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Original Research Article

# Evaluation of the frictional resistance between different bracket types, archwires and ligation materials: An in-vitro study

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A B S T R A C T

**Introduction:** In orthodontic treatment, brackets need to slide along the archwire to allow for alignment of the teeth. The lesser the friction between the bracket and the archwire, the easier it is to align the teeth and the lighter the forces required to make such movements. In recent years, patients' esthetic demands have driven the field of orthodontics to find alternatives to conventional stainless steel bracket systems. While ceramic brackets meet the esthetic demands, their inferior frictional characteristics have always been an issue for orthodontists.
**Aim and Objectives:** The present in-vitro research study evaluates and compares the frictional resistance between various types of brackets, archwire materials and ligation methods. The purpose of the study was to equate the frictional resistance among 12 different groups using the universal testing machine, so as to recognize the factors involved in the in-vitro appraisal of resistance to sliding (RS) and inferring their clinical implications.
**Materials and Methods:** In this study, 120 pre-adjusted edgewise upper central incisor brackets with MBT 0.022″ slot were used, which included 40 standard metal brackets, 40 ceramic brackets, 20 self-ligating metal brackets and 20 self-ligating ceramic brackets. 0.019″ x 0.025″ SS (stainless steel) archwires, esthetic archwires, Teflon-coated ligatures and conventional elastic modules to ligate the archwire to the brackets except in self-ligating brackets, were used.
**Results:** The average frictional resistance of Group A10 was the minimum succeeded by A9, A12, A4, A11, A8, A3, A7, A2, A6, A1 and A5. In the comparison of the mean frictional resistance of 12 different groups, the ANOVA test showed noticeably different frictional resistance amongst the groups ($F=745.80$, $P<0.001$). Self-ligating metal bracket combinations with different archwires showed a significantly smaller magnitude of friction than self-ligating ceramic, metal and ceramic bracket combinations. Teflon-coated ligature combinations possess less friction in comparison with conventional elastomeric module combinations.



## 1. Introduction

Orthodontic treatment is based on tooth movement, and this is achieved by the application of forces through bonded attachments like brackets and tubes. Traditional

