

A Comparison of Frictional Resistance between Active and Passive Self-ligating Brackets with Conventional Bracket Systems

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ABSTRACT

Friction, though, is an inseparable and undeniable orthodontic entity that should be minimized, if not eliminated, for obtaining an optimal biological tissue response.

Aim: The present study compared the frictional resistance of active (time- 2, In-Ovation R) and passive (Damon SL-2, Smart clip) self-ligating brackets with conventional titanium, fiberglass and ceramic brackets under dry and wet conditions with artificial saliva using universal testing machine.

Methods: Modified Tidy's jig was constructed to simulate clinical situation. A total of 200 samples were tested. Specimens were divided into two categories which were run under dry and wet conditions, using artificial saliva. Around 10 samples of each active and passive self-ligating brackets were dry run and 10 others were used in wet conditions. Around 10 samples of each ceramic, titanium and fiberglass 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.

Results: 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, fiberglass and ceramic brackets in both dry and wet conditions.

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

Keywords: Active and passive self-ligating brackets, Conventional brackets, Frictional resistance.

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 cost-effectiveness.

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 has been steadily increasing, the esthetic ceramic material was made available. Though ceramic had excellent color 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, fiber glass brackets were introduced...but had shortcomings in frictional factor.

Though brackets were esthetically and functionally efficient, nothing eliminated the mode of ligation...which increased the

friction factor, chairside time and compromise on oral hygiene maintenance and patient comfort.

To quench this thirst, had come the self-ligating brackets, which were efficient functionally, pleasing esthetically, reduced treatment and chairside 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

Materials

SS self-ligating	} Damon SL-2 (Fig. 1)	SDC California, Ormco
Passive brackets		
SS self-ligating	} Time-2 (Fig. 3)	American Ortho, USA
Active brackets		
	} In-Ovation R (Fig. 4)	GAC, New York
Titanium brackets		
	} Rematitan (Fig. 5)	Dentaurum, Germany
Fiberglass brackets		
	} DB Fiberglass (Fig. 6)	Leone, Italy
Ceramic brackets		
	} Fascination (Fig. 7)	Dentaurum, Germany
Elastomeric modules		
	} Sanities	GAC, New York
Straight shooter wires		
	} (Fig. 8)	TP-Orthodontics
	} 19 × 25 SS	Dentaurum, Germany
Artificial saliva modified		
	} (Fig. 9)	
Tidy's jig		
Trans bond XT	Light cure adhesive	3M Unitek

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° and torque of -2° (Roth version).

Specimens were assorted at JSS Dental College and Hospital, Mysore, Karnataka, India, and tests were carried out at CIPET (Central Institute of Plastics and Engineering Technology), Mysore, Karnataka, India.

SEM specimens were viewed at magnification of X500 at 20 kV (Figs 10A to D). SEM was recorded for each bracket type to compare slot surface texture.

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



Fig. 1: Damon SL 2

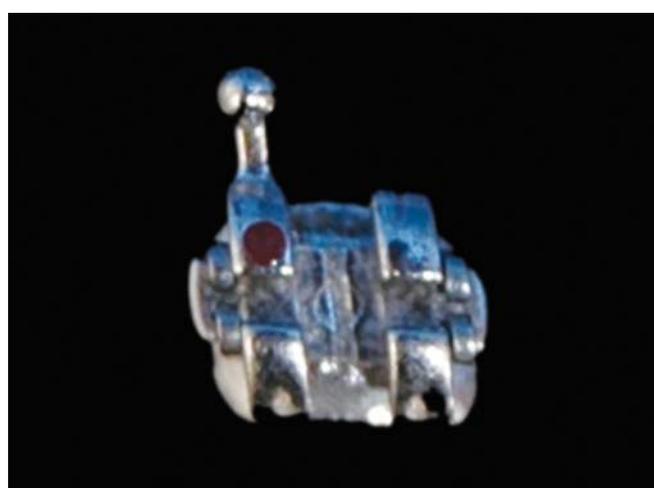


Fig. 2: Smart clip



Fig. 3: Time II

Additional power arm of 12 mm was chosen to represent the distance from bracket slot to the center 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 weight of 100 gm (representing normal force) was suspended from the additional power arm.

