

**“COMPARATIVE EVALUATION OF
FRICTIONAL RESISTANCE IN
CERAMIC BRACKETS & ARCHWIRE –
AN IN VITRO STUDY”**

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**In
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By**

Dr. Anupama Chatterjee

**Under the guidance of
Dr. Shantanu Khattri
Professor (HOD)**

Department of Orthodontics and Dentofacial Orthopaedics

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SCIENCES, LUCKNOW**

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Date:



GUIDE

Dr. Shantanu Khattri,

Professor & HOD,

Department of Orthodontics and Dentofacial Orthopaedics,

BBDCODS, BBDU

Lucknow



CO-GUIDE

Dr. Kamna Srivastava

Reader

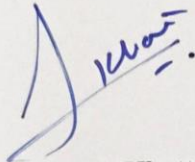
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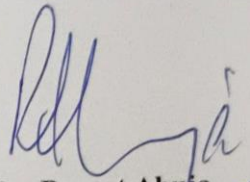
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Dr. Shantanu Khattri,
Professor & Head,
Department of Orthodontics and
Dentofacial Orthopaedics.
BBDCODS, BBDU,
Lucknow



Dr. Puneet Ahuja,
Principal
BBDCODS, BBDU
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Date:

Place:

Anupama Chatterjee
Dr. Anupama Chatterjee

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LIST OF ABBREVIATIONS

S.NO.	ABBREVIATED FORM	FULL FORM
1.	APF	Acidified Phosphate Fluoride
2.	BI	Binding
3.	CIPET	Central Institute of Petrochemical Engineering and Technology
4.	CL	Conventionally Ligated
5.	CM	Centimeter
6.	EDS	Energy dispersive spectroscopy
7.	et al	et alia (and others)
8.	FR	Frictional Resistance
9.	GM	Grams
10.	IMDF	Initial Maximum Drawing Force
11.	MM	Millimeter
12.	Mw/cm²	Milli Watts per Square Centimeter
13.	N	Newton
14.	NiTi	Nickel Titanium
15.	Nm	Nanometer
16.	NO	Notching
17.	RS	Resistance to Sliding
18.	Sec	Second
19.	SEM	Scanning Electron Microscope
20.	SL	Self-Ligating
21.	SLB	Self-Ligating Bracket
22.	SPSS	Statistical Package for the Social Sciences
23.	SS	Stainless Steel
24.	TMA	Titanium Molybdenum Alloy
25.	NCEL	Non – conventional elastomeric ligature

26	SPEED	Spring- loaded ,Precision ,Edgewise ,Energy and Delivery.
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Aim: To evaluate and compare the frictional resistance generated between different types of conventional ceramic and passive self-ligating ceramic brackets with rectangular stainless steel arch wire (0.019" x 0.025" SS) using Instron machine.

Material and Method: Different type of ceramic bracket used in study were grouped as – conventional ceramic bracket - Group I (Unitek Gemini Clear 3M), Group II (Symetri ClearOrmco) and ceramic passive self-ligating brackets - Group III (Clarity 3M) , Group IV (Clear Damon). Four moulds were made each with five premolar teeth mounted in stone to which four different types of brackets were bonded as per groups. 0.019" x 0.025" SS wire was ligated using SS ligature ties for Group I and Group II , whereas it was secured by passive clip in Group III and Group IV . Frictional resistance was tested in Instron by pulling long end of 0.019" x 0.025" SS wire from a mould place vertically in lower compartment . 10 sets of wire were tested in each group and frictional resistance was noted from graph, as seen on computer attached to machine . Results were tabulated and adequate statistical comparison were made using SPSS software.

Result: Passive self ligating bracket had lesser frictional resistance than conventional ceramic bracket. Frictional resistance was highest for Group I (22.86 ± 2.44 N) > Group II (16.43 ± 1.98 N) > Group III (8.42 ± 2.18 N) > Group IV (5.66 ± 1.88 N). Among conventional ceramic bracket – Unitek Gemini Clear 3M had significantly higher frictional resistance than Symetri ClearOrmco . Among passive self-ligating ceramic bracket – 3M Clarity had significantly higher frictional resistance than Damon Clear.

Conclusion: Method of ligation significantly influenced frictional resistance. The use of self-ligating ceramic bracket would be better alternative in aesthetically conscious adults with greater anchorage requirement during space closure by sliding mechanics .

Keywords: Frictional resistance, Passive self-ligating bracket, Sliding mechanics, Conventional ceramic bracket.

Friction is defined as an opposing and parallel force when one surface slides against another¹. In orthodontics, friction arises because of the interplay between an arch wire and the slot of an orthodontic bracket or a ligature wire¹. Friction is only a small part of the resistance to movement as a bracket slides along an archwire². Kusy and Whitley³ divided resistance to sliding during orthodontic tooth movement (RS) into three components - Friction, Static or Kinetic (FR), due to contact of the wire with bracket surfaces; the force that is to be overcome to initiate movement which is known as static friction and the force encountered during motion is known as kinetic friction², binding (BI), created when the tooth tips or the wire flexes, so that there is contact between the wire and the corners of the bracket, and binding occurs; and notching (NO), when permanent deformation of the wire occurs at the wire-bracket corner interface. This often occurs under clinical conditions. Tooth movement stops when a notched wire catches on the bracket corner and resumes only when the notch is released³.

From an orthodontic perspective additional force must be exerted to overcome friction, which may lead to greater loading of anchor teeth and eventual anchorage loss, especially during space closure. This idea had inspired previous studies to evaluate different methods to lower friction and, as a result, lower the possibility of greater anchorage loss⁴.

Friction between the arch wire and bracket is influenced by a number of factors, including the wire's size, composition, and ligation method, archwire material, cross section, shape/size, bracket to arch wire ligation ;bracket properties: material, surface treatment, bracket design, slot width and depth etc ; biological factors include saliva, plaque, acquired pellicle, corrosion and food particles etc⁵.

Friction can be limited or eliminated by modification of technique or material⁶. For space closure, technique can be modified as frictionless or loop mechanics and frictional mechanics or sliding mechanics.

During sliding mechanics friction results from direct contact between the bracket, arch wire, and ligature as a continuous arch wire passes through posterior brackets during the retraction of anterior teeth, irrespective of different methods used for retraction like elastics, active tie-backs, elastomeric chain, NiTi closed coil springs.

Loop mechanics is considered as frictionless mechanics where anterior teeth are retracted by activation of loops (vertical loop, T loop, mushroom loop, opus loop, snail loop, K-SIR) placed in extraction space and the wire does not slide in the brackets as it does in the continuous archwire used in sliding mechanics.

The role of friction has to be considered during sliding mechanics as its frictional mechanics where retraction starts after overcoming friction. During sliding mechanics, to reduce friction, lesser dimension wire will demonstrate lesser friction, however 3-dimensional control of teeth movement is not possible, hence wires with higher dimensions are used, which will demonstrate comparatively more friction^{2,7}. To overcome this to some extent, wire used for retraction are made of stainless steel, which has least coefficient of friction, hence sliding mechanics is attempted using 0.019" x 0.022" SS for 0.022 slot⁴. On contrary 0.019" x 0.025" TMA wire which has highest friction and lowest load deflection rate is recommended for loop / frictionless mechanics.

On evaluation of retraction between method of ligation and friction, stainless steel ligature wire in comparison to elastic ligature ties offer lesser friction^{8,9}. According to **Iwasaki et al**¹⁰, ligation friction accounted for 31–54% of the total frictional force produced by a premolar bracket moving along a 0.019x0.025 stainless steel archwire, with elastic binding accounting for the remainder 46–69%¹⁰.

To overcome the limitations of stainless steel ligature wire and elastomeric modules, efforts were made to step up a new ligation device within the bracket, and it is called self-ligation system. Self-ligating orthodontic bracket can secure the archwire in place with an inbuilt locking mechanism. Self-ligating brackets are available as active and passive¹¹.

Active self-ligating brackets have a spring clip, which encroaches on the slot from the labial aspect, potentially generating an additional force on the tooth². With some of the force being stored in the deflection of the spring clip, these brackets are referred to as active clips. Various active self-ligating brackets include Speed, Time, Activa etc.⁵. Conversely, a slide that can be closed on passive self-ligating brackets typically does not encroach on the slot lumen. The commonly used passive self-ligating brackets are Damon, Smart Clip⁵.

As interference due to ligation methods was omitted in self-ligating brackets, hence it was anticipated that friction would be reduced in self-ligating brackets, more so in passive self-ligating bracket as slide does not encroach the slot lumen².

Few studies showed that metal self-ligating brackets were found to have reduced friction levels when compared to conventional edgewise brackets^{7,12}.

Other studies showed that friction reduced only in the early phases, when there was greater flexibility between the wire and the bracket slot. However, when full size wire was engaged, this reduction was not noticeable¹³. **Gomez et al** found that frictional resistance was comparable between the self-ligating bracket and a traditional bracket with low friction ligation during space closure using sliding mechanics¹⁴.

Another factor that would influence friction is type of material of brackets selected for the patient. For adult orthodontic treatment where aesthetics is a major concern ceramic brackets are more frequently used⁶. The unsightly appearance of modules or SS ligatures when used with tooth coloured wires were a hindrance in making conventional ceramic bracket a good choice for aesthetically conscious adults⁶. Though tooth colour ligature ties solved this problem to certain extent however durability of aesthetic coating during tightening of wires was an issue. To overcome this, ceramic self-ligating brackets were good alternative for use in aesthetically conscious subjects.

Thorstenson in his study compared resistance to sliding between passive and active self ligating bracket¹⁵. He stated, as the dimensions of the archwires increased, the amounts of resistance to sliding depended on the type of self – ligating bracket (passive or active). For brackets with slides, the frictional resistance component of resistance to sliding was negligible regardless of the dimensions. For brackets with clips, the presence of an frictional resistance component depended on whether the clip contacted the archwire considering this, passive self-ligating bracket that are better in terms of frictional resistance were selected in present study. Various studies had shown that ceramic brackets has higher friction than conventional metal brackets.⁶ Also the efficacy of ceramic self-ligating bracket in terms of friction had been evaluated in previous studies. **Williams et al**⁴ reported that self-ligating ceramic bracket (Neoclip) system had significantly less resistance to sliding followed by metal slot ceramic

bracket system (Clarity) and highest friction was conventional ceramic bracket (GAC International) systems on using 0.018" x 0.025" stainless steel wire.⁴

Pillai et al¹⁶ reported that the ceramic bracket (American Orthodontics) showed the highest friction followed by stainless steel bracket, composite bracket and least was in metal self-ligating brackets (Empower) using 0.019" × 0.025" inch stainless steel wire¹⁶.

All these studies evaluated frictional resistance using instron universal testing machine by bonding the brackets to stainless steel bar, jig, acrylic plastic sheet, acrylic block.^{4,7} This methodology could not replicate the clinical scenario completely.

Some of the previous studies evaluated friction by bonding attachment to typhodont or teeth, then pulling the wire using Instron machine and this would replicate the clinical scenario more closely.¹⁷

However ceramic self-ligating bracket had never been evaluated using this methodology. Hence it was decided in present study to bond attachment to five teeth placed in a block of stone, that were aligned using 0.019" x 0.025" stainless steel wire. While mounting only 0.019" x 0.025 "stainless steel was used for measuring friction as this dimension is recommended for sliding mechanics with 0.022 slot.

Frictional resistance varied between different commercially available brackets. Though different types of metal self-ligating bracket had been compared in many studies, however different commercially available ceramic self-ligating bracket had not been extensively evaluated in previous studies, hence it was decided to evaluate.

The frictional resistance of two commercially available passive self-ligating brackets(Damon Clear and 3M Clarity) in present study. Thus the aim of present study was to evaluate and compare the frictional forces generated conventional(Unitek Gemini Clear 3M, Symetri Clear Ormco) and self-ligating (3M Clarity, Damon Clear) ceramic brackets with rectangular stainless steel arch wire (0.019" x 0.025" SS) using Instron machine.

AIM

To evaluate and compare the frictional forces generated conventional (Unitek Gemini Clear 3M, Symetri ClearOrmco) and self-ligating (3M Clarity, Damon Clear) ceramic brackets with rectangular stainless steel arch wire (0.019" x 0.025" SS) using Instron machine.

OBJECTIVES

1. To evaluate frictional resistance force generate between two different conventional ceramic brackets and rectangular stainless steel arch wire.
2. To evaluate frictional resistance force between 2 different ceramic self-ligating brackets and rectangular stainless steel.
3. To make inter group comparisons of frictional resistance between different types of conventional and self-ligating ceramic brackets and rectangular stainless steel wire.

Stolzenberg J (1935)³¹ introduced self-ligating bracket and described the features of the Russell Lock edgewise attachment, they are generally smoother for the patients because of the absence of wire ligature. The precision arm or the sliding fourth wall accurately locks the arch wire within the dimensions of the slot providing robust ligation and controlled tooth movement.

Tidy D C et al (1989)³² conducted a study to assess frictional forces caused by four edgewise brackets both 0.018 and 0.022 slot bonded to a rigid metal baseplate at 8 mm intervals with a 16 mm space for a movable bracket at the center. They used different arch wire 0.016 x 0.022 inch Stainless steel wire, 0.018 x 0.025 inch stainless steel, 0.016 x 0.022 inch nitinol, and 0.016 x 0.022 inch TMA wires tied by wire ligatures. The results showed that friction was greatest for narrow brackets(0.018 slot). For example to produce a 100 gm force on a tooth using 0.016 x 0.022 inch stainless steel arch wire required the application of a force of 295 gm to a 1.1 mm bracket, whereas such a force requires only 176 gm, 168 gm, and 155 gm, respectively, for bracket widths of 2.9 mm, 3.3 mm, and 4.2 mm. The frictional force was in fact inversely proportional to the bracket width. Arch wire and slot dimensions had relatively little influence on friction. To produce a 100 gm force on a tooth with 3.3 mm wide brackets using 0.018 x 0.025 inch stainless steel arch wire required a force of 188 gm. Reducing the arch wire to 0.016 x 0.022 reduces the force to 168 gm, whereas increasing the slot size to 0.022 inch only reduces the force to 181 gm. Nitinol and TMA arch wires had significantly greater friction than do stainless steel arch wires. Friction may therefore be minimized by the use of wide brackets and stainless steel arch wires in preference to nitinol or TMA arch wires.

