Comparative Evaluation of Frictional Resistance in Conventional and Passive Self-Ligating Ceramic Brackets with Rectangular Stainless-Steel Archwire: An In Vitro Study

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Abstract: ***This in vitro study investigated the frictional resistance of conventional and passive self-ligating ceramic brackets when paired with a 0.019" × 0.025" stainless steel (SS) archwire. Four bracket types were tested: conventional ceramic brackets (Unitek Gemini Clear 3M and Symetri Clear Ormco) and passive self-ligating ceramic brackets (3M Clarity and Damon Clear). Brackets were bonded to extracted human premolar teeth mounted in dental stone blocks, and frictional resistance was measured using an Instron universal testing machine. The results revealed that passive self-ligating brackets exhibited significantly lower frictional resistance than conventional brackets, with Damon Clear recording the lowest value (5.66 ± 1.88 N), followed by 3M Clarity (8.42 ± 2.18 N), Symetri Clear Ormco (16.43 ± 1.98 N), and Unitek Gemini Clear 3M (22.86 ± 2.44 N). Statistical analysis confirmed significant differences among all groups ($p < 0.05$). These findings suggest that the ligation method and bracket design play critical roles in frictional performance, potentially impacting treatment efficiency. Clinically, the reduced friction of self-ligating ceramic brackets could enhance sliding mechanics, offering benefits for aesthetically conscious patients seeking shorter treatment durations and improved comfort.***

Keywords: frictional resistance, ceramic brackets, self-ligating brackets, orthodontics, in vitro study

1. Introduction

Friction is an opposing force that develops when two surfaces slide against one another. In orthodontics, friction occurs primarily at the interface between the archwire, bracket slot, and ligation mechanism. Resistance to sliding, however, is not attributable to friction alone and includes friction, binding, and notching.

Frictional resistance is clinically important during space closure with sliding mechanics because part of the applied orthodontic force is dissipated at the bracket–archwire interface. Several variables influence frictional resistance, including archwire material and dimensions, bracket material and design, slot dimensions, bracket–archwire angulation, and the method of ligation.

Ceramic brackets are widely used because of their aesthetic characteristics, particularly among adult patients. Nevertheless, ceramic brackets may demonstrate greater frictional resistance than stainless-steel brackets. Self-ligating brackets retain the archwire using an integrated mechanism rather than an external ligature and may reduce ligation-related friction.
The present study evaluated the frictional resistance of two conventional ceramic and two passive self-ligating ceramic bracket systems using a 0.019 × 0.025-inch stainless-steel archwire.

2. Aim

- To evaluate and compare the frictional resistance generated by conventional and passive self-ligating ceramic brackets with a 0.019 × 0.025-inch stainless-steel archwire using a Universal Instron Testing Machine.

3. Objectives

- To evaluate frictional resistance between two conventional ceramic brackets and a rectangular stainless-steel archwire.
- To evaluate frictional resistance between two passive self-ligating ceramic brackets and a rectangular stainless-steel archwire.
- To compare frictional resistance among the four commercially available ceramic bracket systems.

4. Materials and Methods

Study design and setting: An in vitro experimental study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Babu Banarasi Das College of Dental Sciences, Lucknow, in collaboration with CIPET, Lucknow.

Sample: Twenty human premolar teeth extracted as part of planned orthodontic treatment were collected. Teeth were cleaned and stored in normal saline. Teeth with intact buccal surfaces were included; teeth with developmental anomalies, attrition, abrasion, abfraction, previous restorative/cosmetic treatment, trauma, or structural alteration were excluded.

Experimental groups: Group I- Unitek Gemini Clear, 3M; Group II- Symetri Clear, Ormco; Group III- Clarity, 3M; Group IV- Damon Clear. All brackets had a 0.022-inch slot and a 0.019 × 0.025-inch stainless-steel archwire was used.

Model preparation and bonding: Five premolars were mounted in each dental-stone model. Buccal surfaces were etched with 37% phosphoric acid for 15 seconds, rinsed, dried, primed, and bonded using light-cured orthodontic adhesive. Brackets were positioned and light cured.

Archwire ligation: Groups I and II used stainless-steel ligature ties. Groups III and IV used the passive self-ligating slides to secure the archwire.

Frictional resistance testing: Each model was positioned vertically in the lower compartment of the Universal Instron Testing Machine. The free end of the archwire was attached to the upper compartment. The archwire was pulled through the five brackets at a crosshead speed of 0.05 mm/min, and force was recorded from the force–displacement graph. Ten specimens were tested for each group.

Statistical analysis: Data were analyzed using SPSS. Descriptive statistics were expressed as mean and standard deviation. Intergroup comparisons were performed, with $P < 0.05$ considered statistically significant.

5. Results

The mean frictional resistance values demonstrated a progressive reduction from conventional ceramic to passive self-ligating ceramic brackets.

6. Discussion

The principal finding was that both passive self-ligating ceramic bracket systems demonstrated significantly lower frictional resistance than the conventionally ligated ceramic systems. This is consistent with the concept that eliminating external ligatures can reduce ligation-related contact between the archwire and bracket slot.

Unitek Gemini Clear showed the highest mean frictional resistance (22.86 ± 2.44 N), whereas Damon Clear showed the lowest (5.66 ± 1.88 N). Significant differences were also found between the two conventional ceramic systems and between the two passive self-ligating ceramic systems, indicating that bracket design and construction may influence frictional behavior.