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orthodontics works with the ligation of orthodontic wires, which can be connected to the slot of brackets through different methods, resulting in different forces acting on the teeth. The most commonly used forms for ligation are metal ties and circular elastomeric modules.[1] However, circular elastomeric modules have been the first choice of most of the orthodontists for being more practical and efficient than the two methods. These attachments apply a pushing force against the arch base slot of the bracket, increasing frictional forces, making sliding mechanics difficult and reducing the pace of tooth movement, in addition to making it difficult to control anchoring in traction mechanics. Furthermore, of the total forces applied for orthodontic tooth movement, 50% disperses to overcome friction in the system.[2] In recent years, on the other hand, the use of self-ligating brackets has been popularised. This system was developed in 1935, in the form of a Russel Lock device, consisting of a precision lock for the attachment of the orthodontic wire to the slot and eliminating the need for steel or elastic ligatures. The wire can therefore slide freely, decreasing the friction when compared to traditional ligation modes. Although, several studies have reported that the decrease in friction is important in the initial, levelling and alignment, as well as in space closure and sliding mechanics.[3] On the contrary, the final stages of treatment require greater frictional force, to maintain the tooth position in the spatial space. Consequently, some studies uphold that the self-ligating brackets did not present a satisfactory result, rather conventional brackets with conventional ligation methods seem to have better three-dimensional control.[4] Ceramic brackets came into existence in orthodontics after the 1980s, to overcome the esthetic limitations of conventional metal brackets and approval of treatment by the patients.[5] However, a major drawback of ceramic brackets came to the surface, the frictional coefficient is relatively greater than seen in traditional brackets. It is therefore essential to consider the variations in frictional behavior between the bracket slots and the surface of archwires, as it may affect the duration of the treatment.[6] Thus, an ideal orthodontic system appears to be one in which alternate friction levels can be produced depending on the treatment phase, without the need to change the brackets or increase expenses. Orthodontic forces exerted on the teeth are transmitted to the bone via the periodontal tissues initiating a remodeling activity and facilitating the tooth movement, as bone responds to orthodontic forces according to its structural design.[7] The force of friction is a factor that opposes the movement of surfaces in rest or in motion. In orthodontics, the two surfaces could be bracket and archwire. When the brackets are in contact, two components of forces emerge. The frictional force ($F_f$) and the force normal (N), where $F_f$ is directly proportional to N. Friction is responsible for the sliding resistance observed in orthodontics in the stages of aligning, levelling and closing spaces. In orthodontics, the efficiency is around 40-88%, that is some portion of the orthodontic force applied to teeth gets dissipated to overcome the frictional resistance. Therefore, it is vital to use more efficient treatment mechanics with the optimal levels of force producing the desired amount of tooth movement and without inducing any damage to the periodontal structures.[8] During the space closure stage due to sliding, the decrease in friction will allow using a smaller magnitude of retraction force which brings less need for anchoring. The decrease in friction in the biomechanics of sliding will bring three advantages at a theoretical level (a) an increased rate of tooth movement, (b) less need for anchorage and (c) greater control of movement. Frictional resistance may be affected by multiple factors like the material used for manufacturing brackets, archwires and ligatures, the topography of archwires and bracket slots, wire diameter, the degree of torque acting between the archwire and bracket, types of brackets, salivary flow and composition, and the impact of the orofacial musculature, etc.[5] Hence, the selection of the type of material to be employed in every treatment plan and the stage of treatment is very decisive. Therefore, the aim of the present research is to recognize factors involved in the in-vitro assessment of friction in orthodontics and to identify the finest BAL (bracket-archwire-ligature) combination for accomplishing the best possible treatment outcomes. The present study was undertaken, to gauge the degree of frictional resistance produced by two types of ligation methods (conventional elastomeric module and Teflon coated ligature) on the brackets of various materials with 022 × 028 inches slot (MBT prescription) with two archwires (0.019″ x 0.025″ Stainless Steel and 0.019″ x 0.025″ Teflon coated archwire) combinations under dry conditions.

## 2. Materials and Methods

In this study, 120 pre-adjusted edgewise upper central incisor brackets with 0.022″ slot (MBT prescription) were used, which included 40 standard metal brackets, 40 ceramic brackets, 20 self-ligating metal brackets and 20 self-ligating ceramic brackets. 0.019″ x 0.025″ SS (stainless steel) archwires, esthetic archwires, Teflon-coated ligatures and conventional elastic modules to ligate the archwire to the brackets except in self-ligating brackets were utilized for this experimental study. The descriptions of the brackets, archwires and ligatures employed are specified in Table 1. The methodology was based on a study for experimental frictional evaluation of brackets and archwires done by Mascarelo A.C.et al.(2018)[9] and Monteiro et.al. (2014).[10] The test specimens were prepared by fabricating a rectangular acrylic plate measuring 4 x 14 cm and 0.5 cm in thickness (Figure 1). A groove of 1.5 cm depth and 1.2 cm width was given at 2 cm from one end of the acrylic plate. On this setup, a segment of fixed appliances consisting of five brackets was mounted. The point for attaching each of the five brackets on the acrylic plate was marked and roughened with abrasive sandpaper to assure the improved holding of the brackets. The brackets were attached at a 0.8 cm margin between them. Ethyl alcohol (70%) for 10 seconds was used to clean the brackets and archwires, thereby avoiding the presence of any material that could interfere with the results. The brackets were bonded using instant glue based on cyanoacrylate for standardization positioning and gluing, the brackets were positioned evenly on the flat surface of the plate and glued exactly in the center. The archwire was then placed into the bracket slots and fixed with different types of ligatures except for the self-ligating brackets. Afterward, the testing bracket was ligated onto the archwire, in the groove section. In order to standardize the tests, all ligatures from all groups were exchanged after each test, except the self-ligating brackets, in this, the bracket clip was opened, with a clinical probe, and closed with clinical forceps after each test. A delay of 3 minutes between each test was established so as to release the initial stresses of the ligature. Mathieu forceps was used to install the low-friction ligatures and conventional elastic modules. The Teflon-coated ligatures were installed with the Mathieu forceps, rotating the same in the clockwise direction, ten times. For the simulation of sliding mechanics, the static traction test was used in a straight line, that is the bracket remained at rest while the archwire slides along the slot. To evaluate the frictional force, the machine used was the Universal testing machine EMT-T20 KN, Universal Motion Inc. (Figure 2 ) to record the maximum strength of each set. A 5N load cell was used at a rate of 5mm/min for 2 minutes down a wire portion for a length of 10 mm. A new set of brackets/archwire/ligature was used for each test. The testing plate was placed at right angles to the floor and the test was staged in a dry state. Each bracket was tested 10 times to find an average value for each bracket and, from that, an average for each group. The results obtained were transmitted to the computer connected to the testing machine and registered. The data were subjected to statistical analysis.