Drescher D, Bourauel C, Schumacher H A (1989)³³ conducted this study to investigate the variables influencing the amount of friction, a friction-testing assembly that replicates three-dimensional tooth rotations was built. In relation to three bracket widths (2.2, 3.3, and 4.2 mm) at four levels of retarding force (0, 1, 2, and 3 N), five wire alloys (standard stainless steel, Hi-T stainless steel, Elgiloy blue, nitinol, and TMA) in five wire sizes (0.016, 0.016 x 0.022, 0.017 x 0.025, 0.018, and 0.018 x 0.025 inch) were investigated. The result showed that using medium (3.3 mm) or wide (4.2 mm) brackets to guide a tooth along a continuous arch wire in a 0.018 inch bracket, especially in cases of significant mesiodistal tooth displacement; using the 0.016 x

0.022 inch rectangular arch wire as a working arch to improve spatial root control; avoiding wires with rough surface texture (TMA, nitinol); and reinforcing the anchorage units (e.g., extraoral) in maximal anchorage problems .

Kapila S, Angolkar P V, Duncanson M G, Nanda R S (1990)³⁴ conducted this study to evaluate the effects of wire size and alloy on the frictional forces generated between edgewise bracket(narrow single, medium twin, wide twin) and wire (0.016 inch, 0.016 x 0.016 inch SS and beta Ti, 0.016 x 0.022 inch, 0.017 x 0.017 inch Co-Cr and NiTi and 0.017 x 0.025SS)during in vitro translator displacement of bracket relative to wire.The result showed that the larger frictional forces with wider brackets might be attributed to the higher forces of ligation that result from the grater stretching of elastic ligatures on wider brackets. The frictional forces produced by Co –Cr and SS wires were statistically similar and less than those generated by NiTi and Beta Ti wires.

Angolkar P V, Kapila S, Duncanson M G, Nanda R S (1990)¹⁸ compared evaluation of friction between monocrystalline ceramic edgewise brackets and SS bracket with orthodontic wires (0.019” x 0.025” SS). The results showed that SS bracket had significantly lesser frictional resistance than ceramic bracket

Pratten D H, Popli K, Germane N, Gunsolley J C (1990)²⁴ conducted a study to ecaluate frictional resistance of conventional ceramic (Ceramic A, Ceramic B) and stainless steel (Unitek) brackets. The results showed that did not find statistically significant dirrerent between two conventional ceramic bracket and ceramic bracket had significantly higher frictional resistance than SS bracket.

Bender J R, Gruendeman G W, Sandrik J L (1991)³⁵ conducted a study to investigate the effect of bracket material (Mini Diamond, GAC Allure, SPEED) and ligation technique (power O modules with 0.010 inch steel ligatures, elastomeric or self-ligating) and Tru – Chrome stainless steel orthodontic wire - dimensions were 0.014 inch, 0.016 inch, 0.018 inch, 0.016 x 0.016 inch and 0.016 x 0.022 inch)on the amount of frictional force generated during simulated tooth movement. All testing was done under dry conditions with an Instron Universal machine. The result showed that lightly steel tied brackets had less friction than elastomeric – ligated brackets. For Ormco steel brackets, friction increased with increased wire size. For GAC ceramic

brackets, friction decreased with increased wire size. In general, ceramic brackets produced more friction than steel brackets.

Kemp D W (1992)¹² compared the frictional forces between self-ligating and traditional edgewise brackets with various archwire size, alloy, or second order angulations. A testing device was created to simulate the clinical scenario in which a maxillary canine is retracted along a continuous archwire during the extraction of a first premolar using sliding mechanics. The findings showed that self-ligating brackets had lower levels of friction at 0° and 10° angulation.

Shivapuja P K, Berger J (1994)³⁶ conducted this study to evaluate and compare the three different self-ligating bracket (standard metal twin, active, speed ceramic series 200, edgelok) with conventional elastomeric and stainless steel ligation system (0.012 inch GAC steel tie, polyurethane elastomeric module, lever arm, spring clip and sliding cap). The result showed that the force values to start the wire movement for the twin bracket with metal tie, Activa, Edgelok, and SPEED. Nevertheless, there was more variation in the force values for the metal-tied twin bracket. The twin metal bracket with the elastomeric tie and the ceramic brackets with either the metal tie or the elastomeric tie were found to be statistically different from the other four. The use of the elastomeric power module revealed a higher level with the SPEED bracket system when compared with either the Activa bracket system the Edgelok bracket system. The time involved to open the self-ligated illustrated a significant decrease in time when compared with either of the other two forms of conventional ligation methods. This time difference was even more evident when the time for closing any of the self-ligating bracket systems was compared with that for replacing the stainless steel ligature tie or the elastomeric mode of ligation.

Read-Ward G E, Jones SP, Davies E H (1997)³⁷ The static frictional resistance of three self-ligating brackets and an ordinary steel ligated Ultra trim bracket were compared by the impact of bracket-archwire angulation, archwire size, and the presence of unstimulated human saliva was investigated. The study showed that all bracket types tested had their static frictional resistance increased with increases in wire size and bracket arch wire angulation, but self-ligating brackets only did so in certain circumstances when compared to steel ligated brackets.

Thomas S, Sherriff M, Birnie D (1998)⁹ conducted this study to evaluate the resistance to movement of different archwires(0.014 inch NiTi, 0.0175 inchy multistrand SS, 0.016 x 0.022 inch NiTi, 0.016 x 0.022 inch SS, 0.019 x 0.025 inch SS) through two types of self-ligating brackets (Damon SL, Time)and two conventional elastomerically tied brackets (A company Standard Twin and Tip Edge). The result showed that Damon SL system represent the lowest friction for all dimensions of the test wires and Twin brackets showed highest friction.with all the brackets the 0.019 x 0.025 inch SS wires produced the highest friction and 0.016 x 0.022 inch NiTi wires produced a higher frictional resistance than 0.016 x 0.022 inch SS. Friction increased with Time brackets when the archwire depth was greater than 0.017 inch. Damon SL brackets the friction was negligible at the lower archwire dimensions and very low, even with 0.019 x 0.025 inch rectangular archwires.

Pizzoni L, Ravnholt G, Melsen B (1998)³⁸ conducted this study to apply third type of design to four types of brackets – self-ligating bracket(Speed, Damon SL),two conventional brackets (Dentaurum, A company). the wires used for the study were 0.018 round SS, 0.017x0.025 in rectangular. The result showed that TMA gave rise to significantly more friction than SS. The spring design of the Speed bracket resulted in significant friction even at small angles between brackets and wire. In the case of an undermize round wire the Speed and Damon SL brackets resulted in significantly less friction than any of the conventional brackets and in rectangular wires the Damon bracket was significantly better than any other brackets.

Kusy RP, Whitley JQ (1999)³ divided resistance to sliding (RS) into 3 components:a) friction, static or kinetic (FR), due to contact of the wire with bracket surfaces,b) Binding (BI), created when the tooth tips or the wire flexes so that there is contact between the wire and the corners of the bracket (when a force is applied to a bracket to move a tooth, the tooth tips in the direction of the force until the wire contacts the corners of the bracket, and binding occurs) c) Notching (NO), when permanent deformation of the wire occurs at the wire-bracket corner interface. This often occurs under clinical conditions. Tooth movement stops when a notched wire catches on the bracket corner and resumes only when the notch is released.

Thorstenson GA (2002)¹⁵ in this study frictional resistance of conventional bracket and different types of self-ligating bracket (1 with a slide, 3 with clips) coupled with 5

kinds of arch wire was measured and compared. For brackets requiring ligation stainless steel ligature wire were used with a ligation force ranging from 200 to 600 cN. It was found that when clearance existed between the bracket and the wire, the self-ligating brackets that were open showed equivalent frictional resistance to the conventional brackets, but the self-ligating brackets that were closed showed no friction. When clearance no longer existed, all brackets showed greater sliding resistance as the angulation was increased. Due to the lack of a ligation force when the slide restrained the archwire, the closed self-ligating brackets' sliding resistances were lower overall than those of conventional brackets.

Cacciafesta V, Sfondrini M F, Ricciardi A, Scribante A, Klersy C, Auricchio F (2003)¹¹ conducted this study to compare the frictional forces generated by 3 types of brackets (conventional stainless steel Victory series, stainless steel self-ligating Damon SL and polycarbonate self-ligating Oyster) in combination with 3 different wire alloys (stainless steel, nickel titanium and beta titanium) of 3 different sections (0.016, 0.017 x 0.025 and 0.019 x 0.025 inch). The result showed that self-ligating brackets made of stainless steel produced noticeably less static and kinetic frictional forces than both conventional SS and polycarbonate self-ligating brackets. The frictional resistance of beta-titanium archwires was higher than that of nickel-titanium and stainless steel archwires. There were no discernible differences between nickel-titanium and stainless steel archwires. All brackets displayed greater static and kinetic frictional forces as the wire size increased. Polycarbonate self-ligating brackets was a good substitute for ceramic and conventional stainless steel brackets in patients with aesthetic preferences.

Tecco S, Festa F, Caputi S, Traini T, Iorio D D, Attilio M D (2005)³⁹ conducted a study to compare the frictional forces generated by three types of brackets (conventional stainless steel brackets Victory and two types of stainless steel self-ligating brackets - Damon SL II and Time Plus), using an especially custom designed apparatus that included 10 brackets. Conventional brackets were ligated with elastomeric modules. Three types of archwires, nickel titanium (NiTi), stainless steel (SS) & beta titanium (TMA), of three different sizes of cross sections (0.016, 0.017 x 0.025, 0.019 x 0.025 inch) were selected. The results showed that Time Plus self-ligating brackets generated significantly lower friction than both Damon SL II self-ligating brackets and conventional stainless steel brackets that did not differ significantly between themselves.

the Damon SL II brackets generated significantly lower friction when coupled with round wires and significantly higher friction when coupled with rectangular archwires when compared with the other two types of brackets. Beta titanium archwires had higher frictional resistance than did ss and nickel titanium arches. All brackets showed higher frictional forces as the wire size increased .

Kao C T, Ding S J, Wang C K, He H, Chou M Y & Huang T H et al (2006)⁴⁰ compared frictional resistance after immersion of metal brackets and orthodontic wires in fluoride –containing prophylactic agent (0.2 % acidified phosphate fluoride APF) for 480 bracket-wire samples. Three types of mandibular incisor stainless-steel edgewise metal brackets of different companies (DynaLock, Tomy, Ormco) were used and used Two different 0.018 in and 0.019 x 0.025 inch stainless steel wires, 0.019 x 0.025-inch heat-activated nickel-titanium and 0.017 x 0.025-inch beta-titanium alloy wire, ligated using elastomeric module (Alastic). From this study, fluoride-containing prophylactic material used in orthodontic treatment clearly can increase frictional forces with static force always greater than kinetic force. The TMA wire showed the highest friction followed by NiTi > Stainless steel wire in this study.

Yeh C L, Kusnoto B, Viana G, Evans C A, Drummond J L (2007)⁴¹ conducted this study to evaluate the frictional resistance and corresponding controls generated from two types of passive self-ligating brackets (Damon SL bracket and SmartClip bracket) and one type of novel bracket (Synergy bracket) and 0.014 in round NiTi archwire, 0.016 x 0.022 in NiTi archwires and 0.019 x 0.025 in NiTi archwires were coupled with the brackets in following order second order intrusion than first order rotations than third order inclinations with passive ligations for different phases of orthodontic treatments. The result showed that the SmartClip bracket had larger critical angles and distances for binding than the other two brackets. 0.019 x 0.025 in archwires in alignment phase, SmartClip brackets had lower initial maximum drawing force (IMDF) than other two brackets, in first order rotations, Synergy brackets had significantly lower initial maximum drawing force than others. Damon SL II brackets with smaller critical angles had greater IDMF. The Damon SL II brackets produced significantly greater values IDMF than Smart Clip brackets and Synergy brackets.

Tecco S, Iorio D D, Cordasco C, Festa I V F (2007)⁴² conducted a study using a specially designed apparatus that included 10 aligned brackets, to evaluate the frictional

resistance generated by conventional stainless steel (SS) brackets (Victory Series), self-ligating (Damon SL II brackets, Time Plus brackets), and low-friction ligatures (Slide) coupled with various SS, nickel-titanium (NiTi), and beta-titanium (TMA) archwires. The results showed that when coupled with 0.016 inch NiTi wire, Damon SL II brackets showed significantly higher friction. With 0.016 x 0.022 inch NiTi, the self – ligating brackets (Time & Damon SL II) generated significantly lower friction than victory series brackets and slide ligatures, while with 0.019 x 0.025 inch NiTi and 0.019 x 0.025 inch SS, Slide ligatures generated significantly lower friction, compared with other groups.

Ehsani S, Mandich M A, El-Bialy T H, Flores-Mir (2009)⁴³ conducted this study to compare the amount of expressed frictional resistance between orthodontic self-ligating brackets (active & passive) and conventionally ligated brackets. The results showed that on Comparison with conventional brackets, self-ligating brackets of produce lower friction when coupled with small round arch wires in the absence of tipping and/or torque in an ideally aligned arch.

Burrow (2009)¹⁰ critically examined the role of friction in orthodontic sliding mechanics, challenging the widely marketed claim that self-ligating brackets reduce treatment time by lowering friction. The results of this study suggests that resistance to sliding is primarily due to binding and notching, not friction, and self-ligating brackets do not significantly improve treatment efficiency.

