217.484	887.524

DISCUSSION

Orthodontic tooth movement is carried out through sliding mechanics that involve friction. Because there is an optimum range of forces for movement of teeth. Knowledge of friction is essential to the clinician who uses sliding mechanics. Friction can then be compensated for applied force to achieve the net effective range of optimal forces. (Bazakidou, 1997) Sliding mechanics is the term usually applied in orthodontics to the controlled movement of teeth along arch wires. It is hypothesized that, when a slotted bracket is sliding along an arch wire, friction impedes movement of the tooth to which the bracket is attached and reduces the force available for tooth movement. Andreasen and Quevedo suggested that friction can be reduced by having more freedom of movement between wire and bracket slot. Yet both these conditions allow more tipping, which may actually cause the greater friction. Thurow suggests that when a tooth tips, pressure is exerted by the ends of the bracket on the arch wire, which will cause frictional resistance. As a result, the more a tooth tips, the greater will be the pressure exerted by the ends of the bracket on the arch wire and friction will be increased. (Huffman, 1983) When the two objects are in contact they tends to slide against one another and friction is developed that reduces the force. The direction of friction is tangential to the common boundary of the two surfaces in contact. (Drescher, 1989) When the two surfaces slides against each other, two components of total force arises: the frictional component (F) is parallel but in opposition to the sliding motion, and the normal force (N) perpendicular to the contacting surfaces and to the frictional force component. Frictional force is directly proportional to the normal force, such that F= pN, where p=coefficient of friction. (Kapila, 1990) The force decay during sliding mechanics ranges from 12% to 60%. If frictional forces are high, the efficiency of the system is affected and the treatment time may be extended. (Drescher, 1989; Kapila, 1990) Studies have shown that material used for orthodontic brackets too, can have a profound effect on its resistance to sliding. Composition, as well as the manufacturing and finishing process of the brackets can vary from one material type to the other. For reasons of esthetics and biocompatibility issues, more recently newer materials have been investigated as alternatives to improve friction performance. First of all, stainless steel brackets have been shown by numerous investigators to have lower frictional forces than ceramic brackets but when the esthetic is concerned patient usually prefer for the ceramic brackets. (Pattern, 1990) Ceramic brackets are associated with problems which complicate their clinical use. In particular, ceramic brackets have higher coefficients of friction and greater frictional resistance. (Angolkar, 1990; Pattern, 1990) Under scanning electron microscope, ceramic brackets display a crystalline structure containing many pores while stainless steel brackets slots are smoother with fewer irregularities. (Tanne, 1991; Pattern, 1990) This rougher surface finish of the ceramic bracket slots has been implicated as the reason for the higher frictional force. (Tanne, 1991; Angolkar, 1990) Studies of in-vitro sliding mechanics have demonstrated that archwire material greatly affects the frictional resistance. Frictional resistance generally increases respectively with archwire selections of stainless steel, nickel-titanium, and beta-titanium. [8] Elastomeric and stainless steel ligation methods of engaging the wire in the bracket slot provide varying ligation force levels and may affect frictional values. For bracket size 0.022-inch slot, the elastomeric ligation showed significantly lower frictional values. More variability was observed for the steel ligation, where the standard deviations ranged from ± 9.7 gm for the composite without metal slot bracket, SS wire combination to ± 59.8 gm for the polycrystalline bracket- 0.019 × 0.025-inch beta titanium wire combination. (Bazakidou, 1997) Various types of bracket used in orthodontics are stainless steel, self-ligating stainless steel, ceramic bracket with conventional slot, ceramic bracket with metal reinforced slot and self-ligating ceramic brackets. The results showed that the Damon Self Ligating brackets produced significantly lower static and kinetic frictional resistance than both conventional stainless steel and esthetic self-ligating brackets. Stainless steel self-ligating brackets generated lower frictional resistances than conventional stainless steel brackets. The difference in friction levels between conventional stainless steel and polycarbonate self-ligating brackets could be explained by the difference in the structural design of each bracket body, in addition to the material composition of the bracket slot and cap. The non estheticarchwires used in orthodontics are Stainless steel, Nickel titanium and TMA wires. When the archwires were examined by using the SEM and the profilometer, the surface roughness in increasing order was SS, NiTi and TMA. NiTi wires, although smoother than TMA, showed higher friction values. The higher free titanium content in TMA wires could explain the higher frictional values. TMA has 80 % of Titanium and NiTi has 60 % of titanium. (Downing *et al*., 1995) The present study also showed the same results. Ceramic brackets were developed to improve esthetics during orthodontic treatment but in clinical use, however they have problems including brittleness leading to bracket or tie-wing failure, iatrogenic enamel damage during debonding, enamel wear of opposing teeth, and high frictional resistance to sliding mechanics. Keith *et al*. however did not find any significant advantage of monocrystalline brackets over polycrystalline ceramic brackets with regards to their frictional characteristics. The co-efficient of friction of monocrystalline and stainless steel brackets is however comparable. (Keith, 1990) The effect of wet and dry friction testing environments is an in-vitro model problem that has been a source of debate for researchers. In particular, questions have arisen as to whether the use of saliva substitute's in-vitro is a valid representation of the clinical situation. Basically, investigations comparing the wet and dry environment have met with different results, showing decreases, no change, and increases in friction A reduction in frictional resistance was seen when artificial saliva was used. It is found that a saliva substitute decreased frictional resistance by 15 to 19 percent compared to dry conditions, while glycerine had no effect. (Baker, 1987)