## 3. Statistical Analysis

Data were summarised as Mean ± SD (standard deviation). The one-way analysis of variance test (ANOVA) was used to compare the groups and after establishing normality by Shapiro-Wilk's test and homogeneity of variance between groups by Levene's test, the significance of the mean difference between the groups (Inter-group comparison) was done by Tukey's HSD (honestly significant difference) post hoc test. A two-tailed ($\alpha$=2) $P < 0.05$ was considered statistically significant. Analysis was performed on SPSS software (Windows version 22.0). The samples were randomized and equally distributed into 12 groups (i.e., 10 samples per group-Figure 3) and each group was treated with either of the 12 distinct combinations of bracket types and archwire materials. Outcome measure of this study is the Mean frictional resistance measured in Newton (N) and is summarised in Table 2 and depicted in Figures 4 and 5 for groups A1 to A12, respectively.

## 4. Results

It was found that Group A10 (self-ligating metal with Teflon-coated wire) exhibited significantly minimal frictional resistance in contrast to the evaluated 12 different bracket types, archwire materials and ligatures and is therefore the best selection for orthodontic treatment. Furthermore, Group A9 (self-ligating metal with ss wire) can be used for similar purposes as it exhibited the second least frictional resistance with an insignificant difference when compared to Group A10. The mean frictional resistance of Group A10 was the minimum succeeded by A9, A12, A4, A11, A8, A3, A7, A2, A6, A1 and A5. Comparison of the mean frictional resistance of 12 different groups by ANOVA test (Table 3) showed a substantially diverse frictional resistance among the groups ($F=745.80$, $P< 0.001$). Moreover, evaluating the disparity in the mean frictional resistance between the groups (i.e., pair-wise comparison), the Tukey test showed a considerably distinct frictional resistance ($P< 0.05$ or $P < 0.001$) between all the groups, except Group A1 and A6, Group A3 and A7, Group A4 and A8, Group A4 and A11, Group A8 and A11, and Group A9 and A10 (Table 4)

## 5. Discussion

The best favorable tissue response and efficient treatment progress depend entirely on the respectable magnitude of force during orthodontic treatment. Treatment mechanics that involve the displacement of the bracket along the archwire and consequently, as a result of surface interaction between the bracket and archwire stemming in the development of friction might disrupt reaching such ideal force levels in the periodontal tissues. Therefore, a thorough knowledge of the factors essential to undermine friction is important to achieve impeccable biological tooth movement. To understand the exact process of friction that develops between the archwire, bracket and ligatures, several influencing factors, such as the materials used for their production have been studied.[11] In fixed treatment mechanics, about 12% to 60% of the orthodontic force employed is wasted, due to friction. An amalgamation of several mechanical and chemical factors such as bracket and archwire composition, archwire cross-section, the contact angle between the bracket and archwire during sliding, tipping and torquing movements, dry and wet conditions, and ligation materials and methods, govern the extent of friction at the bracket-archwire-ligature interface.[12]

**Table 1:** Material and manufacturer details.

| Type of Material | Manufacturer |
|---|---|
| Conventional metal brackets | Victory series 3M Unitek |
| Ceramic brackets | Clarity advanced 3M Unitek |
| Self-ligating metal brackets | Smart clip SL3 3M Unitek |
| Self-ligating ceramic brackets | Clarity SL 3M Unitek |
| SS archwires | 3M Unitek |
| Esthetic archwires | Rabbit force |
| Teflon coated ligatures | Ortho system |
| Conventional elastic module | 3M Unitek |