Cordasco G, Farronato G, Festa F, Nuceara R, Parazzoli E and Grossi G B (2009)⁴⁴ conducted this study to evaluate the frictional forces arising from the archwire (0.014 inch copper NiTi) and three identical passive self-ligating brackets (Damon SL2), which were not vertically aligned. The result showed that frictional forces arising from passive self-ligation were significantly lower than those resulting from elastic and metallic ligation.

Krishnan M, Kalathil S and Abraham K M (2009)² compared the effects of stainless steel, nickel-titanium, and beta-titanium archwires of dimension in 0.019 x 0.025 SS, on frictional forces of passive (DamonSL II & Smart Clip) and active (In-ovation & Time) self-ligating brackets with a conventional (Gemini series, 3M Unitek) bracket. Friction was evaluated in a simulated half-arch fixed appliance on a testing

machine. The results showed that Static and kinetic frictional forces were lower for both the passive and active designs than for the conventional brackets. Maximum values were seen with the beta-titanium archwires, and significant differences were observed between nickel-titanium and stainless steel archwires.

Ong E, McCallum H, Griffin MP, Ho C (2010)⁴⁵ Compared the efficiency of Self-ligating (SL) and conventionally ligated (CL) brackets in patients who had undergone premolar extraction during the first 20 weeks of extraction treatment using study models. Forty four arches received SL Damon 3MX brackets, and 40 arches received either CL Victory Series or Mini Diamond brackets. The models were evaluated for anterior arch alignment, extraction spaces, and arch dimensions at pretreatment (T0), 10 weeks (T1), and 20 weeks (T2). The results showed no significant difference between the two and concluded that Ligation technique is only one of many factors that can influence the efficiency of treatment.

Stefanos S, Secchi A G, Coby G, Tanna N, Mante F K (2010)⁴⁶ conducted this study to evaluate the frictional resistance between active (In- Ovation R, In- Ovation C & SPEED) and passive (SmartClip, Synergy R & Damon 3mx) self-ligating brackets with 0.022 inch slot and 0.019 x 0.025 inch SS archwire during sliding mechanics by using an orthodontic sliding simulation device and Instron. The result showed that passive self-ligating brackets had lower static and kinetic frictional forces compared with active self-ligating brackets when coupled with 0.019 x 0.025 inch SS wire. The Damon 3mx bracket has significantly the lowest static and kinetic frictional forces & SPEED has the highest frictional force of the brackets investigated.

Husain N, Kumar A (2011)⁴⁷ conducted a study to evaluate frictional resistance between orthodontic brackets and archwire using Instron. In this study, Brackets: used was Dynalock (Unitek) 0.018" slot, Mini Uni-Twin (Unitek) 0.018" slot, Ultra-Minitrim (Dentaurum) 0.022" slot, Titanium (Dentaurum) 0.022" slot, with different wires : 0.016 x 0.022" stainless steel, 0.017 x 0.025" stainless steel, 0.018 x 0.025" stainless steel tied using elastomeric modules (Ortho Organisers) or 0.009" stainless steel ligature wires. The results showed that brackets with 0.018 slot generated more friction than 0.022 slot. Frictional force was directly proportional to wire dimension. Titanium brackets generated more friction than stainless steel brackets. Archwire and bracket ligated with elastomeric module generated more friction than when ligated with

stainless steel ligature wire. Frictional forces in the wet condition were greater than in the dry condition for all archwire to bracket combinations.

Faizee KM S H, Thomas S, Krishnaswamy N R et al (2011)⁷ conducted this study to evaluate the kinetic frictional resistance of four self- ligating brackets- two active types(Speed, In – Ovation R), two passive types (Damon 3, Smart Clip) and compare them with conventional brackets (Mini Ovation) ligated with elastomeric modules. The brackets were tested against five different dimensions of round and rectangular ss wire (0.018 inches AJ Wilcock SS wires, 0.020 inches – AJ Wilcock SS Wires, 0.017 x 0.025 inches straight length SS wires, 0.019 x 0.025 inch straight length SS wires, 0.021 x 0.025 inches straight length SS wires .The results showed that self – ligating brackets offered less frictional resistance than conventional brackets.Passive bracket systems exhibited less frictional resistance than active bracket systems. Damon 3 brackets produced less frictional resistance than SmartClip brackets in the passive group and In- Ovation R produced less frictional resistance than Speed brackets in active group.

Pliska BT, Beyer JP, Larson BE (2011)⁴⁸ conducted a study to test the null hypotheses that at clinically relevant amounts of applied moment, there are no differences in the amount of resistance to sliding between self-ligating (Damon3, In Ovation R, Smartclip,) and conventionally ligated (Victory) brackets on both stainless steel and nickel titanium archwire of 0.019” x 0.025” dimension. a custom built device was used to simulate canine retraction mechanics which allowed for simultaneous and continuous measurement of resistance to sliding and applied moment at the bracket archwire interface. The resistance to sliding at calculated moments of 2000 g-mm and 4000 g mm was determined and compared between the various brackets and both archwire types. Greater amount of resistance was seen for NiTi arch wire than SS arch wire in all brackets. At low values of applied moment, some statistical differences were found amongst the various SL and CL brackets however, no significant difference was found at higher moments.

Huang T H, Luk H S, Hsu Y C and Kao C T (2012)¹ conducted a study to compare the static and kinetic frictional forces generated, in six different brackets (four passive type SLB (Tenbrook SLB T1, Damon SL III MX, Smart Clip, Carriere LX, one active SLB (CLIPPY),and one conventional bracket (OPA -K) using stainless steel (0.016 x

0.022, 0.017 x 0.025 & 0.018 x 0.025) nickel – titanium (0.018 x 0.025 inch heat activated), and titanium – molybdenum alloy (0.017 x 0.025 inch) archwires. The friction forces were measured by sliding on a bracket– wire combination system in an EZ instron testing machine. A scanning electron microscope (SEM) was used to examine the wear effects of the wall surfaces of bracket slots. Energy-dispersive spectroscopy (EDS) was used to identify the elemental compositions of the bracket surfaces. The results showed that passive SLB are associated with a lower static or kinetic friction force than active SLB or conventional brackets.

Williams C L, Khalaf K (2013)⁴ conducted this study to investigate the static frictional resistance at the bracket/archwire interface mystique systems and compared them to conventional ceramic and conventional metal bracket & metal slot ceramic bracket system, using two archwires (round 0.014 inch SS wires at 0 degree angulation and rectangular 0.018 x 0.025 inch SS wire at an archwire angulation of 0 degree, 7 degree). The results showed that static functional resistance for 0.014 wire had a trend to conventional ceramic brackets > self-ligating ceramic brackets > metal slot ceramic brackets > conventional metal brackets & static functional resistance for 0.018 x 0.025 SS wire at 0 degree angulation was conventional ceramic brackets > conventional metal brackets > self-ligating ceramic brackets > metal slot ceramic brackets & at 7 degree angulation was conventional ceramic > metal slot ceramic brackets > conventional metal brackets > self-ligating ceramic brackets. Conventional ceramic brackets significantly had higher resistance than self-ligating ceramic brackets for each wire except for 0.018 x 0.025 SS wires at 0 degree angulation.

Kaur G, Goyal S, Rajpal S, Gera A (2013)³⁰ conducted this study to compare the frictional forces generated by three different ligation methods (conventional ligation, low frictional ligation, self-ligation), using metallic stainless steel (Gemini series), ceramic (InVu) and self-ligating (Damon SL II) brackets. The wires used for testing were 0.016” NiTi and 0.019 x 0.025 SS. The result showed that conventional ligation exhibited higher friction than low-friction and self-ligation methods with all the archwire-bracket combinations. Damon self-ligating system exhibited less friction than low-friction ligation with lower archwires and higher friction with higher archwires. Slide low-friction ligatures were able to reduce the friction of ceramic brackets in a similar way to stainless steel brackets.

Galvão et al. (2013)²⁵ investigated frictional resistance in monocrystalline ceramic brackets with conventional and nonconventional elastomeric ligatures. Literature suggests that ceramic brackets, though aesthetically favorable, generally produce higher friction than metal brackets, which can hinder tooth movement during sliding mechanics. The study builds upon prior research indicating that monocrystalline ceramic brackets exhibit greater friction than polycrystalline ceramic brackets due to their manufacturing differences. Nonconventional elastomeric ligatures (NCEL) have been proposed to reduce friction in orthodontic treatment. Previous studies confirm that NCEL generates lower frictional resistance compared to conventional elastomeric ligatures (CEL), improving treatment efficiency. Research also highlights that variables such as wire type, ligation method, and bracket design significantly influence frictional forces also demonstrating that NCEL significantly reduces friction in monocrystalline ceramic brackets, making them a preferable option for minimizing resistance in orthodontic treatment.

Monteiro MR, Silva L E, Elias C N, Vilella O D (2014)⁴⁹ compared the frictional force resistance as influence of archwire material (NiTi, betaTi and stainless steel 0.019"x0.025" wire) and brackets design (self-ligating Smartclip, 3M/Unitek and conventional Gemini, 3M/Unitek). The wires were pulled from the bracket slots at a cross head speed of 3 mm/min until 2 mm displacement. The mechanical testing was performed with a universal testing machine EMIC DL 10000. Self-ligating brackets produced significantly lower friction values compared with those of conventional brackets. Frictional force resistance values were directly proportional to the increase in the bracket/ wire angulation. With regard to conventional brackets, stainless steel wires had the lowest friction force values, followed by nickel titanium and beta titanium ones. With regard to self-ligating brackets, the nickel titanium wires had the lowest friction values, significantly lower than those of other materials.

Montasser MA, El Bialy T, Keilig L, Reimann S, Jäger A, Bourauel C (2014)⁵⁰ compared conventional and self-ligating brackets in terms of differences in the force loss during simulated archwire guided canine retraction. A conventional ligating brackets (Victory Series and Mini Taurus), self-ligating brackets (SmartClip: passive, and Time3 and SPEED: active), and a conventional low-friction bracket (Synergy) all with 0.022" slot size was used with 0.019 × 0.025" arch wires (SS, NiTi and TMA).

Stainless steel ligatures were used with the conventional brackets. A superelastic NiTi coil spring (force: 1 N) was used for retraction of upto 4mm. the simulation was carried in Orthodontic Measurement and Simulation System (OMSS). Force loss gradually increased by about 10 per cent for each bracket type in combination with the different wires in the following sequence: stainless steel, NiTi, and TMA. SPEED brackets exhibited the highest force loss with the three wires used and was lowest for the Victory Series and SmartClip brackets with no consistent pattern of force loss when comparing conventional and self-ligating brackets or passive and active self-ligating brackets.

Kumar s, Singh S, P.R R H, Ahmed S, Prasanthma, Bhatnagar A, Sidhu M, Shetty P (2014)⁵ conducted a study to compare frictional resistance which was produced between conventional brackets (0.022 slot Otho-Organiser) and self-ligating brackets (active Forestadent and passive Damon III) by using various arch wire combinations (0.016 Niti, 0.018 Niti, 0.017 x 0.025 SS and 0.019 x 0.025 SS). The results showed that conventional brackets produced highest levels of friction for all bracket / archwire combinations. Both Damon III and forestadent brackets produced significantly higher levels of friction than Damon III as compared to electrometrically tied conventional brackets. Both in the conventional brackets and self-ligating brackets, the friction increased with increasing archwire dimensions, however friction was negligible with Damon III bracket.

Kumar B S, Miryala S, Kumar K K, Shameem K, Regalla R R (2014)⁵¹ compared the frictional resistance of different brackets - titanium, stainless steel, ceramic and ceramic with metal insert with 0.018" slot. Stainless steel wires of varying dimensions (0.016" round, 0.016 x 0.016" square, 0.016 x 0.022" rectangular and 0.017 x 0.025" rectangular) used. The frictional resistance was measured using Instron Universal testing machine (Model no. 4301). The results showed that Ceramic brackets revealed significantly higher static frictional forces than all other brackets for each archwire dimensions. For rectangular 0.017 x 0.025 SS wire, trend for functional force was ceramic > ceramic with metal slot > stainless steel > titanium brackets.

Pillai A R, Gangadharan A, Kumar S, Shah A (2014)¹⁶ The study discusses frictional resistance in orthodontics, a crucial factor in sliding mechanics, affecting tooth movement efficiency. The literature highlights that friction is influenced by bracket composition, size, interbracket distance, and ligation methods. Conventional stainless

steel brackets, ceramic brackets, and self-ligating brackets (SLB) each have varying frictional characteristics. Ceramic brackets, despite their esthetic advantage, have higher friction due to surface roughness, whereas SLBs minimize friction, improving efficiency. Research also suggests that saliva, wire angulation, and bracket design significantly impact frictional resistance. The study aligns with previous findings, reinforcing that SLBs exhibit the least friction, while ceramic brackets generate the highest resistance, influencing orthodontic treatment outcomes.

Kannan M S, Murali R V, Kishorekumar S, Gnanashanmugam K, Jayanth V (2015)¹⁹ conducted this study was to compare and evaluate the frictional forces generated between fully aesthetic brackets (OPAL, Damon clear) and semi aesthetic (Damon 3, Clatity SL)self-ligating brackets of the passive form and 17 x 25, 19 x 25 TMA and 17 x 25, 19 x 25 stainless steel. Friction was tested using Instron universal testing machine. The result showed that for each wire used, Damon 3 displayed significantly lower frictional forces than any self-ligating systems. The trend for friction was Clarity SL < Damon 3 < Opal < Damon clear.

