FRICTION-BOON OR BANE IN ORTHODONTICS

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ABSTRACT: OBJECTIVE: Most fixed appliance techniques involve some degree of sliding between brackets and arch wires. A sound knowledge of the various factors affecting the magnitude of friction is of paramount importance to the clinician. The present study was performed to evaluate and compare the frictional resistance and characteristics between self-ligating brackets and pre-adjusted edgewise brackets with different types of ligation.

MATERIALS AND METHODS: Tidy's frictional test design was used to simulate retraction of tooth along with artificial saliva to simulate wet conditions in oral cavity. The jig with this assembly was mounted on the Instron machine with the cross head moving upwards at a speed of 5mm/min. The movable bracket was suspended from the load cell of the testing machine, while the jig was mounted on cross head of machine and the load cell readings were recorded on digital display. Following wires are used 0.016 HANT, 0.019X 0.025HANT, 0.019X 0.025 SS, 0.021X 0.025 SS wires are used. The brackets used were 0.022 slot Damon, 0.022 Smart clip and 0.022 slot MBT system.

RESULTS: Self ligating brackets were shown to produce lesser friction when compared to the conventional brackets used with modules, and stainless steel ligatures. Damon self-ligating brackets produce a least friction of all the brackets used in the study. Stainless steel ligatures produced the least friction compared to elastomeric.

CONCLUSION: Self ligation brackets produce lesser friction than the conventional brackets ligated with elastomeric modules and stainless steel ligature. Damon self-ligating brackets produce a least friction of all the brackets used in the study width of the bracket was also found to be directly proportional to the friction produced 0.0016HANT with elastomeric modules produce more friction due increase in flexibility of wire.

KEYWORDS: Dynamic friction; Coefficient of friction; sliding mechanics.

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INTRODUCTION: Friction is a primary cause of problems encountered when using sliding mechanics for extraction space closure with conventional brackets. Up to 60% of applied force is dissipated as friction which reduces force available for tooth movement, such that an adequate translating force must be applied to overcome the frictional force. However, as a result of appliance inefficiency and friction, it is difficult both to determine and control the magnitude of force that is being received by individual tooth.[1]

Schumacher stated that friction was determined mostly by the nature of ligation. Friction is related to the applied normal load, which is influenced by the degree of tension of ligature engaging the archwire into the slot and coefficient of friction between the ligature and the archwire material.[2] An alternative approach to reducing friction has been to avoid using any form of ligature this has been achieved by selfligating bracket systems which were introduced in the mid-1930s in the form of the Russel attachment, which was intended to reduce ligation times and improve operator efficiency and decreases the chair side time.[3]

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Self-ligating brackets are ligatureless bracket systems that have a mechanical device built into the bracket to close off the edgewise slot. From the patient's perspective self-ligating brackets are generally smoother, more comfortable, and easier to clean because of absence of wire ligature.

Self-ligating bracket available as active or passive. Several studies have demonstrated a significant decrease in friction for self-ligating brackets, compared with conventional bracket designs. Such a reduction in friction can help shorten overall treatment time, especially in extraction patients in whom tooth translation is achieved by sliding mechanics.[4]

Because of conflicting claims and the availability of vast number of self-ligating brackets in the market with each company claiming its launch to be superior, we undertook this study to compare frictional characteristics of self-ligating Damon, Smart-Clip and PEA brackets with different ligation.

METHODOLOGY: An in vitro study of simulated tooth retraction was undertaken to evaluate the frictional resistance between 2 types of self-ligating brackets and pre adjusted edgewise brackets with steel ligation, pre-adjusted brackets with elastomeric ligation. The study was performed in the Department of Orthodontics and Dentofacial Orthopedics, Academy of Medical Education Dental College, Raichur in association with the Department of Technical Division and Institute Bangalore. For this study, the materials used included different types of brackets and ligation materials. The friction generated by these materials were tested on Instron Universal Friction Testing Machine.

MATERIALS USED:

Wires:

Straight lengths each 7 cm long,

1. 0.016 HANT.
2. 0.019X 0.025HANT.
3. 0.019X 0.025 SS.
4. 0.021X 0.025 SS wires.