**Table 2:** Summary and mean statistics of the tests (T1 to T10) for calculating the frictional resistance (N) of 12 different groups.

| Type of BAL Combination | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [A1] conventional metal with ss wire and elastomeric module | 5.3 | 5.33 | 5.41 | 5.45 | 5.32 | 5.4 | 5.54 | 5.38 | 5.48 | 5.52 | 5.41 |
| [A2] conventional metal with teflon coated wire and elastomeric module | 4.66 | 4.72 | 4.62 | 4.78 | 4.8 | 4.7 | 4.91 | 4.86 | 4.9 | 4.82 | 4.78 |
| [A3] conventional metal with ss wire and teflon coated ligature | 4.2 | 4.22 | 4.18 | 4.16 | 4.28 | 4.2 | 4.23 | 4.3 | 4.24 | 4.22 | 4.22 |
| [A4] conventional metal with teflon coated wire and teflon coated ligature | 3.1 | 3.12 | 3.09 | 3.18 | 3.16 | 3.11 | 3.21 | 3.2 | 3.24 | 3.16 | 3.16 |
| [A5] conventional ceramic with ss wire and elastomeric module | 6.9 | 6.94 | 6.98 | 6.88 | 6.96 | 6.93 | 7.22 | 7.1 | 7.18 | 7.24 | 7.03 |
| [A6] conventional ceramic with teflon coated wire and elastomeric module | 5.2 | 5.32 | 5.1 | 5.16 | 5.22 | 5.03 | 5.54 | 5.4 | 5.55 | 5.6 | 5.31 |
| [A7] conventional ceramic with ss wire and teflon coated ligature | 4.1 | 4.16 | 4.2 | 4.4 | 4.48 | 4.31 | 4.63 | 4.6 | 4.65 | 4.68 | 4.42 |
| [A8] conventional ceramic with teflon coated wire and teflon coated ligature | 3.3 | 3.33 | 3.4 | 3.6 | 3.56 | 3.32 | 3.63 | 3.66 | 3.58 | 3.62 | 3.50 |
| [A9] self-ligating metal with ss wire | 0.5 | 0.55 | 0.3 | 0.44 | 0.22 | 1.01 | 0.2 | 1.05 | 0.3 | 0.26 | 0.48 |
| [A10] self-ligating metal with teflon coated wire | 0.4 | 0.44 | 0.32 | 0.3 | 0.2 | 0.45 | 0.1 | 0.16 | 0.18 | 0.12 | 0.27 |
| [A11] self-ligating ceramic with ss wire | 2.4 | 2.44 | 2.5 | 3.6 | 3.56 | 3.32 | 3.63 | 3.66 | 3.58 | 3.62 | 3.23 |
| [A12] self-ligating ceramic with teflon coated wire | 1.6 | 1.65 | 1.67 | 1.8 | 2.1 | 1.71 | 2.32 | 2.18 | 2.3 | 2.12 | 1.95 |

**Table 3:** Comparison of mean frictionalresistance (N) among 12 different groups by ANOVA

| Source of variation (SV) | Sum of square (SS) | Degree of freedom (df) | Mean square (MS) | F Value | *P Value* |
|---|---|---|---|---|---|
| Between group | 443.30 | 11 | 40.30 | 745.80 | ***< 0.001*** |
| Residual | 5.84 | 108 | 0.05 | | |
| Total | 449.10 | 119 | 40.35 | | |