Another study reported no significant differences between the dry and wet state in comparison to the frictional resistance for combinations of stainless steel and nickel-titanium wires with stainless steel and ceramic brackets. Water was used as the wetting agent. (Downing *et al*., 1995) Human saliva was used in a comparison of dry and wet testing conditions and reported that significant differences were observed between the dry and wet state. (Omana *et al*., 1992) For the purposes of comparing the relative fictional resistance of bracket and archwire materials, it may be adequate to do the testing under dry conditions. To determine the effects on the coefficients of friction, human saliva would provide the most appropriate test conditions, and under these conditions the values for coefficients of friction can have various effects depending on the bracket archwire couple. Teflon coated wires along with the ceramic bracket combination has great esthetic dominance in the recent time. The frictional resistance of Teflon coated wires is less than NiTi and TMA archwires in the present study which is similar to studies done previously. When the stainless steel and Teflon coated archwires were compared, the frictional resistance of Teflon coated were higher but less than that of the NiTi and TMA wires used in orthodontics. It was reported that the Teflon coated archwire has less frictional resistance than that of non-esthetic wires. Teflon coated is non adherent and has excellent chemical inertia as well as good mechanical stability. (Omana *et al*., 1992)

The present study was carried out to compare the frictional resistance of different orthodontic archwire combination with polycrystalline ceramic bracket with .022x.028 slot. The result in the study shows that the frictional resistance of stainless steel is least (185.050 gms) and the frictional resistance of TMA is maximum (537.550 gms) as shown in Table -1. These results were in accordance with the study done previously. (Doshi, 2011) The results of this study shows that the frictional resistance of Teflon coated archwire (217.484 gms) is slightly higher than stainless steel but comparable with stainless steel (185.050 gms). (Omana *et al*., 1992) When the frictional resistance of NiTi was compared other archwires i.e. stainless steel, Teflon coated and TMA, the result showed that the frictional resistance of NiTi was higher than stainless steel and Teflon coated archwires but lesser than TMA archwire as shown in table – 1and graph. These results were familiar to studies done previously. (Omana *et al*., 1992; Doshi, 2011) It is concluded that sequence of frictional resistance as follows: Stainless steel < Teflon coated <NiTi< TMA.

Conclusion

1. The study showed that esthetic wires can be used in esthetic brackets with less of friction as compared to wires like niti and TMA. So patients with high esthetic demands can be treated with Teflon coated archwires.
2. Further studies should be done to evaluate the frictional resistance of different dimensions of archwire on ceramic brackets to make the treatment metal free.
3. The clinical study should also be done to see the similarity of the result between clinical and non-clinical trials.

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