A COMPARISON OF FRICTIONAL RESISTANCE BETWEEN STAINLESS STEEL, TITANIUM, CERAMIC, AND FIBRE GLASS BRACKETS - A COMPARATIVE STUDY

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Abstract

This study aims to compare the frictional resistance of active (TIME- 2, IN-OVATION R) and passive (DAMON SL-2, SMART CLIP) self- ligating brackets with conventional TITANIUM, FIBREGLASS and CERAMIC brackets under dry and wet conditions with artificial saliva using universal testing machine.

A total of 200 samples were tested of which 80 were self- ligating and 120 were conventional brackets.. Specimens were divided into 2 categories which were run under dry and wet conditions, using artificial saliva.10 samples of each active and passive self-ligating brackets were dry run and 10 others were used in wet conditions. 10 samples of each CERAMIC, TITANIUM and FIBRE GLASS brackets were run using elastomeric ties in both dry and wet conditions and 10 each of them using stainless steel ligatures under dry and wet conditions.

The study revealed that the least frictional resistance was demonstrated by the brackets in the following order i.e. PASSIVE SELF- LIGATING BRACKETS, ACTIVE SELF- LIGATING BRACKETS, TITANIUM, FIBREGLASS and CERAMIC brackets in both dry and wet conditions. Paired t-test, two sample t-test, and Analysis of variance were done to evaluate the results statistically.

Surface topography of the brackets slots in higher magnification(X 500 at 20kv) under scanning electron micrographs also confirmed the same results.

The self-ligating brackets seems to be functionally efficient with reduced friction, aesthetically pleasing, reduced treatment and chair side time, combined with better oral hygiene maintenance and patient comfort because of absence of ligation.

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Introduction

Since advent of fire by stone aged man, the virtues of friction have been bestowed upon mankind; sometimes as a hindrance and at other times … as a boon!!!

Friction is an inseparable and undeniable orthodontic entity and has been documented in orthodontic literature by stoner as far back as 1960.[1]

During tooth movement it is crucial that frictional forces be minimized if not eliminated to apply an appropriate force for obtaining an optimal biologic tissue response for efficient and desired tooth movement ... the ultimate goal in clinical orthodontics!!

Availability of wide array of brackets, wires, and ligatures has provided the clinician a multitude of combinations for use during various stages of orthodontic treatment. In the workhouse of sliding mechanics the bracket material of choice for many years has been stainless steel for its many desirable properties like high fracture resistance, lesser friction and

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cost effective. But concern was expressed regarding nickel hypersensitivity and corrosion in the oral environment.[2]

To bridge this gap, pure titanium brackets have been made available (by dentaurum Germany) TITANIUM – a material whose biocompatibility has been demonstrated beyond doubt.

Titanium has been heralded as a material totally biocompatible in the oral environment and superior in structural integrity compared to stainless steel.[3]

However since the number of adult patients have been steadily increasing the aesthetic ceramic material was made available. Though ceramic had excellent colour fidelity and stain resistance, it had shortcomings such as fracture of enamel during debonding and of the bracket itself, high friction and enamel abrasion of the opposing tooth.[4]

To rectify these shortcomings fibre glass brackets were introduced...but had shortcomings in frictional factor.

Though brackets were aesthetically and functionally efficient nothing eliminated the mode of ligation...which increased the friction factor, chair side time, and compromise on oral hygiene maintenance and patient comfort.

To quench this thirst, came the self-ligating brackets...Which were efficient functionally, pleasing aesthetically, reduced treatment and chair side time combined with patient comfort and better oral hygiene maintenance because of absence of ligation.

The present study was undertaken to compare all these brackets for their frictional resistance in dry and wet conditions along with higher magnification to confirm slot surface topography under SEM

Materials and methods

In this study conventional brackets were chosen to compare with active and passive self- ligating brackets.

All brackets used in the study were maxillary right cuspid's of 0.022" slot dimension with angulations of 13^o and torque of -2^o. (Roth version).

Specimens were assorted at J.S.S.Dental College & Hospital, Mysore, Karnataka, India, and tests were carried out at CIPET (Central Institute of Plastics & Engineering technology), Mysore, Karnataka, India. SEM specimens were viewed at magnification of (X500 at 20 kv). (fig 10) SEM was recorded for each bracket type to compare slot surface texture.

Figure 1. showing DAMON SL-2 bracket samples.