**F value:** ANOVA F value

**Table 4:** Comparison of difference inmean frictional resistance (N) between groups by Tukey test

| Comparison | Mean diff. | q value | *P value* | 95% CI of diff. |
|---|---|---|---|---|
| A1 vs. A2 | 0.64 | 8.65 | ***P < 0.001*** | 0.2881 to 0.9839 |
| A1 vs. A3 | 1.19 | 16.19 | ***P < 0.001*** | 0.8421 to 1.538 |
| A1 vs. A4 | 2.26 | 30.69 | ***P < 0.001*** | 1.908 to 2.604 |
| A1 vs. A5 | -1.62 | 22.04 | ***P < 0.001*** | -1.968 to -1.272 |
| A1 vs. A6 | 0.10 | 1.37 | ***P > 0.05*** | -0.2469 to 0.4489 |
| A1 vs. A7 | 0.99 | 13.49 | ***P < 0.001*** | 0.6441 to 1.340 |
| A1 vs. A8 | 1.91 | 26.02 | ***P < 0.001*** | 1.565 to 2.261 |
| A1 vs. A9 | 4.93 | 67.07 | ***P < 0.001*** | 4.582 to 5.278 |
| A1 vs. A10 | 5.15 | 70.00 | ***P < 0.001*** | 4.798 to 5.494 |
| A1 vs. A11 | 2.18 | 29.68 | ***P < 0.001*** | 1.834 to 2.530 |
| A1 vs. A12 | 3.47 | 47.18 | ***P < 0.001*** | 3.120 to 3.816 |
| A2 vs. A3 | 0.55 | 7.54 | ***P < 0.001*** | 0.2061 to 0.9019 |
| A2 vs. A4 | 1.62 | 22.04 | ***P < 0.001*** | 1.272 to 1.968 |
| A2 vs. A5 | -2.26 | 30.69 | ***P < 0.001*** | -2.604 to -1.908 |
| A2 vs. A6 | -0.54 | 7.28 | ***P < 0.001*** | -0.8829 to -0.1871 |
| A2 vs. A7 | 0.36 | 4.84 | ***P < 0.05*** | 0.0081 to 0.7039 |
| A2 vs. A8 | 1.28 | 17.37 | ***P < 0.001*** | 0.9291 to 1.625 |
| A2 vs. A9 | 4.29 | 58.41 | ***P < 0.001*** | 3.946 to 4.642 |
| A2 vs. A10 | 4.51 | 61.35 | ***P < 0.001*** | 4.162 to 4.858 |
| A2 vs. A11 | 1.55 | 21.03 | ***P < 0.001*** | 1.198 to 1.894 |
| A2 vs. A12 | 2.83 | 38.53 | ***P < 0.001*** | 2.484 to 3.180 |
| A3 vs. A4 | 1.07 | 14.50 | ***P < 0.001*** | 0.7181 to 1.414 |
| A3 vs. A5 | -2.81 | 38.23 | ***P < 0.001*** | -3.158 to -2.462 |
| A3 vs. A6 | -1.09 | 14.81 | ***P < 0.001*** | -1.437 to -0.7411 |
| A3 vs. A7 | -0.20 | 2.69 | ***P > 0.05*** | -0.5459 to 0.1499 |
| A3 vs. A8 | 0.72 | 9.84 | ***P < 0.001*** | 0.3751 to 1.071 |
| A3 vs. A9 | 3.74 | 50.88 | ***P < 0.001*** | 3.392 to 4.088 |
| A3 vs. A10 | 3.96 | 53.82 | ***P < 0.001*** | 3.608 to 4.304 |
| A3 vs. A11 | 0.99 | 13.49 | ***P < 0.001*** | 0.6441 to 1.340 |
| A3 vs. A12 | 2.28 | 30.99 | ***P < 0.001*** | 1.930 to 2.626 |
| A4 vs. A5 | -3.88 | 52.73 | ***P < 0.001*** | -4.224 to -3.528 |
| A4 vs. A6 | -2.16 | 29.32 | ***P < 0.001*** | -2.503 to -1.807 |
| A4 vs. A7 | -1.26 | 17.19 | ***P < 0.001*** | -1.612 to -0.9161 |
| A4 vs. A8 | -0.34 | 4.67 | ***P > 0.05*** | -0.6909 to 0.0049 |
| A4 vs. A9 | 2.67 | 36.38 | ***P < 0.001*** | 2.326 to 3.022 |
| A4 vs. A10 | 2.89 | 39.31 | ***P < 0.001*** | 2.542 to 3.238 |
| A4 vs. A11 | -0.07 | 1.01 | ***P > 0.05*** | -0.4219 to 0.2739 |