0.016 inch round stainless steel wire was used to pull the bracket over a test distance. (Fig. 3)

Brackets: Four types of 6 each premolar brackets which were used as follows:

Group A: 0.022 slot, MBT prescription pre-adjusted edgewise brackets with elastomeric ligation-incorporating -7° torque and 0° angulation (Fig. 1)

Group B: 0.022 slot, PEA brackets with steel ligation-incorporating -7° torque and 0° angulation.

Group C: Damon self-ligating brackets -incorporating 0° torque and 2° angulation.

Group D: Smart clip self-ligating brackets - incorporating -7° torque and 0° angulations.

Ligation Materials: The Ligation materials used were as follows:

a) Stainless steel ligature 0.010 inch.
b) Regular elastic modules (Fig. 3).

Jig: A custom made apparatus was constructed to hold the wires parallel to the vertical framework of the universal strength testing machine. (Fig. 7)

Saliva: Artificial saliva made from bovine plasma was prepared at the Department of Oral Pathology, Academy of Medical Education Dental College, Raichur. (Fig. 5)

The chemical used for the preparation are:.

	Constituent (Inorganic)	Concentration (mg/liter)
1.	Ammonium chloride	233
2.	Calcium chloride dehydrate	210
3.	Magnesium chloride hexahydrate	43
4.	Potassium chloride	1163
5.	Potassium dihydrogen orthophosphate	354
6.	Potassium thiocynate	222
7.	Sodium citrate	13
8.	Sodium hydrogen carbonate	535
9.	Disodium hydrogen orthophosphate	375

Armamentarium used: Number of other armamentarium was used which included the following:

Mathew needle holder, pin and ligature cutter, ligature tucker, bird beak pliers, straight probe, alcohol, and cotton. (Fig. 6)

Machine: A universal strength testing machine (Model: 4467 INSTRON) was used to carry out the test. (Fig. 8)

Method: In this study, Tidy's frictional test design 8 was used to simulate retraction of tooth along with artificial saliva to simulate wet conditions in oral cavity.

The forces acting on the surface of the tooth root were simulated by single equivalent force acting at the Centre of resistance of the root-The measurements of friction between bracket and archwire were done with an Instron Universal testing machine. It consisted of a simulated fixed appliance with the archwire in vertical position. Four edgewise brackets were bonded to a specially constructed jig at 8mm intervals with a 16 mm space for a movable canine bracket at the centre. To simulate force acting at the centre of resistance of tooth, power arms of 10mm in length from bracket slots were welded at base of each premolar bracket. The 10mm distance was chosen according to Burstone's findings about location of centre of resistance.[5]

Straight lengths each 7 cm long following wires are used;

1. 0.016 HANT.
2. 0.019X 0.025HANT.
3. 0.019X 0.025 SS.
4. 0.021X 0.025 SS wires are used.

The brackets used were 0.022 slot Damon, 0.022 Smart clip and 0.022 slot MBT system.

The ligatures on the brackets were first tightened and then slackened to permit free sliding along the archwire.

The jig with this assembly was mounted on the Instron machine with the cross head moving upwards at a speed of 5mm/min. The movable bracket was suspended from the load cell of the testing machine, while the jig was mounted on cross head of machine. In each test, the brackets was moved a distance of not less than 2.5mm across the central space and the load cell readings were recorded on digital display.

A constant l00gm load was suspended from power arm to simulate single load acting at the centre of resistance. This load was kept constant for all tests because author found that friction increases with an increase in the applied load and it causes proportional increase in the applied force.[6]

The load cell readings represented the clinical force of retraction that was to be applied to the tooth, part of which was lost due to friction while the remainder was transmitted to the tooth root. The difference between load cell reading and load on the power arm thus represented the frictional force decay.

For each combination of bracket and archwire six readings were taken. To eliminate an element of doubt, the tests were re conducted on the same samples after 48 hours and the mean of the 2 readings were considered.

The results were subjected to statistical analysis for standard deviation and an unpaired students t' test conducted to check the significance of the results obtained.

RESULTS: The load cell readings are tabulated in Table 1, the loss of force due to friction in Table 2, Mean values and Standard deviation in Table 3.

The data is analysed statistically using one way ANOVA Studentized Newman Keul Test and unpaired T test.