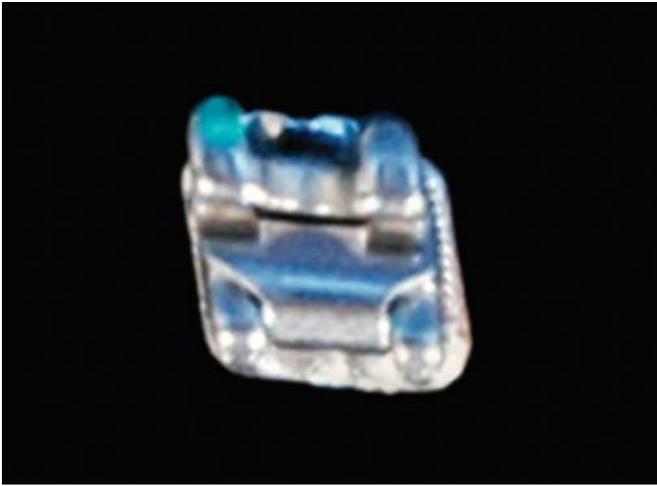


Fig. 4: In-Ovation R

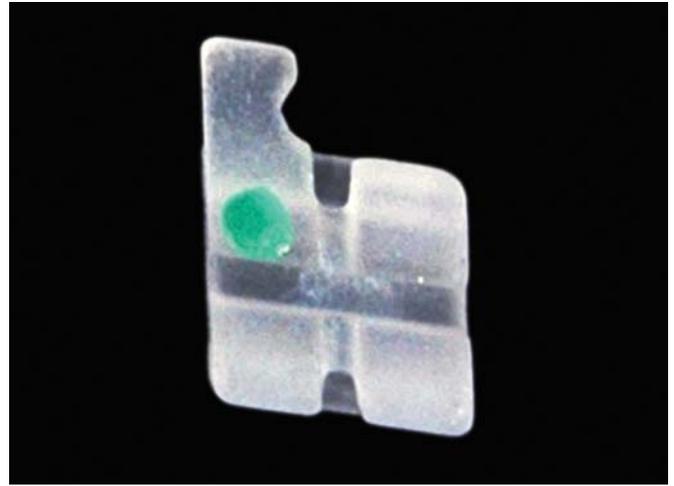


Fig. 7: Fascination (ceramic)



Fig. 5: Rematitan



Fig. 8: Straight shooter

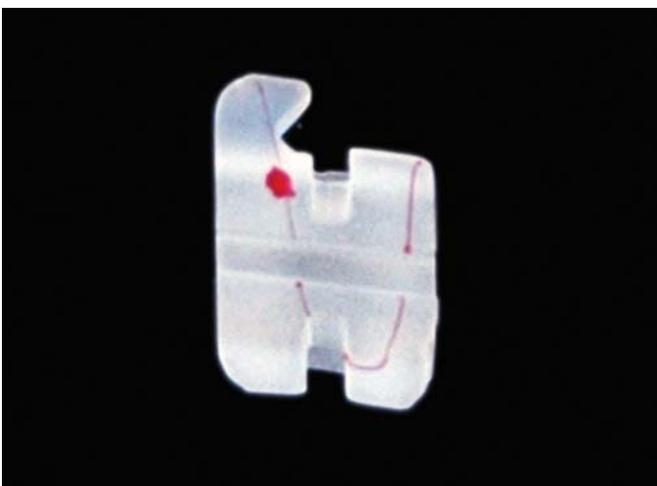


Fig. 6: DB fiberglass



Fig. 9: Modified Tidy's jig

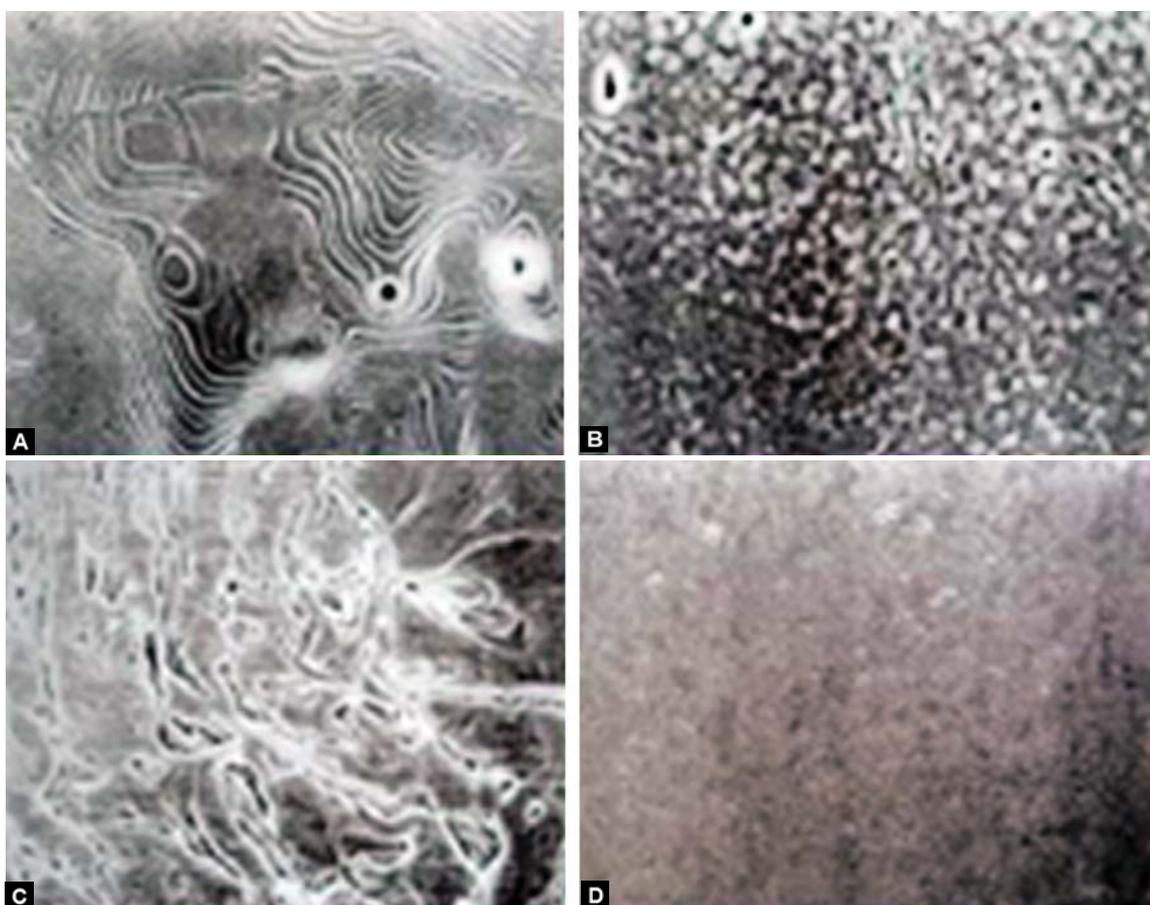
A 19×25 SS wire was chosen as this is the usual working wire in cases of retraction in 0.022" slot.