Alio- Sanz J J, Claros- Stucchi M, Albaladejo A, Iglesias – Conde C, Alvarado – Lorenzo A (2016)⁵² conducted this study to evaluate the in vitro behavior of JAL 90458 as a buffering agent which reduces friction between brackets and stainless steel arch wires (two 0.020 round archwires, two 0.019 x 0.025 rectangular arch wire) of different cross sections (45 degree & 60 degree angulation) and sizes. They used a 35 x 40 cm inclined plane with a 0.5 cm groove in the middle where two rubber wheels could roll. The result showed that without JAL, the longest period of time was registered with the 0.021 x 0.025 inch wire and conventional elastic ligature. With JAL 90458 the time used was much lower. JAL 90458 significantly reduced sliding resistance on all the SS wire bracket couples.

Kumar D, Dua V, Mangla R, Solanki R, Solanki M, Sharma R (2016)⁸ Conducted this study to evaluate the resistance to movement of various arch wires (0.016 NiTi, 0.019 x 0.025 beta titanium, 0.019 x 0.025 SS)through three types of conventional stainless steel brackets (0.022 x 0.028 SS conventional bracket <mini 2000, victory series, Optimum series >, 0.022 x 0.0275 SS passive self-ligating bracket < Damon 3MX, Carriere LX, Smart Clip > using slide and silver mini module. The results showed that Silver mini modules produced greater friction than slide ligature and self-ligation

method with different archwires combinations. Damon 3MX self-ligation produced lesser friction than slide ligation with lower archwires and higher friction with higher arch wires. Slide ligation also showed lower friction with different archwires combinations. In present study, among all SLBs produced lowest frictional. When compared with $0.019 \times 0.025''$ SS wire Smart Clip produced lowest friction.

Hirunyapanum N, Nanthavanich Saengfai N, Chintavalakorn R, Joachakarasiri P (2017)²³ conducted this study to evaluate different types of SLBs and conventional brackets consistently shows that self-ligating metal brackets produce the least friction, followed by self-ligating ceramic brackets, with conventional ceramic brackets generating the highest resistance. The results suggest that while SLBs, especially metal ones, offer advantages in reducing friction, factors like archwire coating, bracket design, and manufacturing techniques continue to influence their overall performance in orthodontic treatment.

Mascarelo A C, Godoi A P, Furletti V, Custodio W, Valdrighi H C (2018)⁶ conducted this study to compare the frictional force and there orthodontic brackets (conventional metal, self-ligating metal & conventional polycrystalline) and 0.019×0.025 Stainless Steel wire in sliding mechanics. The results showed that ceramic bracket had maximum and significantly different frictional forces in self-ligating bracket and incomparision to the metal bracket. However conventional metal bracket and self-ligating metal bracket did not show significant differences between frictional forces.

Patni V, Joshi D, Ravindranath V K, Mhatre A, Daga P, Madhaswar A (2019)²¹ Conducted this study to evaluate that SLBs into active and passive types, where passive SLBs create a tube-like slot that minimizes friction by eliminating the need for elastic or metal ligatures. Previous research has demonstrated that passive SLBs generate lower frictional resistance compared to active SLBs and conventional brackets. Studies by Burrow (2009) and Chen et al. (2010) highlighted the advantages of self-ligating systems, emphasizing their reduced resistance to sliding mechanics. Additionally, Krishnan (2009) found that passive SLBs exhibited lower frictional forces than active ones, reinforcing the benefits of these brackets. However, variations exist depending on bracket material, slot design, and archwire type. The coating of archwires further influences frictional resistance, as seen in studies comparing coated and uncoated

stainless steel (SS) and nickel-titanium (NiTi) archwires. The current study builds upon existing literature by analyzing the frictional characteristics of three newly introduced passive ceramic SLBs—Damon Clear, Truklear, and Cabriolet—when used with different coated and uncoated archwires.

Stefanski S, Ptaszna A K, Stefanska L P (2019)⁵³ conducted this study to evaluate the effect of simulated erosive conditions(1% citric acid) on the frictional behavior between the brackets of 3 different materials (stainless steel, monocrystalline ceramic, titanium) and 3 different wire alloys (stainless steel, nickel titanium, beta – titanium). The result showed that, irrespective of the conditions, SS brackets with SS wire demonstrated significantly lower static and kinetic frictional resistance than other bracket wire combinations. With metallic brackets the highest friction demonstrated was the TMA >Ni Ti. erosive conditions did not affect the frictional behavior of stainless steel, NiTi, TMA orthodontic archwire.

Gómez-Gómez SL, Sánchez-Obando N, Álvarez-Castrillón MA, Montoya-Goez Y, Ardila CM (2019)¹⁴ conducted a fem study to compare the frictional force resulting from the bracket/arch wire interface and the stress at the root/periodontal ligament/bone interface, between passive self-ligating brackets (smartclip) and conventionally ligated brackets (logic line), during the space closure stage with different arch wire types. Stress was used as an indicator of the frictional resistance of these systems. Results showed similar frictional stress (0.50 MPa for SmartClip, 0.64 MPa for Logic Line) while using 0.019x0.025" SS wire but lower load transmission to the periodontal ligament with passive self-ligating brackets.Low-friction ligatures exhibited similar bracket/archwire friction but less stress on the bone/root interface with passive self-ligating brackets

Wu C L, Chang C J, Lee T M, Lo J B, Liu J K (2020)²² conducted this study The study on shear bond strengths and friction forces among various self-ligating ceramic brackets builds upon previous research on orthodontic bonding and resistance to sliding. Early studies on orthodontic bonding emphasized the importance of adequate bond strength to prevent bracket failure while minimizing enamel damage. The development of ceramic brackets introduced aesthetic advantages, but early versions had excessive bond strength, leading to enamel fractures. Later studies focused on improving base designs to optimize adhesion while reducing the risk of enamel

damage. Research on frictional resistance in orthodontics has highlighted the role of bracket material, slot design, and wire type in determining friction forces. Metal brackets generally exhibit lower friction compared to ceramic brackets due to their smoother surface and different ligation mechanisms. Previous studies demonstrated that self-ligating brackets, particularly those with passive designs, reduce friction compared to conventional brackets with elastic ligatures. Additionally, the interaction between wire size, angulation, and bracket slot geometry significantly affects resistance to sliding. The results showed that optimizing ceramic bracket designs requires balancing bond strength and frictional resistance to achieve efficient orthodontic tooth movement.

Galavotti Viana et al. (2021)²⁶ conducted this study to evaluate friction in metallic and ceramic orthodontic brackets after prophylaxis with a sodium bicarbonate jet. Literature indicates that friction is a major factor in sliding mechanics during orthodontic treatment, affecting tooth movement efficiency. The interaction between brackets, archwires, and ligation methods influences friction levels. Research has shown that metal brackets generally produce lower friction than ceramic brackets due to their smoother surfaces. The results of this study was confirming that metal brackets exhibit reduced friction after sodium bicarbonate jet application, whereas aesthetic brackets show no significant change. Further investigations, particularly using scanning electron microscopy, are needed to evaluate micromorphological changes caused by prophylaxis.

Joseph J N, Ammayappan P, Sankar H, Yashwant V A, Alexander L (2021)¹⁷ conducted this study to evaluate the frictional resistance of different esthetic archwires in ceramic brackets, addressing a key concern in orthodontics—reducing friction for efficient tooth movement. Previous research highlights that ceramic brackets, though aesthetically pleasing, generate higher friction than metal brackets, potentially hindering treatment progress. To mitigate friction, modifications such as metal slots in ceramic brackets and coated archwires (Teflon, epoxy, rhodium) have been introduced. Studies indicate that Teflon-coated wires exhibit the lowest friction, while rhodium-coated wires have the highest due to surface roughness. Research also suggests that wet conditions (saliva or artificial saliva) significantly reduce friction compared to dry conditions. However, there is limited data on rhodium-coated wires, necessitating further investigation. The literature underscores the importance of selecting the optimal

bracket-wire combination to minimize friction and enhance treatment efficiency. This study builds upon existing knowledge by comparing different esthetic bracket-wire systems under dry and wet conditions, aiming to identify the best combination for clinical applications.

Dragomirescu A.O. et al (2022)¹³ conducted a study to determine the differences between the static frictional forces generated by stainless steel (metallic) Mini Sprint, Forestadent and polycrystalline alumina (ceramics) Discovery Pearl, Dentaurem conventional and self-ligating brackets (Damon Q, Damon ClearOrmco). The brackets were tested with ovoid archwires (AlphaWire, Orthofocus, Bucharest, Romania) with different sizes and materials, respectively, 0.016" NiTi and 0.019 x 0.025" SS. Static friction assessment was carried out in vitro with universal testing machine, HV-500N-S (Schmidt Control Instruments, Hans Schmidt & Co. GmbH), intended for measuring compression and traction forces. The study revealed significant differences in static frictional forces at the bracket-archwire interface between the tested brackets. Stainless steel brackets produced lower static friction forces than polycrystalline alumina and self-ligating brackets generally produced lower static frictional forces than conventional brackets. The reduction of frictional forces was noticeable in the first stages of treatment, when thin, flexible orthodontic archwires (0.0160 0 NiTi) are used. Engaged with large rectangular stainless steel archwires, (0.019 _ 0.0250 0 SS), the frictional forces produced by conventional and self-ligating metal brackets were similar, no significant differences being observed between the two types of metallic design. However, in the case of tested ceramic brackets, the results showed that the self-ligating type allows a reduction in frictional forces even in advanced stages of treatment compared to conventionally ligation.

Bazergan N, Nicolas E, Helou M E (2022)²⁰ conducted this study to evaluate the sliding resistance of self-ligating ceramic brackets builds upon existing literature on orthodontic friction and bracket design. Previous studies indicate that friction in orthodontic treatment is influenced by bracket material, slot dimensions, and wire characteristics. Self-ligating brackets are generally considered to reduce friction and improve treatment efficiency compared to conventional brackets. However, ceramic brackets typically generate higher frictional forces than metal ones due to their rougher surface texture. Prior research has shown that self-ligating brackets reduce chair time

and provide better sliding mechanics, especially during canine retraction. However, studies comparing self-ligating ceramic brackets suggest that friction levels vary based on the bracket's micro-morphological characteristics. Metal-slot ceramic brackets have been reported to produce lower friction compared to full-ceramic brackets. Additionally, the slot's size and chamfering play a crucial role in reducing resistance. The results show that Clarity Ultra™ by 3M™ exhibits higher friction than its competitors due to its slot width, chamfering, and cover design. These observations reinforce the role of bracket morphology in orthodontic mechanics and highlight the need for further clinical investigations to optimize bracket design for reducing friction.

Hussein A M (2022)²⁷ conducted this study to evaluate the frictional resistance of different tooth-colored orthodontic brackets, emphasizing the impact of bracket material on frictional forces during sliding mechanics. Friction plays a significant role in orthodontic treatment efficiency, with early research identifying issues with plastic brackets, such as deformation and discoloration. Ceramic brackets, introduced later, demonstrated higher friction than metal brackets, particularly monocrystalline alumina brackets, due to their smooth but hard structure. This result shows that plastic brackets with metal slots exhibit the least frictional resistance compared to monocrystalline and polycrystalline ceramic brackets.

Bhanderi V, Digumarthi U K (2024)²⁹ investigates the frictional resistance between different orthodontic bracket systems and archwire combinations. This study aligns with existing findings by demonstrating that ceramic brackets with TMA wires exhibit the highest mean frictional resistance, while metal brackets with SS wires show the lowest. The results showed that selecting the appropriate bracket-wire combination can optimize orthodontic treatment efficiency.

Niyaj D, Vinit S, Shruti B, Harshal P, Sukumar L, Vasanthi S et al (2024)²⁸ conducted this study to evaluate the frictional behavior of Teflon-coated wires in different esthetic brackets, comparing traditional and self-ligating systems. The results showed that monocrystalline ceramic bracket exhibited the higher frictional resistance force than polycrystalline self-ligating ceramic without metal slot using Teflon coated stainless steel archwires with dimensions of 0.019" x 0.025" SS.

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with Central Institute of Plastic Engineering and Technology (CIPET), Lucknow with an aim to evaluate and compare the frictional forces generated between various ceramic brackets and rectangular stainless steel arch wire using Instron machine. The groups for the study included two different types of conventional ceramic brackets – Group – I included Unitek Gemini Clear ceramic conventional bracket (3M), Group II included Symetri Clear (Ormco) conventional ceramic bracket and two different types of commercially available ceramic self-ligating brackets- Group III included Clarity (3M) passive ceramic self-ligating bracket, Group – IV included Clear (Damon)) passive ceramic self-ligating bracket. Five brackets from each group were bonded on set of five premolar teeth mounted on a block of stone.

Frictional force was tested using 10 sets of 0.019 x 0.025 in stainless steel wires for each group of ceramic brackets.

Collection of sample (Teeth)

The sample consisted of 20 human premolar teeth taken from patients in whom first premolar extraction was planned as a part of fixed orthodontic treatment. Extracted teeth were obtained from the Department of Oral and Maxillofacial surgery, Babu Banarasi Das College of Dental Sciences, Lucknow. The extracted teeth were cleaned for any blood and debris, then collected in the glass bottle filled with normal saline until they were subjected to evaluate and compare the frictional forces testing.

Criteria for sample selection:

Inclusion criteria:

1. Freshly extracted premolars which were extracted as a part of fixed orthodontic treatment.
2. The extracted premolars with intact buccal surface, non hypoplastic surface would be taken.
3. Premolars of subjects who were willing to participate in this study.

Extrusion criteria:

1. Developmentally malformed teeth
2. Tooth with dental anomalies like attrition, abrasion, abfraction.
3. Premolars in which any restorative or cosmetic dental treatment had been done.
4. No history of trauma or any structural alteration caused by mechanical procedure during extraction.

A total of 20 premolar teeth were selected based on above mentioned Inclusion and Exclusion criteria.