STATISTICAL ANALYSIS: Descriptive data that included mean, standard deviation and standard error were determined for all the groups separately and all together, and were used for comparison between groups. Graphical presentation is used wherever necessary.

ANOVA was used for multiple group comparison followed by Newman-KEUL"s range for any significant difference between groups.

Pairwise comparison were done by student t-test.

For all the tests a P value of 0.001 or less was considered for statistical significance.

Formulae used in the study:

1) Mean $= \dfrac{\text{Sum of values}}{\text{No.of values}} = \dfrac{\Sigma x}{n}$

2) Standard Deviation $= \sigma = \sqrt{\dfrac{\Sigma (x - \overline{x})^2}{(n-1)}}$

3) ANOVA test $F = \dfrac{\text{Between sample variance}}{\text{Within sample variance}}$

4) Studentized Newman Keul Test

$$(x_1 - x_2) = Q_{0.05} \sqrt{\frac{S^2}{n}}$$

Table 1 shows the load cell readings represented the clinical force of retraction that was to be applied to the tooth, part of which was lost due to friction while the remainder was transmitted to the tooth root. The difference between load cell reading and load on the power arm thus represented the frictional force decay.

For each combination of bracket and archwire six readings were taken. To eliminate an element of doubt, the tests were reconducted on the same samples after 48 hours.

Table 1 shows the effect of all variables that is, bracket type, ligation method, and wire type on friction by means of one way ANOVA and Mann-Whitney test.

When group C and D are compared with group A and B self-ligating brackets was found to need less clinical force of retraction for all the 4 wire variables. Between group C and D, C required less force than D group (Graph I – IV). The difference was statistically significant.

When the ligation methods are compared (A & B) with each other, elastomeric modules i.e. A was found to have more clinical force of retraction than stainless steel ligation. The difference between them found to be statistically significant (Table 3).

Table 2 shows the difference between load cell reading and load on the power arm thus represented the frictional force decay. Effect of all variables that are bracket type, ligation method, and wire variable on friction by means of one way ANOVA and Mann-Whitney test.

When group A and B are compared with group C and D, self-ligating brackets was found to produce less frictional force decay and the difference was statistically significant (Graph-I, II, III, and IV).

When the ligation methods (A & B) are compared with each other elastomeric modules found to have more frictional force loss than stainless steel ligation. The difference between them found to be statistically significant.

When group C and D are compared with each other, group C self-ligating brackets was found to produce least force decay (Graph I, II, III, IV).

Table 3 shows the mean and standard deviation between different archwires and different bracket systems.

Table 4 shows the mean, standard deviation F value, p value and significance values with respect to 0.016 heat activated nitinol wire f value of 361.64 and P less than 0.001 shows highly significant between A & B, A & C, A & D, A & C, B & C, B & D, C & D with 0.016 HANT frictional force is maximum with Group A and least with Group C.

Table 5 shows the mean, standard deviation F value, p value and significance values with respect to 0.019x0.025 heat activated nitinol wire. f value of 1238.31 and P less than 0.001 shows highly significant between A & B, A & C, A & D, A & C, B & C, B & D, C & D and the sequence of frictional force from higher to lower order is in the sequence of A, B, C & D.

Table 6 shows the mean, standard deviation F value, p value and significance values with respect to 0.019X0.025 SS wire. f value of 341.00 and P less than 0.001 shows highly significant between A & B, A & C, A & D, A & C, B & C, B & D, C & D. With 0.019 x 0.025 SS wire group C showed lowest friction.

Table 7 shows the mean, standard deviation F value, p value and significance values with respect to 0.021x0.025 SS wire. f value of 3022.5 and P less than 0.001 shows highly significant between A & B, A & C, A & D, A & C, B & C, B & D, C & D. 0.021 x 0.025 SS wire showed least friction with Group C.

Table 8 shows the mean, standard deviation t value and p value with respect to all the four archwires the values of group C shows less comparatively than group D (graph I-IV). So Group C with all the variable wire showed least frictional forces followed by Group D.