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

Around 10 samples of ceramic, titanium and fiberglass brackets were run using elastomeric ties and 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.



Figs 10A to D: Sem of bracket slots at $\times 500$: (A) Stainless steel, (B) ceramic, (C) fiberglass, (D) titanium

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 and upper member was connected to load cell of 100 Newton.

The suspended movable bracket was adjusted to move upward along with the bracket and suspended weight at a constant speed of 5 mm/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 archwire for a distance of 5 mm/min.

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

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.

RESULTS

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

1. Paired t-test (Table 1)
2. Two sample t-test (Table 2)
3. Anova (Table 3)
 - Around 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 nonsignificant at 0.01
 - For titanium brackets, the values were not significant, whereas for fiberglass and ceramic the values were significant
 - Around 10 samples each were tested under dry and other 10 under wet conditions with elastomeric and stainless steel ligatures. 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

Table 1: Paired t-test

	Paired t-test		p-value	Comments
	Dry Mean ± SD	Wet Mean ± SD		
Damon SL-II	46.01 ± 2.93	47.4 ± 3.87	0.229	NS
Smart clip	62.3 ± 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 2: Two-sample t-test

	Dry Mean ± SD	Wet Mean ± SD	p-value	Comments
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
Fiberglass-L	194.97 ± 10.33	209.23 ± 8.53	0.003	Sig
Fiberglass-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
Dry	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

NS: Not significant; Sig: Significant

Table 3: ANOVA

	Sum of squares	Df	Mean square	F	Sig.
<i>Dry</i>					
Between groups	380136.918	5	76027.384	939.337	0.000
Within groups	4370.615	54	80.937		
Total	384507.533	59			
<i>Wet</i>					
Between groups	451069.181	5	90213.836	1762.179	0.000
Within groups	2764.502	54	51.194		
Total	453833.683	59			

One way anova was conducted to see whether samples differ significantly in their mean differences and Duncan's multiple range test revealed that the mean differences obtained for each pair both in wet and dry conditions were significant (alpha = 0.5)

Friction exists in two forms as follows:

- Static friction
- 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 archwire 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, mesiodistal tooth movement is accomplished by guiding a tooth along a continuous archwire 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 archwires.

MECHANICAL

1. Archwire
 - a. Material^{11,12}
 - b. Cross-sectional shape/size^{11,13}
 - c. Surface texture¹²
 - d. Stiffness¹²
2. Ligation of archwire 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. Interbracket distance¹³
 - b. Level of slot b/n adjacent teeth¹³
 - c. Forces applied for retraction¹³
5. Intraoral biological variable
 - a. Saliva¹⁴
 - b. Plaque and acquired pellicle¹⁴
 - 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 archwire to secure it in the bracket slot. The primary objective of active self-ligation is to seat the archwire 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.¹⁵⁻¹⁷

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 Damon-2 showed lesser friction compared to Innovation R. The difference may be due to spring clip designs that press against the archwire in the slot.

In general, among conventional bracket systems titanium brackets showed least friction followed by fiberglass 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 contact areas b/n materials.

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

CONCLUSION

The self-ligating brackets seem to be promising in quenching the thirst of orthodontist to have a bracket that is functionally efficient with reduced friction, esthetically pleasing, reduced treatment and chairside 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 with stainless steel.

Recently, ceramic self-ligating brackets have been introduced by Gac (In-Ovation C). Further studies may be conducted using these newer brackets.

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