Ethical Committee Approval

The approval was taken from the Ethical Committee of BBDCODS, BBDU, Lucknow prior to the start of the present study. Written informed consent was obtained from the selected subjects participating in this study before beginning of the study and was explained about the study

Distribution of sample

The set of five premolar were randomly divided into four groups : Group I, Group II, Group III and Group IV, to make four models. (Table 1)

TABLE 1 : Distribution of sample

Groups	Type of bracket	Types of wire (N =40)
Group I	Conventional ceramic bracket(Unitek Gemini Clear 3M)	10 sets of 0.019" x 0.025" stainless steel wire (straight length)
Group II	Conventional ceramic bracket (Symetri Clear Ormco)	10 sets of 0.019" x 0.025" stainless steel wire (straight length)
Group III	Self-ligating ceramic bracket(3M Clarity)	10 sets of 0.019" x 0.025" stainless steel wire (straight length)
Group IV	Self-ligating ceramic bracket(Damon Clear)	10 sets of 0.019" x 0.025" stainless steel wire (straight length)

Material used in study**I. Extracted Premolar Teeth (Figure 1)**

Figure 1 : Extracted premolar teeth

II. Materials used for making mould for mounting of teeth (Figure 2)

- a. Dental stone – Dental stone (Neelkanth's stone plaster).
- b. Thermoforming Sheets - Avac S clear thermoforming sheets of 2 mm thickness
- c. Vacuum Forming machine (Easy – Vac)
- d. Bowl and Spatula
- e. A small rectangular shape box

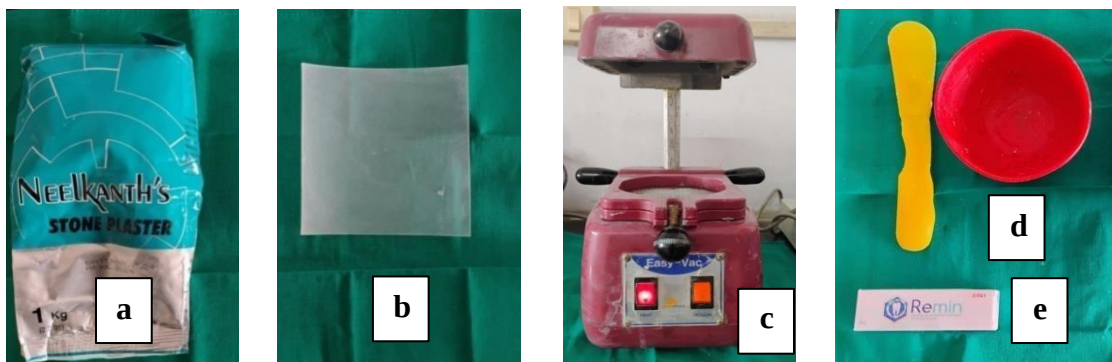


Figure 2: Material used for making mould for mounting of teeth
a.Dental stone b.Thermoforming sheet c.Vacuumpress machine d. Bowl and spatula e. A small rectangular shape box

III. Materials used for bonding (Figure 3-4)

A. Brackets (Figure 3)

- i. Two different types of conventional ceramic bracket were used in this study:
 - a. Conventional ceramic brackets (Unitek Gemini Clear 3M) with 0.022 slot
 - b. Conventional ceramic brackets (Symetri Clear Ormco) with 0.022 slot
- ii. Two different types of Ceramic self-ligating brackets:
 - c. Passive ceramic self-ligating brackets (3M Clarity) with 0.022 slot.
 - d. Passive ceramic self-ligating brackets (Damon Clear)with 0.022 slot.

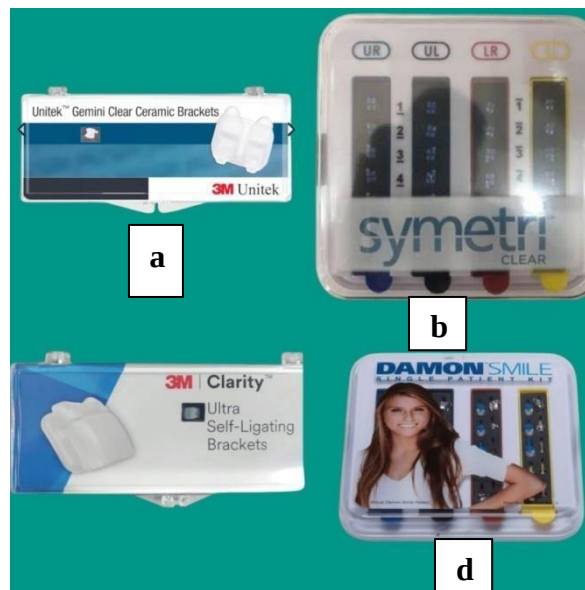


Figure 3 : Different brackets used in study:
 (a) Conventional ceramic bracket (Unitek Gemini Clear 3M)
 (b) Conventional ceramic brackets (Symetri Clear Ormco)
 (c) Passive ceramic self ligating brackets (3M Clarity)
 (d) Passive ceramic self ligating brackets (Damon Clear)

Other materials used in fixed orthodontic treatment are as follows (Figure 4)

- B. Gloves
- C. 0.019 x 0.025 in SS wire for aligning brackets before bonding
- D. Etchant – DPI etchant gel (37 % phosphoric acid)
- E. E. Adhesive – Light curable orthodontic material adhesive (Enlight,ormco)
supplied
- F. Primer – Ormco primer(Enlight).
- G. Disposable micro applicator.
- H. Bracket positioning tweezer

- I. Three way syringe
- J. Light cure unit –Woodpecker LED curing light unit with light intensity of 1000 mw/cm² -1700mw /cm² and wavelength of 420 nm – 480 nm.

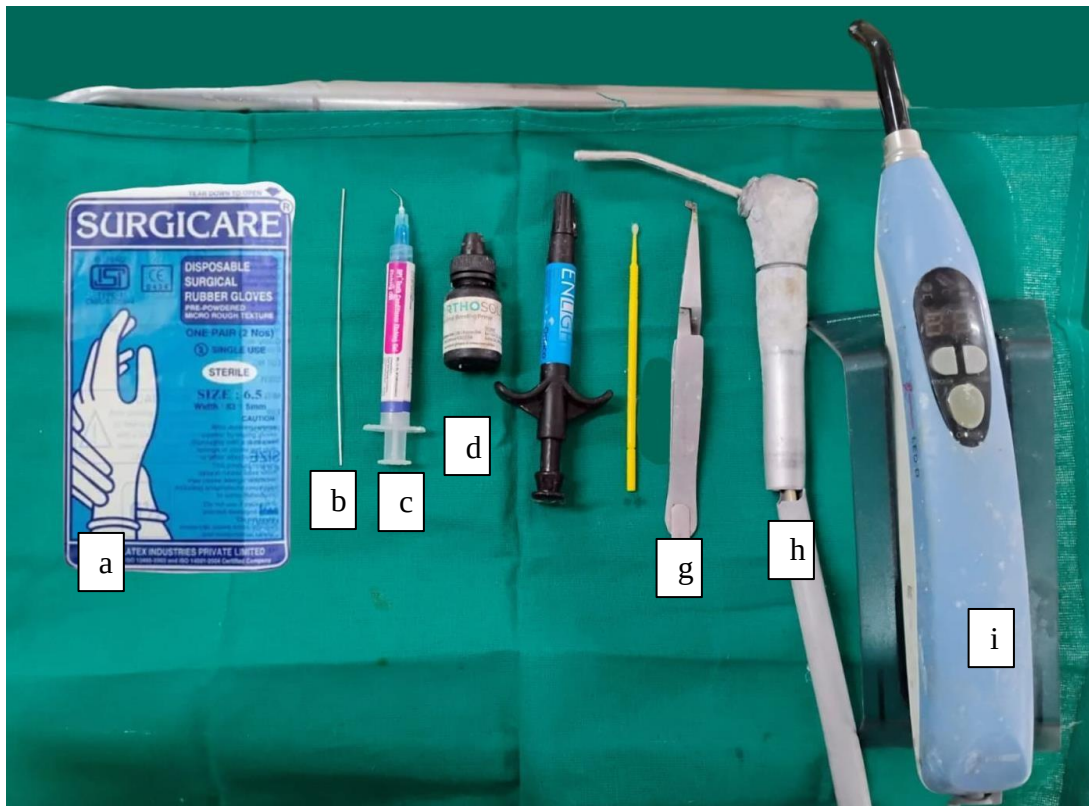


Figure 4 : Armamentarium used for bonding the teeth
a. Gloves b..0.019 X 0.025 I ss wire c. Etchant d. Primer
e. Adhesive f. Disposable micro applicator. g. Bracket positioning tweezer
h. Three way syringe i. Light cure unit

- IV. Wires **Used** for measuring frictional force with different bracket (Figure 5)
0.019" x 0.025" SS straight length (Libral Traders)



Figure 5 : Wires Used for measuring frictional force

V. Material used for measuring frictional force (Figure 6)

Universal Instron Testing Machine :

The machine had a specification of:

- working range 1-100 KN at temp 25 0 c
- the cross head speed 0.5 mm / min
- accuracy was 1N.



Figure 6 : Universal Instron Testing Machine.

Methodology:**I. For making mould for mounting of teeth**

- a. A 10 mm width and 10 cm length and 15 mm height rectangular shaped box was taken. Dental stone was poured in this the box to make a block of dimension 10 mm x 10 cm x15 mm.(Figure 7a)
- b. Dental stone was allowed to set for 20 min before removing.
- c. For fitting the stone mould in Instron machine, shape was altered using model trimmer. (figure 7b)

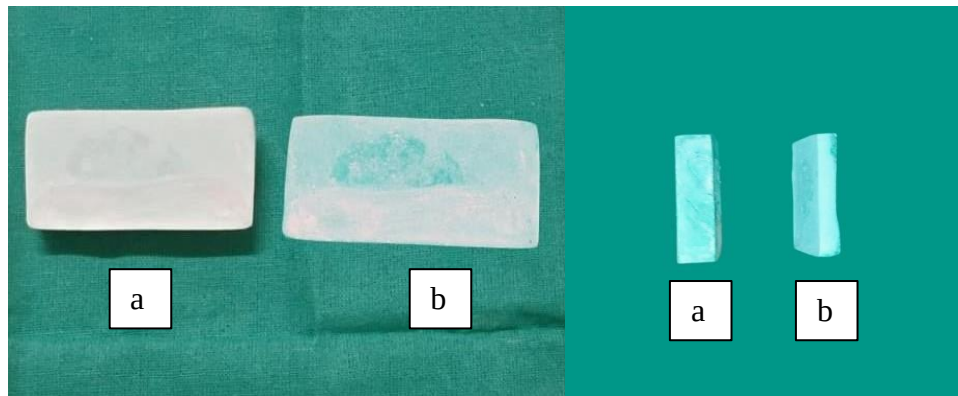


**Figure 7 : a.10 mm x 10 cm x15 mm dimension dental stone block
b. Altered dental stone block**

- d. Mould for this attend stone block was made using thermoforming sheet of 2 mm thickness and vacuum forming machine .
- e. Stone block was kept on the lower compartment of the vacuum forming machine and sheet was placed on the upper compartment. Heat this sheet until it was soft, then draping it over the mold and using a vacuum to pull it into place. Mould of thermoform sheet was obtained.(Figure 8 a –b)



**Figure 8 : a. Placement of stone block in thermo forming machine
b.Mould of thermo forming sheet**

II. For mounting of teeth (Figure 9)

- 0.019" x 0.025" SS arch wire to which brackets were attached was used for aligning teeth during mounting in mould made of thermoforming sheets.(figure – 9a)
- Dental stone was mixed with water and poured in mould. Five extracted premolar teeth were mounted in this mould when stone was partially set .0.019 " x 0.025 " SS wire along with bracket were attached was used for aligning teeth during preparation of block. It allowed to set for 20 minutes.(figure 9 b - d)

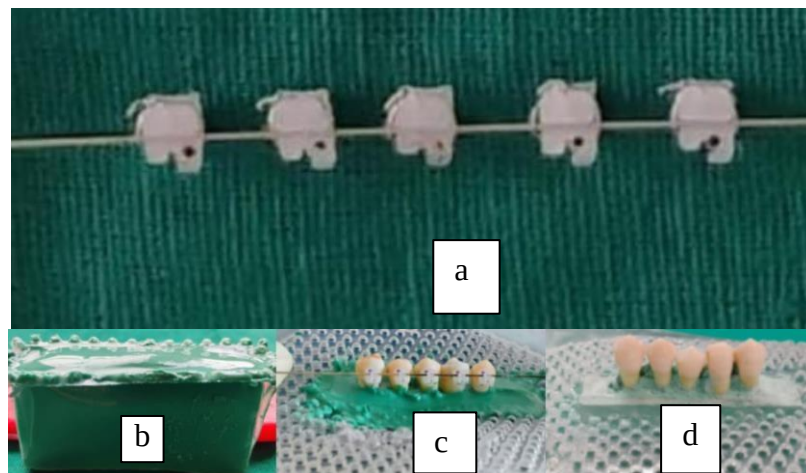


**Figure 9 a: 0.019" x 0.025" SS arch wire used for alignment b. Dental stone poured in mould
c. Alignment of teeth using 0.019 " x 0.025 SS wire with bracket attached
d. Model with premolar teeth**

- c. Similar procedure was used for mounting of teeth for all the groups. (figure 10)

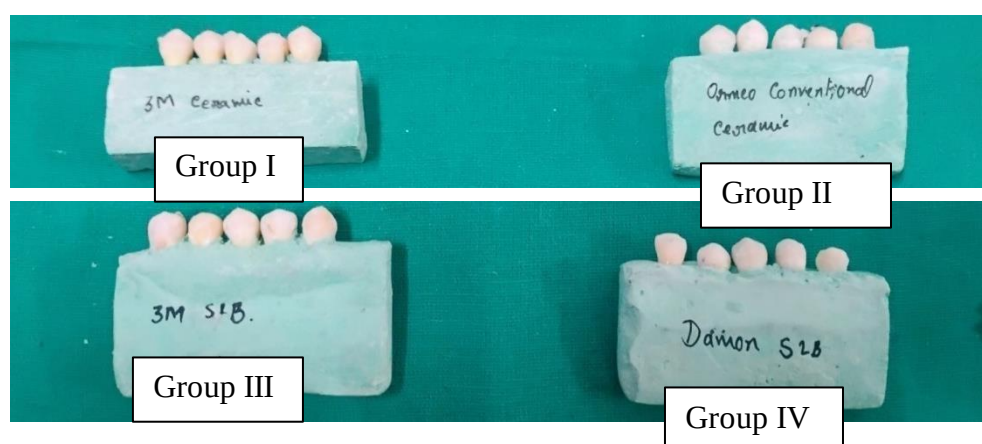


Figure 10 : Model for different groups of present study

III. For bonding of brackets (Figure 11)

- a. On mould for Group I, 37 % orthophosphoric acid was applied to the center of the clinical crown on the buccal surface of each tooth for 15 sec
- b. The teeth were then thoroughly washed with distilled water for 20 sec.
- c. The conditioned enamel surface was then dried for 5 sec with the compressed air until the buccal surface of the etched teeth had frosty appearance
- d. The primer was applied to the etched surfaces of the teeth and then light cured for 20 seconds.
- e. Primer was applied to the bracket base of all brackets tied to 0.019 “ x 0.025 “ SS wire. Adhesive was placed on single bracket base and placed on demarcated etched enamel surface.
- f. The bracket was seated on the tooth surface with gentle pressure to squeeze out resin which was removed with an explorer.
- g. The bracket adhesive interface was cured for 20 sec with light curing unit from mesial and distal side of bracket.
- h. As bracket were tied loosely to 0.019 “ x 0.025 : SS aligning wire, they were moved to apply adhesive and placed them in correct position on next tooth in the mold and cured them for above mentioned time duration.
- i. All brackets were bonded using same protocol.