	0.016 HANT	19 x 5 HANT	19 x 5 SS	21 x 5 SS
MBT with elastomeric ligering. (A)	446.8	318.0	198.2	396.2
	443.5	312.0	196.2	395.5
	438.0	313.3	194.3	391.1
	432.0	315.4	199.3	389.0
	449.0	314.2	201.3	394.0
	447.2	313.8	202.7	386.0
MBT – Stainless Steel Ligatures (B)	413.8	285.9	170.3	309.0
	417.0	284.6	171.2	312.5
	418.0	273.8	168.4	311.2
	414.2	269.2	187.3	301.8
	415.5	283.2	168.2	311.0
	420.3	280.3	163.3	316.0
Damon (C)	327.0	206.0	124.0	195.5
	326.8	206.2	127.2	190.1
	328.4	205.0	120.0	193.8
	323.3	204.2	128.2	189.0
	325.6	203.8	123.0	189.8
	320.8	206.1	122.8	194.0
Smart-clip (D)	357.0	222.0	129.3	254.8
	351.0	222.8	129.4	251.2
	350.1	220.1	128.8	250.0
	351.8	221.0	127.3	249.0
	360.0	221.5	130.3	248.0
	363.2	221.2	131.3	256.8

Table 1: Load Cell Readings in Grams

	0.016 HANT	19x25 HANT	19 x 25 SS	21 x 25 SS
MBT-Elastomeric Ligering (A)	346.8	218.0	98.2	296.2
	343.5	212.2	96.2	295.5
	338.0	213.3	94.3	291.1
	332.0	215.4	99.3	289.0
	317.0	214.2	101.3	294.0
	349.0	213.8	102.7	286.0
	337.2	214.70	98.7	291.97
MBT-Stainless Steel Ligatures (B)	313.8	185.9	70.3	209.0
	317.0	184.6	71.2	212.5
	318.0	173.8	68.4	211.2
	314.2	169.2	87.3	201.8
	315.5	183.2	68.2	211.0
	320.3	180.3	63.3	216.0
	316.47	179.5	72.1	210
Damon (C)	227.0	106.0	24.0	95.5
	226.8	106.2	27.2	90.1
	226.4	105.0	20.0	93.8
	223.3	104.2	28.2	89.0
	225.6	103.8	23.0	89.8
	220.8	106.1	22.8	94.0
	224.98	105.22	24.25	92.03
Smart-clip (D)	257.0	122.0	29.3	154.8
	251.0	122.8	29.4	151.2
	250.1	120.0	28.8	150.0
	251.8	121.0	27.3	149.0
	260.0	121.5	30.3	148.0
	263.2	121.2	31.3	156.8
	255.62	121.43	29.4	151.63

Table 2: Frictional force value in each group

	0.016 HANT	19 x 25 HANT	19 x 25 SS	21 x 25 SS
MBT-Elastomeric Ligerings. (A)	346.8	218	98.2	296.2
	343.5	212.2	96.2	295.5
	338	213.3	94.3	291.1
	332	215.4	99.3	289
	347	214.2	101.3	294
	349	213.8	101.8	286
Mean	**337.2**	**214.70**	**98.7**	**291.97**
SD	**6.51**	**2.02**	**2.91**	**3.99**
MBT – Stainless Steel Ligatures (B)	313.8	185.9	70.3	209
	317	184.6	71.2	212.5
	318	173.8	68.4	211.2
	314.2	169.2	87.3	201.8
	315.5	183.2	68.2	211
	320.3	180.3	63.3	216
Mean	**316.47**	**179.50**	**72.10**	**210.0**
SD	**2.47**	**6.63**	**9.03**	**4.74**
Damon (C)	227	106	24	95.5
	226.8	106.2	27.2	90.1
	226.4	105	20	93.8
	223.3	104.2	28.2	89
	225.6	103.8	23.3	89.8
	220.8	106.1	22.8	94
Mean	**224.98**	**105.22**	**24.25**	**92.03**
SD	**2.45**	**1.04**	**3.01**	**2.72**
Smart-clip (D)	257	122	29.3	154.8
	25.1	122.8	29.4	151.2
	250.1	120.1	28.8	150
	251.8	121	27.3	149
	260.6	121.5	30.3	148
	263.2	121.2	31.3	156.8
Mean	**255.62**	**121.43**	**29.40**	**151.63**
SD	**5.49**	**0.92**	**1.36**	**3.46**