*Continued on next page*

*Table 4 continued*

| | | | | |
|---|---|---|---|---|
| A4 vs. A12 | 1.21 | 16.49 | ***P < 0.001*** | 0.8641 to 1.560 |
| A5 vs. A6 | 1.72 | 23.41 | ***P < 0.001*** | 1.373 to 2.069 |
| A5 vs. A7 | 2.61 | 35.53 | ***P < 0.001*** | 2.264 to 2.960 |
| A5 vs. A8 | 3.53 | 48.06 | ***P < 0.001*** | 3.185 to 3.881 |
| A5 vs. A9 | 6.55 | 89.10 | ***P < 0.001*** | 6.202 to 6.898 |
| A5 vs. A10 | 6.77 | 92.04 | ***P < 0.001*** | 6.418 to 7.114 |
| A5 vs. A11 | 3.80 | 51.72 | ***P < 0.001*** | 3.454 to 4.150 |
| A5 vs. A12 | 5.09 | 69.21 | ***P < 0.001*** | 4.740 to 5.436 |
| A6 vs. A7 | 0.89 | 12.12 | ***P < 0.001*** | 0.5431 to 1.239 |
| A6 vs. A8 | 1.81 | 24.65 | **P < 0.001** | 1.464 to 2.160 |
| A6 vs. A9 | 4.83 | 65.69 | ***P < 0.001*** | 4.481 to 5.177 |
| A6 vs. A10 | 5.05 | 68.63 | ***P < 0.001*** | 4.697 to 5.393 |
| A6 vs. A11 | 2.08 | 28.31 | ***P < 0.001*** | 1.733 to 2.429 |
| A6 vs. A12 | 3.37 | 45.80 | ***P < 0.001*** | 3.019 to 3.715 |
| A7 vs. A8 | 0.92 | 12.53 | ***P < 0.001*** | 0.5731 to 1.269 |
| A7 vs. A9 | 3.94 | 53.57 | ***P < 0.001*** | 3.590 to 4.286 |
| A7 vs. A10 | 4.15 | 56.51 | ***P < 0.001*** | 3.806 to 4.502 |
| A7 vs. A11 | 1.19 | 16.19 | ***P < 0.001*** | 0.8421 to 1.538 |
| A7 vs. A12 | 2.48 | 33.68 | ***P < 0.001*** | 2.128 to 2.824 |
| A8 vs. A9 | 3.02 | 41.04 | ***P < 0.001*** | 2.669 to 3.365 |
| A8 vs. A10 | 3.23 | 43.98 | ***P < 0.001*** | 2.885 to 3.581 |
| A8 vs. A11 | 0.27 | 3.66 | ***P > 0.05*** | -0.0789 to 0.6169 |
| A8 vs. A12 | 1.56 | 21.15 | ***P < 0.001*** | 1.207 to 1.903 |
| A9 vs. A10 | 0.22 | 2.94 | ***P > 0.05*** | -0.1319 to 0.5639 |
| A9 vs. A11 | -2.75 | 37.38 | ***P < 0.001*** | -3.096 to -2.400 |
| A9 vs. A12 | -1.46 | 19.89 | ***P < 0.001*** | -1.810 to -1.114 |
| A10 vs. A11 | -2.96 | 40.32 | ***P < 0.001*** | -3.312 to -2.616 |
| A10 vs. A12 | -1.68 | 22.83 | ***P < 0.001*** | -2.026 to -1.330 |
| A11 vs. A12 | 1.29 | 17.49 | ***P < 0.001*** | 0.9381 to 1.634 |