Figure 11 : Bonding procedure of different brackets

IV. For ligating test wire before testing of Frictional Resistance:

- i. For conventional ceramic bracket (Figure 12)
 - a. Stainless Steel ligature wire was wound around mirror handle and turned five turns to make preformed stainless steel ligature ties. This was done to ensure uniformity while tying wire.
 - b. A 10 cm straight rectangular wire (longer then the mould) which had to be tested was placed into the bracket slot and tied with preformed SS ligature ties.

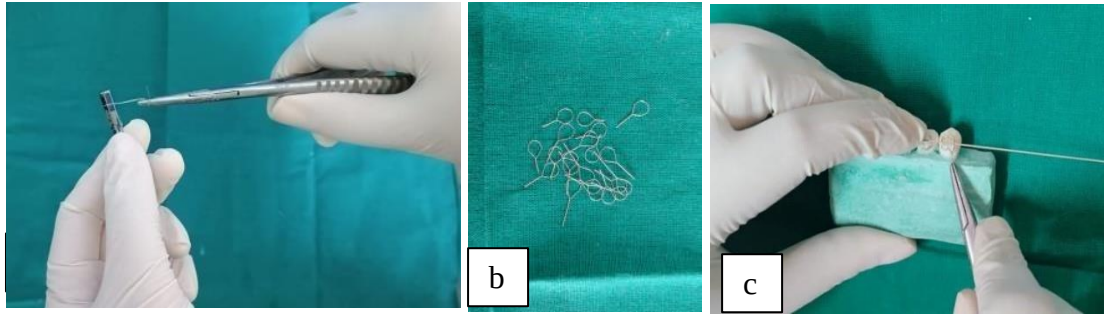


**Figure 12 : a. Making preformed SS ligature ties
b. Preformed SS ligature ties
c. Ligating 0.019" x 0.025" SS using preformed ligature ties**

- ii. For ceramic self-ligating bracket (figure 13)
 - a. Open the slide with the help of explorer
 - b. Wire was placed in between the bracket slot and close the slide with same instrument to secure the wire.

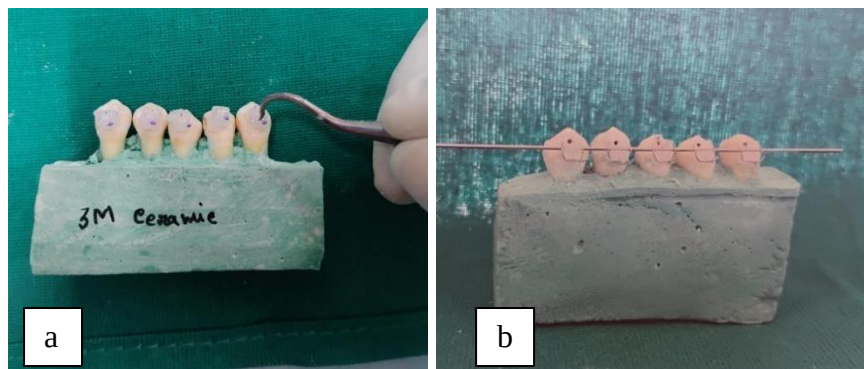


**Figure 13 : a. Opening of slide
b. Placement of 0.019" x 0.025" SS wire and closure of slide**

V. For assessment of frictional resistance (figure 14)

- a. Mould with test wires placed was oriented vertically in lower compartment of Instron machine.
- b. Long end of 0.019" x 0.025" SS wire was secured in upper compartment of the machine that moved at cross head speed of 0.05 mm/ min till wire was pulled out of all the five brackets.
- c. Graph was obtained on computer attached to Instron machine and frictional force as shown on graph were noted.

- d. Same procedure was followed for 10 sets of 0.019" x 0.025" SS wire for each model and readings were tabulated.

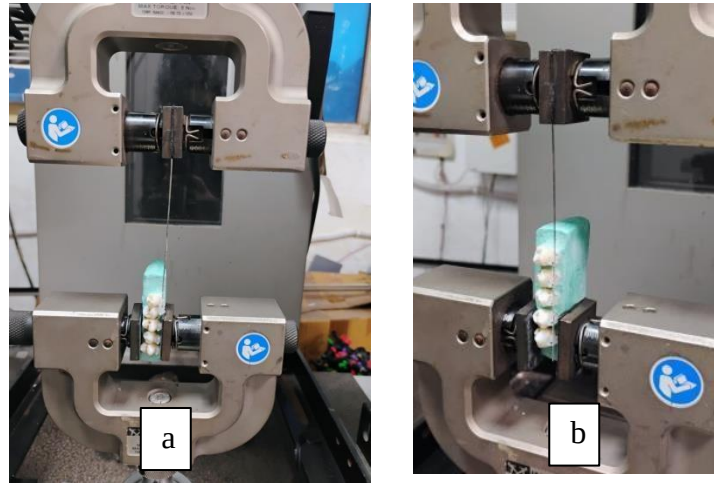


**Figure 14 : a. Placement of model in lower compartment of Instron machine
b. Attachment of 0.019" x 0.025" SS in upper compartment of Instron machine.**

Table 2: Measurement of Reliability

	N	1st set of reading (N)	2nd set of reading(N)	Sig.
Group I	10	22.43N	22.26 N	p> 0.05
Group II	10	16.43N	16.23 N	p> 0.05
Group III	10	8.42N	8.12 N	p>0.05
Group IV	10	5.66N	5.46 N	p>0.05

On repeating testing of Frictional Resistance for each group using 0.019" x 0.025" SS wire, the mean difference between first and second set of records was as statistically non-significant , suggestive of reliability of sample of present study .(p>0.05)

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College Of Dental Sciences, Lucknow in collaboration with Central Institute of Plastic Engineering and Technology (CIPET), Lucknow with an aim to evaluate and compare the frictional forces generated conventional(Unitek Gemini Clear 3M, Symetri Clear Ormco) and self-ligating (3M Clarity, Damon Clear) ceramic brackets with rectangular stainless steel arch wire (0.019” x 0.025” SS) using Instron machine.

A total of 40 extracted premolars were equally divided into four groups. Group – I included Unitek Gemini Clear ceramic conventional bracket (3M), Group II included Symetri Clear (Ormco) conventional ceramic bracket, Group III included Clarity (3M) passive ceramic self-ligating bracket and Group IV included Clear (Damon) passive ceramic self-ligating bracket. Five brackets from each group were bonded on set of five premolar teeth mounted on a block of stone that was used for testing frictional resistance.

Friction was calculated for all the groups and results are tabulated as follows :-

Table 3: Mean frictional resistance of different groups

Table 4: Variability of Frictional Resistance in each groups

Table 5: Comparison of frictional resistance between groups

Table 3 : Mean friction resistance of different groups

	N	Min (N)	Max(N)	Mean(N) ± Std.Dev(in N)
Group I (Conventional ceramic bracket Unitek Gemini Clear 3M)	10	20.45N	28.93N	22.86 ± 2.44N
Group II(Conventional ceramic bracket Symetri Clear Ormco)	10	13.78N	20.82N	16.43 ±1.98N
Group III (Self-ligating ceramic bracket 3M Clarity)	10	4.61N	10.45N	8.42±2.18N
Group IV (Self-ligating ceramic bracket Damon Clear)	10	2.58N	8.61N	5.66±1.88N

Table 3 showed the mean value of frictional resistance for all groups. The frictional resistance for Group I was in range of 20.45N to 28.93 N with a mean value of 22.86 N ± 2.44 N, for Group II it was in range of 13.78 N to 20.82 N with a mean value of

16.43 $\pm$ 1.98 N, for Group III it was in range of 4.61 N to 10.45 N with a mean value of 8.42 $\pm$ 2.18 N and for Group IV in range of 2.58 N to 8.61 N with a mean value of 5.66 $\pm$ 1.88 N. (Gr I > Gr II > Gr III > Gr IV)

Table 4: Variability of Frictional Resistance in each groups

	N	Mean $\pm$ Std. Dev	Chi Sq	P Value
Group I	10	22.86 $\pm$ 2.44	.00	1.00
Group II	10	16.43 $\pm$ 1.98	.00	1.00
Group III	10	8.42 $\pm$ 2.18	1.20	0.991
Group IV	10	5.66 $\pm$ 1.88	.00	1.00

Table 4 showed variability of frictional resistance in each groups using Chi Square test. The sample distribution was homogenous in each group with statistically non significantly difference.

Table 5: Comparison of frictional resistance between groups

Group	Mean Difference (N)	Std. Error	95% Confidence Interval		Sig.
			Lower Bound	Upper Bound	
Group I V/s II	6.437*	.953	3.869	9.004	<0.0001***
Group I V/s III	14.446*	.953	11.878	17.013	<0.0001***
Group I V/s IV	17.207*	.953	14.878	19.774	<0.0001***
Group II V/s III	8.009*	.953	5.441	10.576	<0.0001***
Group II V/s IV	10.770*	.953	8.202	13.337	<0.0001***
Group III V/s IV	2.761*	.953	0.193	5.328	0.031**

P> 0.05 – Not significant (NS), P <0.05 – Just significant(**), P< 0.01 – moderate significant (*), P<0.001 – highly significant (***)

On comparison of mean values of frictional resistance of conventional ceramic brackets (Group I Vs II), Grp I had higher frictional resistance than Grp II with a mean difference of 6.437 N and difference was statistically highly significant.(P value <0.0001***)

On comparison of mean values of frictional resistance of conventional ceramic brackets (Group I) with self-ligating ceramic bracket (Group III), Grp I had higher frictional

resistance than Grp III with a mean difference of 14.446 N and difference was statistically highly significant. (P value <0.0001***)

On comparison of mean values of frictional resistance of conventional ceramic brackets (Group I) with self-ligating ceramic bracket (Group IV), Grp I had higher frictional resistance than Grp IV with a mean difference of 17.207 N and difference was statistically highly significant. (P value <0.0001***)

On comparison of mean values of frictional resistance of conventional ceramic brackets (Group II) with self-ligating ceramic bracket (Group III), Grp II had higher frictional resistance than Grp III with a mean difference of 8.009 N and difference was statistically highly significant. (P value <0.0001***)

On comparison of mean values of frictional resistance of conventional ceramic brackets (Group II) with self-ligating ceramic bracket (Group IV), Grp II had higher frictional resistance than Grp IV with a mean difference of 10.770 N and thus difference was statistically highly significant. (P value <0.0001***)

On comparison of mean values of frictional resistance of two self-ligating ceramic bracket (Group III Vs Group IV), Grp III had higher frictional resistance than Grp IV with a mean difference of 2.761 N and difference was statistically just significant. (P value 0.031**)

In orthodontics, friction arises because of the interplay between an arch wire and the slot of an orthodontic bracket or a ligature wire¹. Kusy and Whitley divided resistance to sliding during orthodontic tooth movement (RS) into three components - Friction, Static or Kinetic, due to contact of the wire with bracket surfaces; the force that is to be overcome to initiate movement which is known as static friction and the force encountered during motion is known as kinetic friction, binding (BI) due to tipping of tooth, created when the tooth tips or the wire flexes, so that there is contact between the wire and the corners of the bracket, and binding occurs; and notching (NO), when permanent deformation of the wire occurs at the wire-bracket corner interface.³

Friction between the arch wire and bracket is influenced by a number of factors, including the wire's size, composition, and ligation method, archwire material, cross section, shape/size, bracket to archwire ligation ;bracket properties: material, surface treatment, bracket design, slot width and depth etc ; biological factors includes saliva, plaque, acquired pellicle, corrosion and food particles etc ⁵.