Table 3: Each group (in grams) frictional force value (gm)

Groups	Mean±SD	F value	P value	Significance Gp
A	337.2±6.51	361.64	P less than 0.001 Highly significant	A&B,A&C, A&D, B&C, B&D, C&D
B	316.47±2.47			
C	224.98±2.45			
D	255.62±5.49			

Table 4: 0.016 HANT

Groups	Mean±SD	F value	P value	Significance Gp
A	214.70±2.02	1238.31	P Value less than 0.001 HS	A&B, A&C, A&D, B&C, B&D, C&D
B	179.50±6.63			
C	105.22±1.04			
D	121.43±0.92			

Table 5: 0.019 x 25 HANT

Groups	Mean±SD	F value	P value	Significance Gp
A	98.7.70±2.91	341.00	P value less Less than 0.001 HS	A&B, A&C, A&D, B&C, B&D, C&D
B	72.10±9.03			
C	24.25±3.01			
D	29.40±1.36			

Table 6: 0.019 x 0.025 SS

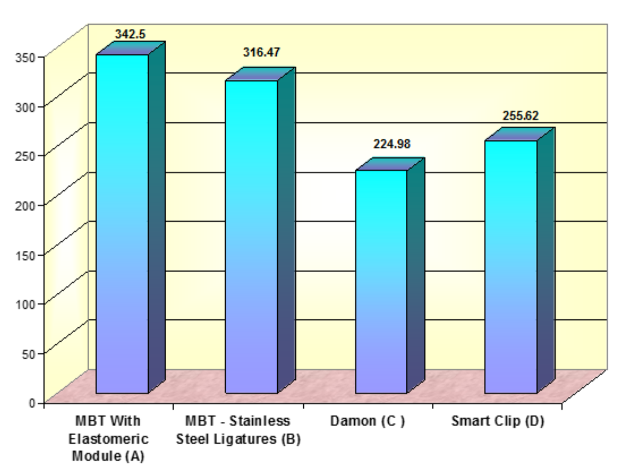
Groups	Mean±SD	F value	P value	Significance Gp
A	291.97±3.99	3022.5	P value less than 0.001 HS	A&B, A&C, A&D, B&C, B&D, C&D
B	210.0±4.74			
C	92.03±2.72			
D	151.63±3.46			

Table 7: 0.021 x 0.025 SS

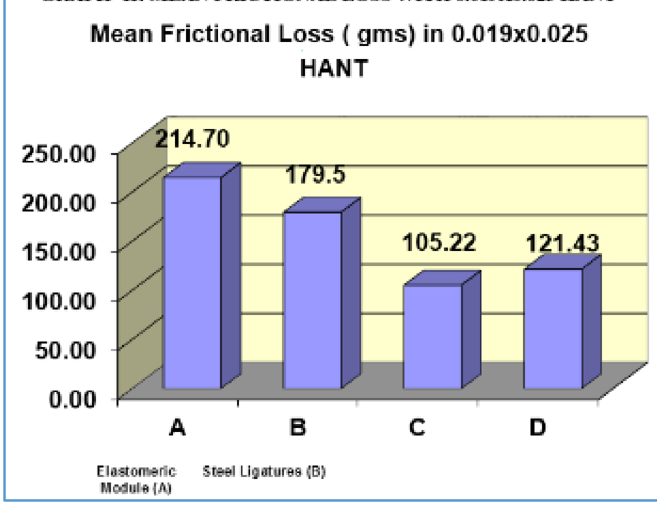
Wires	Mean±SD of C	Mean±SD of D	t* Value	P Value
0.016 HANT	225±2.45	255.5±5.38	12.64	P < 0.001 HS
0.019x25 HANT	105.2±1.04	121.4±0.98	28.14	P < 0.001 HS
0.019x25 SS	24.2±3.03	29.4±1.35	3.83	P < 0.001 VS
0.021x0.0 25 SS	92.03±3.71	151.63± 3.45	33.214	P < 0.001 HS