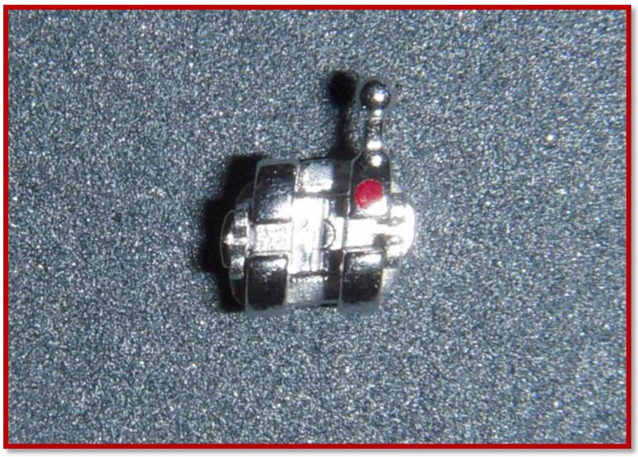


Figure 2. showing SMART CLIP bracket samples.

Figure 3. showing TIME-2 bracket samples.

Figure 4. showing IN-OVATION-R bracket samples.

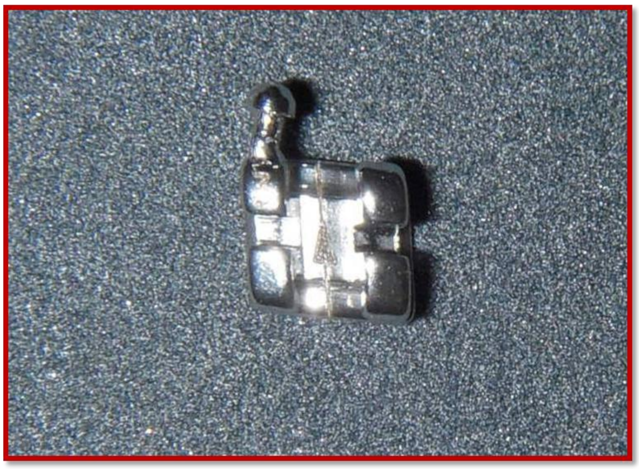


Figure 5. showing REMATITAN bracket samples.

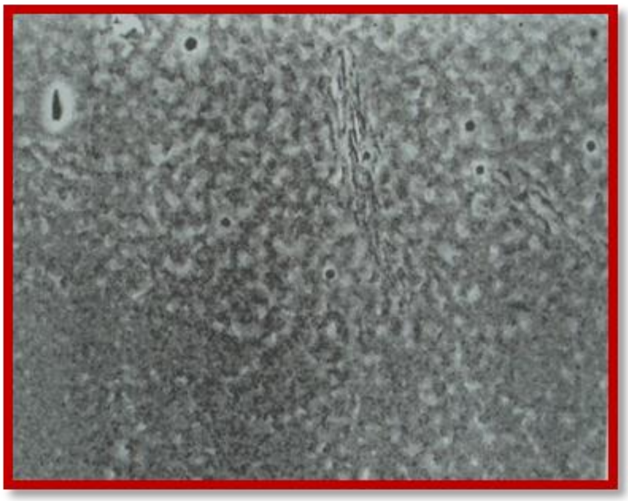
Figure 6. showing D.B.FIBRE GLASS bracket samples.

Figure 7. showing FASCINATION bracket samples.

Figure 8. Straight shooter.

Figure 9. Modified Tidy's jig.

STAINLESS STEEL (10. A)



CERAMIC (10. B)

FIBER GLASS (10. C)

TITANIUM (10. D)

Figure 10. SEM specimens viewed at magnification of (X500 at 20 kv)

Modified Tidy's jig was constructed to simulate clinical situation. The device consisted of stainless steel framework with 15mm space for movable bracket at the centre. Arch wires were secured with hex screws using Allen keys.

Additional power arm of 12mm was chosen to represent the distance from bracket slot to the centre of resistance of a typical canine tooth, which was bonded to the base of the bracket using Transbond-XT from which the weights could be suspended.

A fixed wt of 100gm (representing normal force) was suspended from the additional power arm.

19X25 S.S. wire was chosen as this is the usual working wire in cases of retraction in 0.022" slot.

A total of 200 samples were tested. Specimens were divided into 2 categories which were run under dry and wet conditions, using artificial saliva .10 samples of each active and passive self-ligating brackets were dry run and 10 others were used in wet conditions.

10 samples of each CERAMIC, TITANIUM and FIBRE GLASS brackets were run using elastomeric ties in both dry and wet conditions and 10 each of them using stainless steel ligatures under dry and wet conditions.

A total of 200 samples were tested of which 80 were self- ligating and 120 were conventional brackets. Elastomeric modules were ligated using elastomeric gun to eliminate stretching differences.

The steel ligature on the movable bracket was fully tightened till it doubled back and then slightly slackened to allow the bracket to slide freely.

To avoid bias due to repeated use, tests were done each time with a fresh assembly. Tests were done on a universal testing machine, (LLOYD MODEL LR-100R ENGLAND).