Friction is an important factors to be considered when doing space closure using frictional mechanics or sliding mechanics as higher dimension wire are to be used for good 3-dimensional control of teeth, that will generate more friction than light wires.^{2,7} The attempts had been made to reduce friction during sliding mechanics by modification of ligation method or bracket design.^{8,9} As interference due to ligation methods was omitted in self-ligating brackets, hence it was anticipated that friction would be reduced in self-ligating brackets,that are available as Active and Passive. Passive self-ligating bracket have slides that closes passively an arch wire without encroaching the slot lumen, hence generate lesser friction than Active self-ligating bracket whose clip preeses actively on slot lumen.²

Various studies have evaluated friction of self-ligating brackets.^{2,7} Few studies showed that friction reduced only in the early phases, when there was greater flexibility between the wire and the bracket slot. Other studies demonstrated reduced frictional resistance of metal self-ligating bracket in comparison to conventional metal brackets.²

Another factor that would influence friction is type of material of brackets selected for patient. For adult orthodontic treatment where esthetics is a major concern ceramic brackets are more frequently used.⁶

However, various studies had shown that conventional ceramic brackets have higher friction than conventional metal brackets. **Angolkar et al**¹⁸ found that SS bracket had significantly lesser frictional resistance of 175.4 ± 38.3 gm than ceramic bracket that had frictional resistance of $(250.3 \pm 50.6 \text{ gm})$ for 0.018" slot also for 0.022" slot, SS bracket had significantly less frictional resistance $(193.3 \pm 28.9 \text{ gm})$ than ceramic brackets $(265.2 \pm 40.9 \text{ gm})$. Also, ceramic brackets were not completely aesthetic as tooth coloured arch wire had to be tied using stainless steel ligature wire or elastomeric ties. Tooth colour ligature ties solved this problem to certain extent however durability of aesthetic coating during tightening was an issue.⁶ To overcome this ceramic self-ligating brackets were good alternative for use in aesthetically conscious subjects. Hence, passive ceramic self-ligating bracket were selected in present study.⁸

A study by **Cacciafesta et al**¹¹ stated that type of ligation influenced frictional resistance as they found Damon SL metal self-ligating bracket had significantly lesser frictional resistance of 46.53 gm than other two type of bracket. Oyster (ceramic self-ligating bracket) and Victory (conventional metal bracket) that had values of 115.99 gm and 116.63 gm respectively.

Most of these studies evaluated Frictional Resistance of brackets using Instron Universal testing machine by bonding the brackets to stainless steel bar, jig, acrylic plastic sheet acrylic block, however this methodology could not replicate the clinical scenario completely.^{4,7}

Few studies evaluated friction by bonding attachment to typhodont or teeth, which would replicate the clinical scenario more accurately.¹⁷

However ceramic self-ligating bracket had never been evaluated using this methodology hence it was decided to bond set of bracket to teeth for evaluating frictional resistance in present study. Frictional resistance varied with different commercially available metal or ceramic self-ligating brackets, as demonstrated in various studies.^{1,2,6} Friction of two commercially available passive self-ligating brackets (Damon Clear and 3M Clarity) and two types of commercially available conventional ceramic bracket (Unitek Gemini Clear 3M, Symetri Clear Ormco) were assessed in present study.

Thus the aim of present study was to evaluate and compare the frictional forces generated between conventional (Unitek Gemini Clear 3M, Symetri Clear Ormco) and passive self-ligating (3M Clarity, Damon Clear) ceramic brackets with rectangular stainless steel arch wire (0.019" x 0.025" SS) using Instron machine.

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with Central Institute of Plastic Engineering and Technology (CIPET), Lucknow. Different type of ceramic bracket used in study were grouped as - Group-1 included Unitek Gemini Clear ceramic conventional bracket (3M), Group II included Symetri Clear (Ormco) conventional ceramic bracket, Group III included Clarity (3M) passive ceramic self-ligating bracket, Group IV included Clear (Damon)) passive ceramic self-ligating bracket. Five brackets from each group were bonded on set of five premolar teeth mounted in dental stone poured in a mould and aligned using 0.019" x 0.025" SS with bracket attached. This mould was made after altering a block of stone so as to fit in lower compartment of Instron machine, using thermoforming sheet and vacuum forming machine. Four blocks of stone with mounted premolar was then used for bonding bracket of respective groups. Brackets were tied loosely on 0.019" x 0.025" SS wire and bonded individually on mounted premolars by following standard bonding protocol.

For conventional ceramic bracket. Stainless Steel ligature wire was wound around mirror handle and turned five ligature turn to make preformed stainless steel ligature ties that was used to ligate 0.019" x 0.025" SS wire to the brackets Group 1 and Group II For both types of ceramic passive self-ligating bracket, slide was opened with the help of explorer, 0.019" x 0.025" SS wire was placed and slide was closed using with same instrument to secure the wire. 0.019" x 0.025" SS wire was always kept longer than length of the mould for each group. Each block with test wires was oriented vertically in lower compartment of Instron machine. Long end of 0.019" x 0.025" SS wire was secured in upper compartment of the machine that moved at a cross head speed of 0.05 mm/min till wire was pulled out of all the five brackets. Graph was obtained on computer attached to Instron machine and Frictional Force as shown was noted Same procedure was followed for 10 sets of 0.019" x 0.025" SS wire for each model and readings were tabulated.

The results of present study showed that mean frictional resistance of all groups showed statistically significant difference with frictional resistance. Frictional resistance was highest in Group I (22.86 ± 2.44 N) > Group II (16.43 ± 1.98 N) > Group III (8.42 ± 2.18 N) > Group IV (5.66 ± 1.88 N) This result suggested that type of ligation significantly influenced the frictional resistance of brackets as conventional ceramic brackets had significantly higher frictional resistance than ceramic passive self-ligating brackets. Among conventional ceramic bracket Unitek Gemini Clear 3M had significantly higher frictional resistance than Symetri Clear Ormco. Among passive self-ligating ceramic bracket-3M Clarity had significantly higher frictional resistance than Damon Clear.

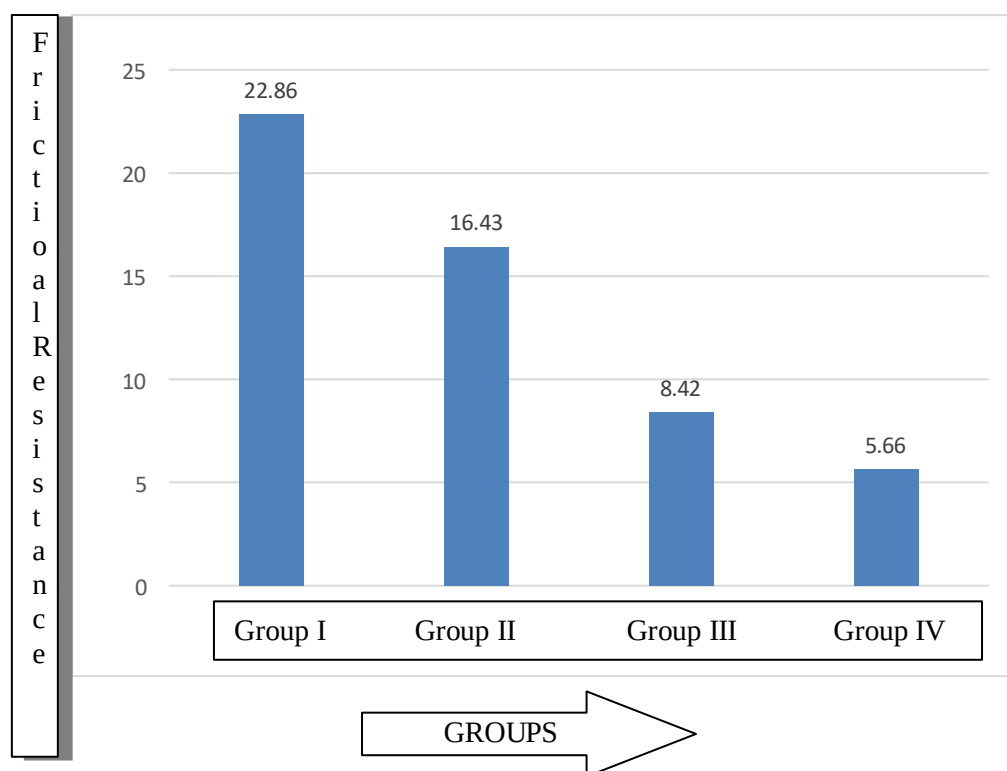


Figure 15: Bar diagram for Frictional Resistance of different group

The role of friction during orthodontic tooth movement cannot be overlooked. This friction has to be considered during space closure by sliding mechanics.

As frictional resistance of ceramic self-ligating bracket had not been extensively evaluated in previous studies, results would be compared to previous studies that evaluated frictional resistance of different types of ceramic self-ligating bracket^{19,20,21} or compared frictional resistance of different types of ceramic self-ligating bracket to

conventional ceramic bracket^{4,22,23} or compared frictional resistance of different types of conventional ceramic bracket.^{24,25,26,27,28,29}

The variation in frictional resistance as observed for different types of ceramic self-ligating brackets in present study was also seen in a study by **Kannan et al**¹⁹, however trend was contrary to present study as they found higher frictional resistance of 3.10 ± 0.23 gm for Damon Clear in comparison to Clarity ceramic self-ligating bracket that had frictional resistance of 1.76 ± 0.021 gm with 0.019" x 0.025" SS wire. The reason for contradictory results was presence of metal slot in Clarity self-ligating bracket used in their study to fully ceramic self-ligating bracket of present study or due to different in methodology as brackets were placed on flat metallic bar in their study and bracket were attached to premolar teeth with curved surface in present study. Similarly, **Bazergan et al**²⁰ also found significant difference in average sliding resistance (ASR) of 3 ceramic self-ligating bracket with 0.021" x 0.025" SS wire attached to plexiglass with cyano acrylate industrial fluid glue. They found that Empower 2 Clear (American Orthodontics) bracket had least ASR of 5.49 gm followed by Damon Clear (6.72 gm) and highest was in Clarity ceramic bracket (33.22 gm). Though Empower 2 Clear and Damon Clear did not differ significantly for ASR, however difference between Damon Clear and Clarity was statistically significant in their study as well as in present study.

The results of present study were compared to study by **Madhaswar et al**²¹ where they found statistically significant difference in frictional resistance of three passive ceramic self-ligating bracket (Cabriolet, Truklear, Damon Clear). They found Damon Clear bracket had lowest frictional resistance (0.076gm) followed by Cabriolet bracket (0.084gm) than Truklear bracket ($0.146 \pm$ gm).

The variation in frictional resistance as observed for different ceramic self-ligating bracket in present study was also seen in a study by **Krishnan et al**² for different passive metal self-ligating bracket with 0.019" x 0.025" SS in a simulated half arch fixed appliance on a Instron testing machine. They found that Damon metal self-ligating bracket had significantly lesser frictional resistance of 13.42 ± 0.86 N than Smart Clip (3M) metal self-ligating bracket that had frictional resistance of 20.13 ± 2.53 N.

Williams et al⁴ found that static functional resistance for 0.018 x 0.025 SS wire at 0 degree angulation was higher for conventional ceramic brackets (4.68 ± 0.6 N) than self-ligating ceramic brackets (Mystique) (2.92 ± 0.5 N) but difference was not statistically significant. On comparing result to our study we had a similar trend of higher frictional resistance in both types of conventional ceramic than both types of ceramic self-ligating bracket with statistically significant difference for 0.019"x0.025" SS wire.

Wu et al²² showed that conventional ceramic bracket (Clarity Advanced) exhibited the higher frictional force (2.06 ± 0.43 N) than passive self-ligating ceramic bracket (Damon Clear 2) (0.64 ± 0.44 N) using 0.016" x 0.02" NiTi however the difference was not statistically significant at 0 degree. The reason might be due to lesser critical contact angle of wire of lesser dimension (0.016" x 0.022" NiTi) in 0.022 slot. However, in present study higher dimension wire 0.019" x 0.025" SS wire in 0.022 slot had higher critical contact angle, hence variation in frictional resistance.

Niyaj et al³⁰ showed that monocrystalline ceramic bracket (Radiance) exhibited the higher frictional resistance force (259.23 ± 74.77 gm) than polycrystalline self-ligating ceramic with out metal slot (Trueclear) (46.66 ± 14.47 gm) using Teflon coated stainless steel archwires with dimensions of 0.019" x 0.025" (Ortho-Direct).

Hirunyapanum et al²³ showed that static frictional force of AO self-ligating ceramic (Empower Clear) bracket (0.4012 ± 0.015 N) was significantly lesser than AO conventional ceramic (20/40 Ceramic) brackets (1.6799 ± 0.036 N).

Contrary to findings of present study where frictional resistance of two types of conventional ceramic bracket differed significantly **Pratten et al²⁴** did not find statistically significant difference between two conventional ceramic bracket Ceramic A (Allure, GAC International) and Ceramic B (Transcend) that had frictional resistance of 115 gm and 100gm respectively. The variation could be due to difference in methodology as they attached brackets on an acrylic plate.

In a study by **Galvao et al²⁵** no significant differences were assessed among the three types of monocrystalline ceramic brackets (Inspire Ice, Radiance and Pure brackets) when used in combination with low friction ligation and 0.012" NiTi wire. However, in presence of conventional ligation and 0.012" NiTi frictional resistance was significantly highest in Inspire Ice followed by Pure and least in Radiance bracket Also

in 0.014" NiTi wire, the Radiance brackets showed significantly greater frictional forces when compared with the other esthetic brackets. This is similar to our study where commercially available conventional ceramic bracket differed significantly in frictional resistance.

Viana et al²⁶ did not find any significant difference in frictional resistance among two types of aesthetic brackets polycrystalline (Aditek) (2.72 ± 0.64 N) and monocrystalline (2.25 ± 0.57 N), irrespective of being subjected to prophylaxis with sodium bicarbonate jet.

On comparing 2 different types of conventional ceramic brackets **Hassanen et al²⁷** found that significantly higher values of static frictional force for monocrystalline alumina bracket (Perfect Clear II) as 692.3 ± 25.4 g in comparison to Polycrystalline alumina bracket (Unitek Gemini Clear) that had frictional resistance of as 413.7 ± 27.1 g.