Table 8: Statistical Comparison between Group C & D

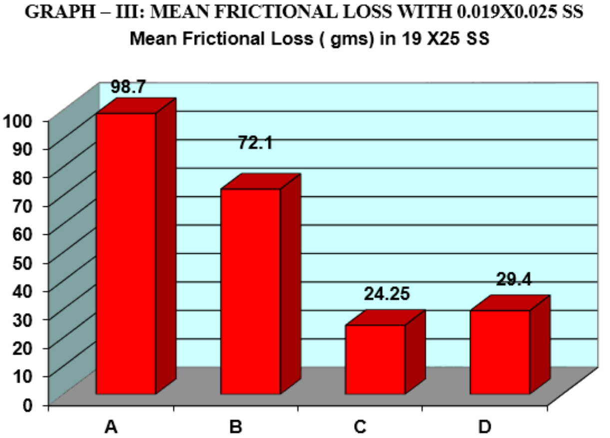
GRAPH – I: MEAN FRICTIONAL LOSS WITH 0.016 HANT



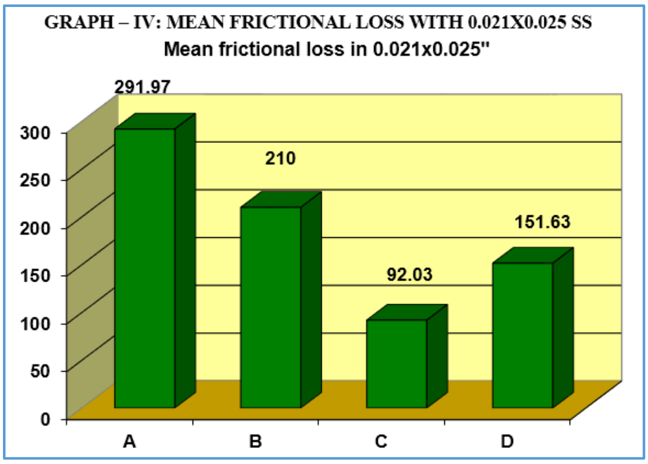
GRAPH – II: MEAN FRICTIONAL LOSS WITH 0.019X0.025 HANT



GRAPH – III: MEAN FRICTIONAL LOSS WITH 0.019X0.025 SS



GRAPH – IV: MEAN FRICTIONAL LOSS WITH 0.021X0.025 SS



DISCUSSION: Friction is a function of the relative roughness of two surfaces in contact. It is the force that resists the movement of one surface past another and acts in a direction opposite the direction of movement.

Fixed appliances used for orthodontic therapy are always associated with generation of friction between the bracket-wire interface or the ligature-wire interface. It has been proven in previous studies that the material properties of the bracket, wire and the ligature play an important role in the amount of friction generated. Tooth movement can occur only when applied forces adequately overcome the friction at the bracket wire interface.[7]

If the frictional forces are high the efficiency of the system is affected and treatment time may be extended or the outcome may be compromised because of little or no tooth movement and/ or loss of anchorage.[8,9] Binding of the bracket on the guiding arch wire occurs through a series of tipping and uprighting movements even though it creates friction, it signifies orthodontic tooth movement.

Friction could be advantageous in providing anchorage in respect to other planned tooth movements, but however anchorage generated by the friction phenomenon could also cause unwanted tooth movement.[10]

Nature of friction in orthodontic is multifactorial derived from both a multitude of mechanical or biological factors.[11]

Mechanical factors can include - arch wire properties, bracket to arch wire ligation, bracket properties.

Biological factors include - saliva, plaque, acquired pellicle, corrosion, food particles.

Whenever the force is applied to tooth, movement of crown mostly precedes displacement of the root (tipping tooth movement). Tipping leads to increased friction from binding between arch wire and bracket respecting the movement of intact tooth. Engagement of arch wire with the bracket creates a counter moment that will bring the root of the tooth in the direction of the crown. The coupled sequence of successive crown tipping then root uprightening will continue along the same plane of space as the direction of applied motive force. This allows approximation of translation of the tooth during sliding mechanics. The static and kinetic frictional forces should be minimized to obtain optimal tooth movement.

The present study was performed to evaluate the effect of factors such as bracket type, bracket size, ligation method on the friction produced.

Type of Wire: Kapila et al[7] with 0.022′ bracket found that in general, increasing the size of the wire, increases the frictional force, although small increase in size may not be significantly affect the friction.