**diff:** difference, **CI:** confidenceinterval, **q value:** Tukey test value

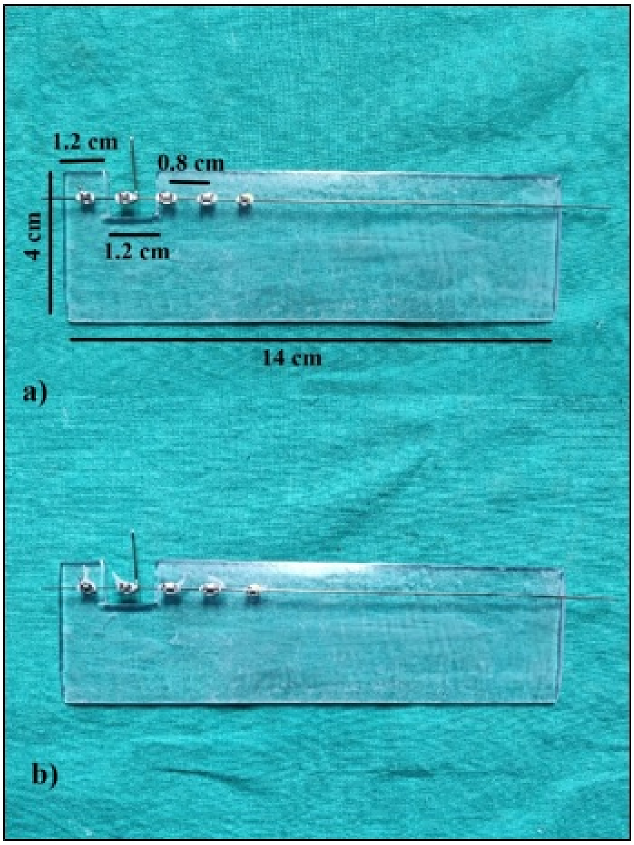


**Fig. 1:** Test model and its dimensions: a) Conventional metal brackets with elastic module, b) Conventional metal brackets with Teflon coated ligature.

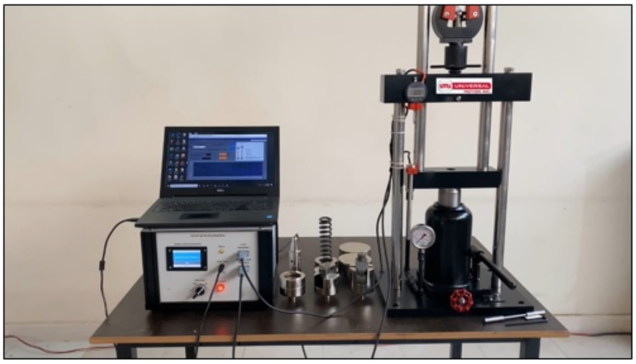

**Fig. 2:** Universal testing machine (UMI).

The sliding of the bracket along the archwire during orthodontic tooth movement is not a uniform movement, but rather a series of small increments of tipping and up righting waves.

Therefore, two components of frictional resistance, static and kinetic, come into play in such an active scenario, and since the two elements of friction are dynamically related, it is clinically inept to distinguish between the