The jig was fixed to the lower member of universal testing machine & upper member was connected to load cell of 100 Newton.

The suspended movable bracket was adjusted to move upwards along with the bracket & suspended weight at a constant speed of 5mm/min and the frictional values were recorded.

The testing machine was adjusted such that the weight suspended at the power arm was nullified and load cell readings represented the maximum frictional force required to move the bracket along the arch wire for a distance of 5mm/min.

Readings were recorded in Newton and were converted to grams. (1N=101.97gms)

Saliva was dropped onto bracket- wire junction at rate of 1 drop/mm with the help of a syringe. Readings in both dry and wet conditions were charted separately

Materials.

s.s. self ligating Passive brackets	DAMON SL-2	(fig 1)	SDC California, ormco.
	SMART CLIP	(fig 2)	3M Unitek
s.s. self ligating Active brackets	TIME-2	(fig 3)	American Ortho, USA
	IN-OVATION-R	(fig 4)	GAC, Newyork
Titanium brackets	REMATITAN	(fig 5)	Dentaurum, Germany
Fibre glass brackets	D.B.FIBRE GLASS	(fig 6)	Leone, Italy
Ceramic Brackets	FASCINATION	(fig 7)	Dentaurum, Germany
Elastomeric modules	SANI-TIES		GAC, Newyork
Straight shooter		(fig 8)	TP-Orthodontics
Wires	19X25 S.S.REMANIUM		Dentaurum, Germany
Artificial saliva			
Modified Tidy's jig		(fig 9)	
Trans bond XT	LIGHT CURE ADHESIVE		3M Unitek

Results

To evaluate the results statistically, the following analysis were done.

1. Paired t-test (Table 1)
2. Two sample t-test (Table 2)
3. ANOVA (Table 3 and 4)

	Paired t-Test			
	Dry	Wet	P-Value	Comments
	Mean±SD	Mean±SD		
Damon SL-II	46.01±2.93	47.40±3.87	0.229	NS
Smart clip	62.30±6.09	66.38±7.39	0.172	NS
Time-II	74.21±7.46	73.33±5.93	0.474	NS
In-Ovation R	85.73±2.63	88.43±0.81	0.015	Sig(at 0.05) and NS(at 0.01)
Passive	108.31±7.78	113.78±3.29	0.156	NS
Active	159.95±8.31	161.75±5.73	0.318	NS

Table 1. Shows the mean frictional resistance in gms under dry & wet conditions b/n active and passive self- ligating brackets.

10 samples of each bracket type were tested under dry and 10 each in wet condition. A total of 80 self- ligating brackets were tested. Paired t-test for active and passive self- ligating brackets revealed that frictional resistance values were not significant for each bracket type under dry and wet conditions except in IN-OVATION-R where the values were significant at 0.05 and non significant at 0.01. For TITANIUM brackets the values were not significant where as for FIBRE GLASS and CERAMIC the values were significant.10 each were tested under dry and 10 each under wet conditions with elastomeric and stainless steel ligatures.

	Dry	**Wet**	**P-Value**	**Comments**
	Mean±SD	Mean±SD		
Titanium-L	100.62±4.24	103.44±3.89	0.138	NS
Titanium-E	113.74±4.88	115.75±4.26	0.342	NS
Fiber Glass-L	194.97±10.33	209.23±8.53	0.003	Sig
Fiber Glass-E	219.14±8.59	240.74±10.01	0.000	Sig
Ceramic-L	286.65±15.02	303.74±6.68	0.004	Sig
Ceramic-E	313.74±6.14	334.55±7.49	0.000	Sig
	Active	Passive	P-Value	Comments
	Mean±SD	Mean±SD		
Dry	159.94±8.31	108.31 ±7.78	0.000	Sig
Wet	161.75±5.73	113.78±10.42	0.000	Sig

Table 2. Two sample t-tests were done to compare friction b/n conventional brackets with steel ligatures and elastomeric ties under dry and wet conditions. (Two-sample t-test)

Dry

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	380136.918	5	76027.384	939.337	.000
Within Groups	4370.615	54	80.937		
Total	384507.533	59			

Wet

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	451069.181	5	90213.836	1762.179	.000
Within Groups	2764.502	54	51.194		
Total	453833.683	59			

Table 3 and 4. Analysis of variance (ANOVA) was carried out b/n the groups and within the groups in dry and wet conditions and was found that the test was significant as p value is 0.000.

Analysis of Variance was carried out between the samples in Wet condition and it was found that the test was significant because p-value is 0.000. Further Duncan's multiple range test was conducted and was found that all the pairs were significantly different.