Tidy et al[6] stated that within a bracket size changing the wire dimension has no effect on frictional force, although Nitinol wire gives greater values than steel.

Garner[12] stated increase in friction with wire size and in changing form steel to Nitinol wire.

In the present study, we found increased friction with 0.016 HANT i.e. low dimension of wire, because of its increased flexibility and there is increased friction forces with increase in the size of stainless steel wire in all the brackets (Table 1 to 4, Graph I-IV).

Type of Brackets: Hain M. et al,[13] Shivapuja P.K. et al,[14] and Cacciafesta V. et al.[8] found out that self-ligating brackets produced less friction when compared to conventional brackets tied with elastomeric ligatures. Similar results were also seen in the present study (Table II; Graph I, II & IV).

However, Studies performed by Loftus B.P. ct al.[9] found no significant difference between self-ligating brackets and elastomerically tied conventional brackets.

In the present study, friction values were observed to be less with self-ligating brackets when compared to conventional brackets tied with stainless steel ligatures and elastomer. Berger JL[15] also showed in their study reduced friction with self-ligating brackets compared to stainless steel ligated conventional brackets (Table II; Graph I, II).

The most probable reason may be due force of ligation, as it is known that friction generated is directly proportional to the force of ligation. In the present study, probably the force exerted by elastomeric ligature and stainless steel ligature was higher than both self-ligating brackets.

Self-Ligating Brackets: Kapila S. et al,[7] and Frank C.A. et al[5] found increased friction with increase in bracket width. This finding was in accordance with the present study where we found that increased friction seen with Smart clip bracket system, because it is directly proportional to the width of the bracket (Table II; Graph I, II, III & IV).

However, Drescher D. et al[1] Tidy DC.[6] Bednar JR. et al,[16] Chin and Liong and Sims AP et al[17] found in their studies that friction increases with decrease in bracket width. The probable reason for this finding may be that unlike the present study, in these studies the tested brackets had the freedom of tipping and this freedom would probably have caused a locking phenomenon and an increase in friction when forces were applied.

In the present study, the tip and torque values were effectively eliminated by the self-alignment of wire when the bracket was being pulled. The results of the study showed that the frictional force value decreased with decrease in bracket width. Other possible explation which may be given for this result could be based on the fact that increased width causes an increased surface area in contact with the wire. Also, the greater stretching of ligature can contribute to an increase in friction.

Ligation Method: Bednar JR. et al[16] Taylor NG15 found stainless steel ligatures to produce less friction when compared to elastomeric ligatures. This is also found to be true in the present study (Graph I – IV).

However Defranco DJ et al[18] and Edwards GD et al[14] found elastomeric ligatures to produce least friction of all ligation methods.

But Edward GD et al[19] Frank CA et al.[20] and Thorstenson GA[21] found in their studies no significant difference between stainless steel and elastomeric ligation methods.

CONCLUSION: The orthodontic practitioner is well aware of the importance of friction produced by his/her orthodontic mechanotherapy. Numerous factors play an interactive role during frictional mechanics and all these factors have to be controlled to achieve optimum correction of the malocclusion with minimum trauma to the surrounding structures.

Clinician should select the proper combination of brackets, method to reduce the friction and increase efficiency of the appliance. Stainless steel ligatures produce less friction when compared to elastomeric ligatures. Elastomeric ligatures produce highest friction of all ligation methods.

Self-ligating brackets can be concluded to produce less friction when compared to conventional brackets with elastomeric ligatures and conventional brackets with stainless steel ligatures. Magnitude of friction can be concluded to be directly proportional to the width of the bracket.

The frictional force value decreased with Damon self-ligating brackets due to decrease in bracket width. Other possible explanation which may be given for this result could be based on the fact that increased width causes an increased surface area in contact with the wire.

A summary of results deducted from the study;

1. Self-ligating brackets produced less friction than conventional brackets tied elastomeric modules and conventional brackets tied with stainless steel ligatures.
2. Stainless steel ligatures to produce less friction when compared to elastomeric ligatures.
3. Elastomeric ligatures to produce highest friction of all ligation methods.
4. The frictional force value decreased with Damon self-ligating brackets.

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