Previous studies have reported variable frictional behavior among ceramic and self-ligating bracket systems. Differences may be related to slot characteristics, bracket morphology, surface texture, presence or absence of a metal slot, archwire dimensions, bracket angulation, and experimental methodology.

The use of extracted premolars in the present experimental model represents an attempt to reproduce the tooth-related bracket configuration more closely than models using flat metallic or acrylic substrates. Nevertheless, in vitro frictional measurements should not be interpreted as direct predictors of clinical treatment time or tooth-movement efficiency.

7. Limitations

- The study was performed under in vitro and dry experimental conditions and therefore did not reproduce the full oral environment.
- The experimental setup did not reproduce all three-dimensional clinical tooth movements, including variations in bracket angulation.
- Only one archwire material and dimension (0.019 × 0.025-inch stainless steel) was evaluated. Only two conventional and two passive self-ligating ceramic bracket systems were investigated.

8. Clinical Implications

Under the experimental conditions of this study, passive self-ligating ceramic brackets generated substantially lower frictional resistance than conventional ceramic brackets. They may therefore be considered when aesthetic brackets are required and reduced friction is desirable during sliding mechanics. Clinical decisions, however, should consider biological and mechanical factors beyond friction alone.

9. Conclusion

- Bracket type and ligation method significantly influenced frictional resistance.
- Conventional ceramic brackets generated significantly greater frictional resistance than passive self-ligating ceramic brackets.
- Unitek Gemini Clear demonstrated significantly greater frictional resistance than Symetri Clear. Clarity demonstrated significantly greater frictional resistance than Damon Clear.
- Damon Clear demonstrated the lowest mean frictional resistance among the four tested bracket systems.
- Within the limitations of this in vitro study, passive self-ligating ceramic brackets may be an alternative when reduced friction is desirable in aesthetic orthodontic treatment involving sliding mechanics.

Declarations

Ethics approval: Institutional ethical approval was obtained before commencement of the study, and informed consent was obtained for the use of extracted teeth.

Consent for publication: Not applicable.

Availability of data: Data generated during the study are available from the corresponding author on reasonable request.

Conflict of interest: The authors declare that there is no conflict of interest.

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Authors' contributions: Conceptualization, methodology, investigation, data collection and manuscript preparation: Dr. Anupama Chatterjee. Supervision and critical review: Dr. Shantanu Khattri, Dr. Kamna Srivastava and Dr. Tripti Tikku.

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Tables

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)

Table 2: Mean frictional resistance of the four ceramic bracket systems

Group	Bracket system	N	Mean ± SD (N)	Minimum	Maximum
I	Unitek Gemini Clear, 3M	10	22.86 ± 2.44	20.45	28.93
II	Symetri Clear, Ormco	10	16.43 ± 1.98	13.78	20.82
III	Clarity, 3M	10	8.42 ± 2.18	4.61	10.45
IV	Damon Clear	10	5.66 ± 1.88	2.58	8.61

Table 3: Pairwise comparison of frictional resistance between groups

Comparison	Mean difference (N)	P value
Group I vs II	6.437	<0.0001
Group I vs III	14.446	<0.0001
Group I vs IV	17.207	<0.0001
Group II vs III	8.009	<0.0001
Group II vs IV	10.770	<0.0001
Group III vs IV	2.761	0.031

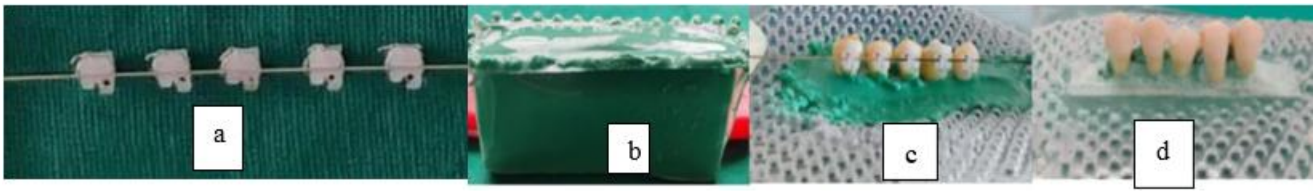

Figure 1 (a): Fabrication of block of stone with mounted premolars

(b) Four blocks of stone for each group

Figure 2: Bonding of brackets on mould using 0.019 * 0.025 SS wire with bracket attached

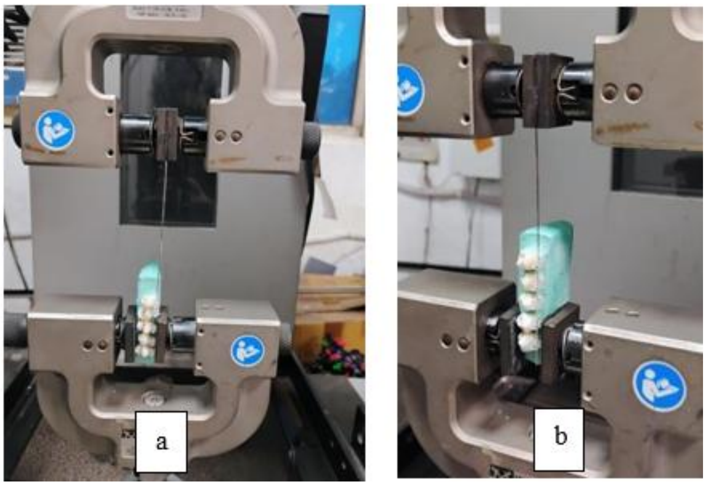

Figure 3: (a) Placement of model in lower compartment of Instron machine (b) Pulling of 0.019” x 0.025” SS by upper compartment of Instron machine