A total of 120 samples were tested. But when active and passive self- ligating brackets were compared under dry and wet conditions, the values were statistically significant.

Further Duncan's Multiple Range test was conducted and was found that all the pairs were statistically different.

Discussion

Friction is a function of relative roughness of two surfaces in contact and is defined as the resistance to motion encountered when one solid body slides / tends to slide over another.[5]

Friction exists in 2 forms, Static friction and Kinetic friction. Static friction is force needed to start the motion of solid surfaces that were previously at rest with respect to each other.[5, 6.]

Kinetic friction is the force that resists the sliding motion of one solid object over another at a constant speed.[6]

The coefficient of static friction is always greater than that of kinetic friction.[7]

In orthodontic sliding mechanics, the magnitude of friction is mainly determined by bracket- arch wire type and material and mode of ligation.[7]

Friction is a factor in all forms of sliding mechanics such as canine retraction into extraction site and in levelling and alignment where wire must slide through brackets and tubes.

In orthodontic sliding mechanics, mesio-distal tooth movement is accomplished by guiding a tooth along a continuous arch wire with the use of orthodontic brackets. This type of tooth movement generates frictional forces that must be overcome to elicit periodontal response for the tooth movement.[8]

Rate of tooth movement during orthodontic treatment is dependent on a number of mechanical and biological variables.[9, 10]

These variables can directly or indirectly contribute to frictional force levels between brackets and arch wires.

Mechanical

1. **Arch wire**
   a. Material[11, 12]
   b. Cross sectional shape/size[11, 13]
   c. Surface texture[12]
   d. Stiffness[12]
2. **Ligation of arch wire to the bracket**
   a. Ligature wire[13, 14]
   b. Elastomeric[13, 14]
3. **Bracket**
   a. Material[13, 14]
   b. Slot width and depth[13, 14]
   c. First order bends (in-out) [13, 14]
   d. Second order bends (angulations) [13, 14]
   e. Third order bends (torque) [13, 14]
4. **Orthodontic appliance**
   a. Inter-bracket distance[13]
   b. Level of slot b/n adjacent teeth[13]
   c. Forces applied for retraction[13]
5. **Intra-oral biological variable**
   a. Saliva[14]
   b. Plaque & acquired pellicle[14]
   c. Corrosion[14].

In the present study the passive self-ligating brackets showed least frictional resistance followed by active self- ligating brackets.

This difference is due to differences in the bracket design. In ACTIVE self-ligating brackets the spring- clip presses against the arch wire to secure it in the bracket slot. The primary objective of ACTIVE self-ligation is to seat the arch wire against the back of the slot for torque and rotational control. This results in reduction of slot size in passive state increasing the level of friction. In PASSIVE self-ligating bracket when the fourth wall is closed it converts into a tube, where the lumen of the bracket remains at full size, thus generating lesser friction.[15, 16, 17]

In passive self-ligating brackets DAMON SL-2 showed lesser friction than SMART CLIP. The reason may be difference in the fourth wall where in DAMON SL-2 the complete width of slot is covered by fourth wall making it as a tube whereas in SMART CLIP only the mesial and distal ends are covered by closing clips leaving the slot open.

In active self-ligating brackets TIME-2 showed lesser friction compared to IN-OVATION R. The difference may be due to spring clip designs that press against the arch wire in the slot.

In general among conventional bracket systems TITANIUM brackets showed least friction followed by FIBER GLASS and CERAMIC brackets. This may be due to difference in surface roughness of the material and presence of titanium oxide layer on brackets which render the surface chemically passive, and promote excellent sliding mechanics with lower frictional force.[18] The greater friction of CERAMIC bracket is most likely related to surface roughness of the slot and hardness of the material.

In general among conventional bracket system friction was greater in elastomeric compared to stainless steel ligation and self-ligating brackets had least friction.[19]

Friction is contributed by chemical structure, structural integrity and mechanical properties, which is largely due to the atomic and molecular forces of attraction at small contacts areas b/n materials.

When a single bracket is tested under dry and wet conditions, the role of saliva was not significant, where as when compared b/n bracket groups, the result was significant i.e. with saliva the frictional resistance encountered was more when compared to dry run samples.[20]

Conclusions

The self-ligating brackets seems to be promising in quenching the thirst of orthodontist to have a bracket that is functionally efficient with reduced friction, aesthetically pleasing, reduced treatment and chair side time, combined with better oral hygiene maintenance and patient comfort because of absence of ligation.

Self-ligating brackets made of titanium may prove to be more efficient than stainless steel due to its superior structural integrity and surface smoothness compared to stainless steel.

Recently ceramic self-ligating brackets have been introduced by GAC (IN OVATION-C). Further studies may be conducted using these newer brackets.

Declaration of Interest

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