The variation in frictional resistance as observed for different ceramic conventional bracket in present study was also seen in a study by **Guerrero et al²⁸** they found that ceramic monocrystalline (A- Inspire Ice /0.022" slot) had higher frictional resistance (4.53 N) followed by ceramic polycrystalline (B-InVu/0.022" slot) bracket (3.74 N) and least was in polycrystalline metal slot brackets (C- Clarity /0.022" slot)(3.41N). However, they did not find statistically significant difference between two conventional ceramic bracket (Clarity and InVu bracket) and whereas statistically significant difference was seen between Clarity and Inspire bracket.

Bhanderi et al²⁹ also found that the frictional resistance generated by two different types of ceramic polycrystalline bracket (Clarity advanced 3M and Pure company) with 0.019×0.025 " SS archwires had statistically significant difference between them. Clarity Advanced bracket had higher frictional resistance (3.443 ± 0.4015 N) than Pure bracket (3.408 ± 0.4826 N)

The effect of type of ligation on frictional resistance was seen in a study by **Kaur et al³⁰** when they found ceramic bracket with normal ligation had higher frictional resistance than ceramic bracket with low frictional ligation ties. This could be corroborated with findings of present study where method of self-ligation decreased frictional resistance in comparison to conventional ceramic bracket that wire tied with SS ligature wire.

The limitation of present study included testing of frictional resistance outside oral cavity, in a dry environment whereas presence of saliva, influences frictional resistance to considerable extent clinically. 2 Another factor factors are absence of consideration of roots in second or third order in which in- vitro studies would also influence frictional resistance in mechanics.

With in limitation of present study, it can be concluded that both type of bracket as well as type of ligation influenced frictional resistance with higher frictional resistance in conventional ceramic bracket than ceramic self-ligating bracket. Also, frictional resistance varied with different commercially available bracket as frictional resistance of both types of conventional ceramic bracket as well as ceramic passive self-ligating bracket differed significantly.

Orthodontic tooth movement starts once applied force overcome the frictional resistance during space closure by sliding or frictionless mechanics. Therefore, the development of materials with low coefficient of friction for sliding mechanics are extremely desirable because they can reduce the strain on anchorage.

The main clinical implication of this study would be selection of type of bracket in aesthetically conscious adults where during space closure after extraction of premolar there is greater anchorage requirement.

For aesthetically conscious individuals, ceramic brackets are a good alternative, but higher frictional resistance puts strain on anchorage. Self-ligating brackets generally produced significantly lower static frictional resistance than conventional brackets, hence in such adults where maximum anchorage requirement is there, selection of passive ceramic self-ligating bracket would be a better choice than conventional ceramic bracket.

Also, elimination of ligation ties with passive ceramic self-ligating bracket would help in better maintenance of oral health hence especially periodontally compromised subjects.

Future scope of the study would include validating results of present study on a large sample sized. Also, typhodont could be used for bonding bracket so wire is pulled similarly as it happens in clinical set up. Different types of other commercially available

ceramic or active ceramic self-ligating brackets or ceramic with metal slot could be compared for different arch wire and at different angulation both for 0.018 and 0.022" slot.

Following conclusion were drawn from the present study conducted with an aim to evaluate and compare the frictional forces generated conventional(Unitek Gemini Clear 3M, Symetri ClearOrmco) and self-ligating (3M Clarity, Damon Clear) ceramic brackets with rectangular stainless steel arch wire (0.019" x 0.025" SS) using Instron machine.

- Type of ligation and type of bracket significantly influence of frictional resistance, when used with 0.019" x 0.025" SS wire.
- frictional resistance was significantly higher in conventional ceramic bracket than passive self-ligating ceramic bracket (GrI > GrII > GrIII > GrIV).
- Among two types conventional ceramic brackets, Grp 1 (Conventional ceramic bracket Unitek Gemini Clear 3M) had higher frictional resistance than Grp II(Conventional ceramic bracket Symetri ClearOrmco).
- Among two types of self-ligating ceramic bracket Grp III(self-ligating ceramic bracket 3M Clarity) had higher frictional resistance than Grp IV (self-ligating ceramic bracket Damon Clear).

Method of ligation significantly influenced frictional resistance. The use of self-ligating ceramic bracket would be better alternative in esthetically conscious adults with greater anchorage requirement during space closure by sliding mechanics

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In orthodontics, friction arises because of the interplay between an arch wire and the slot of an orthodontic bracket or a ligation wire.

Friction between the arch wire and bracket is influenced by a number of factors, including the wire's size, composition, and ligation method, archwire material, crosssection, shape/size, bracket to archwire ligation; bracket properties: material, surface treatment, bracket design, slot width and depth etc; biological factors includes saliva, plaque, acquired pellicle, corrosion and food particles etc

Friction is an important factors to be considered when doing space closure using frictional mechanics or sliding mechanics.

The attempts had been made to reduce friction during sliding mechanics by modification of ligation method or bracket design.

As interference due to ligation methods was omitted in self-ligating brackets, hence it was anticipated that friction would be reduced in self ligating brackets, passive self ligating bracket that have slides that closes passively on arch wire without encroaching the slot lumen.

Another factor that would influence friction is type of material of brackets selected for patient. For adult orthodontic treatment where esthetics is a major concern ceramic brackets are more frequently used. However, various studies had shown that conventional ceramic brackets has higher friction than conventional metal brackets.

Also ceramic brackets were not completely aesthetic as tooth coloured arch wire had to be tied using stainless steel ligation wire or elastomeric ties. Tooth colour ligation ties solved this problem to certain extent however durability of esthetic coating during tightening was an issue. To overcome this ceramic self ligating brackets were good alternative for use in aesthetically conscious subjects. Hence, passive ceramic self ligating bracket were selected in present study.

Most of these studies evaluated Frictional Resistance of brackets using Instron Universal testing machine by bonding the brackets to stainless steel bar, jig, acrylic plastic sheet acrylic block, however this methodology could not replicate the clinical scenario completely. Few studies evaluated friction by bonding attachment to typhodont

or teeth, which would replicate the clinical scenario more accurately. However ceramic self ligating bracket had never been evaluated using this methodology hence it was decided to use this in present study . As frictional resistance varied with different commercially available brackets, thus it was decided to evaluate and compare the frictional forces generated between conventional ceramic (Unitek Gemini Clear 3M, Symetri Clear Ormco) and passive ceramic self ligating (3M Clarity, Damon Clear) brackets with rectangular stainless steel arch wire (0.019" x 0.025" SS) using Instron machine.

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow in collaboration with Central Institute of Plastic Engineering and Technology (CIPET), Lucknow. Different type of ceramic bracket used in study were grouped as - Group-1 included Unitek Gemini Clear ceramic conventional bracket (3M), Group II included Symetri Clear (Ormco) conventional ceramic bracket, Group III included Clarity (3M) passive ceramic self ligating bracket, Group IV included Clear (Damon)) passive ceramic self ligating bracket.

Four moulds were , each with five premolar teeth mounted in stone to which four different types of brackets were bonded as per groups. 0.019" x 0.025" SS wire was ligated using ligature ties for Group I and Group II , where as it was secured by passive clip in Group III and Group IV . Frictional resistance was tested by Instron machine by pulling long end of the wire from a mould placed vertically in lower compartment of the machine . 10 sets of wire were tested in each group and frictional resistance was noted from graph , as seen on computer attached to the machine. Data was tabulated and adequate statistical comparison were made using SPSS software.

Following conclusion were drawn from the results of present study-

- Type of ligation and type of bracket significantly influence of frictional resistance, when used with 0.019" x 0.025" SS wire.
- Frictional resistance was significantly higher in conventional ceramic bracket than passive self ligating bracket (GrI > GrII > GrIII > GrIV).

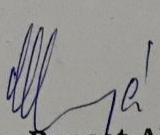
- Among two types of conventional ceramic brackets, Grp 1 (Conventional ceramic bracket Unitek Gemini Clear 3M) had higher frictional resistance than Grp II (Conventional ceramic bracket Symetri Clear Ormco).
- Among two types of self ligating ceramic bracket Grp III (self ligating ceramic bracket 3M Clarity) had higher frictional resistance than Grp IV (self ligating ceramic bracket Damon Clear).

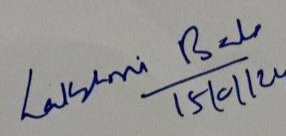
Method of ligation significantly influenced frictional resistance. The use of self ligating ceramic bracket would be better alternative in esthetically conscious adults with greater anchorage requirement during space closure by sliding mechanics.

ANNEXURE-I**BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES
(Faculty of BBD University, Lucknow)****INSTITUTIONAL RESEARCH COMMITTEE APPROVAL**

The project titled "**Comparative Evaluation Of Frictional Resistance In Ceramic Brackets & Archwire – An In Vitro Study.**" submitted by **Dr. ANUPAMA CHATTERJEE** Postgraduate student in the **Department of Orthodontics and Dentofacial Orthopaedics** for the Thesis Dissertation as part of MDS Curriculum for the academic year 2022-2025 with the accompanying proforma was reviewed by the Institutional Research Committee in its meeting held on **16th October, 2023** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.


(Prof. Dr. Puneet Ahuja)
Chairperson (IRC)
Principal
BBD College of Dental Sciences
BBD University, Lucknow


(Dr. Lakshmi Bala)
Co-Chairperson (IRC)
HOD Biochemistry
BBD College of Dental Sciences
BBD University, Lucknow.

ANNEXURE-II

BABU BANARASI DAS UNIVERSITY
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala

Professor and Head, Deptt of Biochemistry and
Member-Secretary, Institutional Ethics Committee (IEC) of BBD University, Lucknow

Communication of the Decision of the VIIIth Institutional Ethics Committee Meeting

IEC Code: 30

BBDU/MDS/30/2024

Date: 07/03/2024

Title of the Project: Comparative Evaluation Of Frictional Resistance In Ceramic Brackets & Archwire – An In Vitro Study

Principal Investigator: Dr. ANUPAMA CHATTERJEE **Department:** Department of Orthodontics and Dentofacial Orthopaedics

Name and Address of the Institution: BBD University, Lucknow
Type of Submission: New, MDS Dissertation proposal

Dear Dr. Anupama Chatterjee

The meeting of the Institutional Ethics Committee (IEC) was held on 06-02-2024 in Conference room, First Floor, BBDCODS, BBD University, Lucknow. Following members were present:

1	Dr. Chandishwar Nath Rtd. Chief Scientist, CDRI, Lucknow.	Chairman
2	Dr. JS Srivastava, Rtd. Chief Scientist, CDRI, Lucknow.	Member
3	Dr. Manodeep Sen, Professor, Department of Microbiology, RMLIMS, Lucknow	Member
4	Dr. Shaleen Chandra, Professor & Dean, Dental Sciences, Atal Bihari Vajpai Medical University (ABVM University), Lucknow	Member
5	Dr. Manuka Khanna, Professor, Deptt. of Political Science, Lucknow University, Lucknow	Member
6	Mr Abhishek Chaudhary, Advocate, Lucknow	Member
7	Dr. Puneet Ahuja, Professor of Oral Pathology and Principal, BBD College of Dental Sciences, BBD University, Lucknow	Member
8	Dr. Lakshmi Bala, Professor & Head, Department of Biochemistry, BBD College of Dental Sciences, BBD University, Lucknow	Member-Secretary

The committee reviewed and discussed your submitted documents of the research proposal in the meeting.

Decisions: The committee provided waiver to obtain consent for the above proposal.

Lakshmi Bala
07/03/24
(Dr. Lakshmi Bala)

Member-Secretary IEC
BBD University
Ethics Cell (Vth Floor, BBDCODS)
ethics@bbdu.ac.in

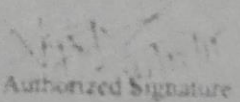
Dr. LAKSHMI BALA
Member-Secretary
Institutional Ethics Committee
BBD University, Lucknow-28

ANNEXURE-III

सेन्ट्रल इंस्टीट्यूट ऑफ प्लॉस्टिक्स इंजीनियरिंग एण्ड टेक्नोलॉजी (आइएन एन पेट्रोकेमिकल विभाग) प्लॉस्टिक एंड पेट्रोकेमिकल विभाग, बॉम्बे रोड बै-23, अमरावती इंडस्ट्रियल एरिया, कोकन-400 002 फोन : 2437645 फैक्स : 2437646 Email : cipetnag@gmail.com / kcknow@cipet.gov.in www.cipet.gov.in		केन्द्रीय पेट्रोकेमिकल अभियांत्रिकी एवं प्रौद्योगिकी संस्थान (सिपेट) Central Institute of Petrochemicals Engineering & Technology (CIPET) (Formerly Central Institute of Plastics Engineering & Technology) Department of Chemicals & Petrochemicals Ministry of Chemicals & Fertilizers Unit of India B-27, Amravati Industrial Area, Lucknow-226 008 Phone : 2437645 Fax : 2437646 Email : cipetko@gmail.com / kcknow@cipet.gov.in www.cipet.gov.in
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TO WHOM IT MAY CONCERN

**This is to certify that Dr. Anupama Chatterjee
Has carried out Frictional Resistance test on Universal
Testing Machine for her thesis "Comparative evaluation of
Frictional Resistance in ceramic brackets & arch wire – An
In Vitro Study" at CIPET.**


Authorized Signature

ANNEXURE-IV

Anupama Chatterjee Thesis

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Ki-Ho Park, Se Jik Han, Samjin Choi, Kyung Sook Kim, Steven Park, Jae Hyun Park.
 "Surface Roughness on the Slots and Wings of Various Ceramic Self-Ligating Brackets and their Potential Concern on Biofilm Formation", Journal of Clinical Pediatric Dentistry, 2020

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