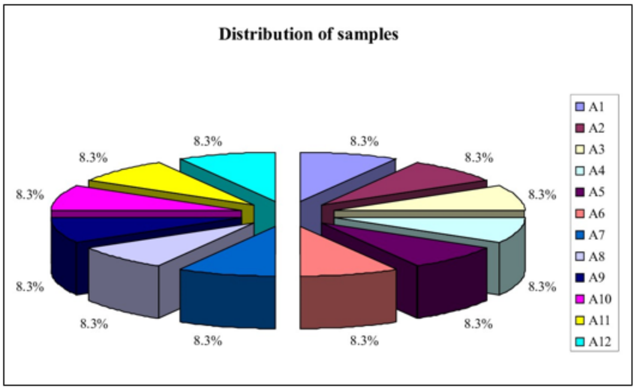


**Fig. 3:** Pie chart showing distribution of samples in 12 different groups.

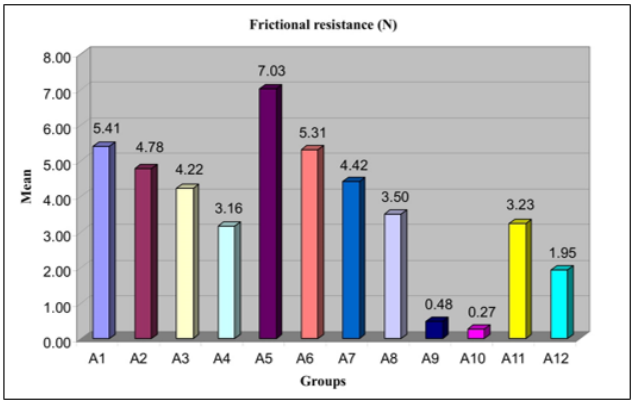


**Fig. 4:** Bar graphs showing the mean frictional resistance (N) of 12 different groups.

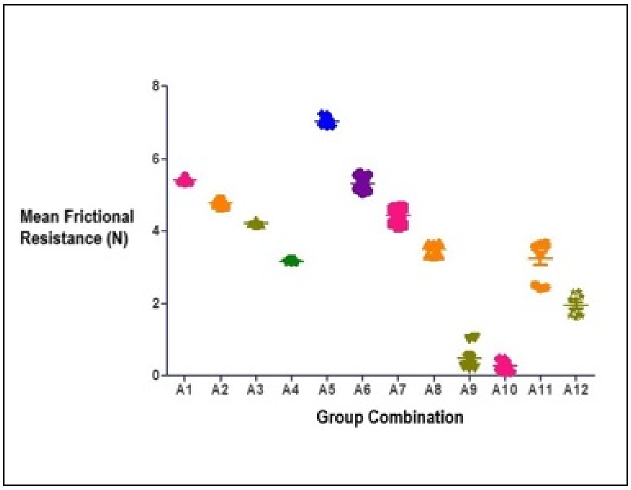


**Fig. 5:** Scatter plot showing distribution of the observed frictional resistance (N) of 12 different groups.

two.[13] Since orthodontic sliding mechanics relies more on the static mode of friction, therefore, in our study, we have evaluated the static friction between different bracket types, archwires and ligatures. Friction (FR) may be defined as the opposition to changing the relative position of objects when they tend to move obliquely against one another. However, resistance to sliding (RS) is a more inclusive notion and comprises friction (FR), binding (BI), and notching (NO). Thus, RS = FR + BI + NO. Therefore, a higher RS (resistance to sliding) requires a greater orthodontic force. However, forces of greater magnitude are attributed to the loss of anchorage and are considered to be the major limitation of high RS (resistance to sliding). Ligating methods, material compositions and lubricants, alterations in the spatial pattern, and elastic deformation of the contact areas, may also influence RS (resistance to sliding).[9] Hence, the management of differential forces is still an underlying principle in orthodontics and the bio-physical basis of RS (resistance to sliding) still requires clarification.

Overall, ceramic (polycrystalline) bracket combinations demonstrated statistically significant and greater mean maximum static frictional force values than stainless steel bracket combinations. This is in accordance with the study done by Shweta et. Al.[14] On comparison of Frictional Resistance (FR) among the four types of brackets in combination with stainless steel and beta-titanium archwires, the self-ligating metal bracket combinations demonstrated minimal friction values whereas the ceramic bracket combinations exhibited maximum friction values, followed by stainless steel bracket combinations, self-ligating ceramic bracket combinations and self-ligating metal bracket combinations. This is in agreement with the findings obtained by Ajith et. Al.[15] Uncoated archwire combinations were correlated with generally greater values of frictional forces than coated archwire combinations. This concurs with the observations of Kusy et. Al.[16] The greater magnitude of frictional forces seen with uncoated archwires can be ascribed to the lower coefficient of static friction for Teflon when placed in SS slots. Disparities in the static coefficient of friction, similarly, generate higher frictional forces between ceramic bracket slot and uncoated archwire combinations. Coated archwire combinations produced significantly lower mean frictional values than uncoated archwire combinations in ceramic (polycrystalline) bracket slots. Comparable remarks were also confirmed by Robert et. Al.[17] Stainless steel brackets, however, produced similar frictional forces when used in coated and uncoated archwire combinations. Although Teflon may be considered a suitable layering substance for orthodontic archwires due to its smaller coefficient of friction with major bracket types (SS or ceramic), the propensity of rapid surface fissuring and stripping has traditionally confined its use.[18]

## 6. Limitations of the study

It is challenging to imitate the valuable phenomenon and out-of-the-plane deformities that occur at the bracket-archwire interface generated in real-time clinical conditions intraorally, thereby encouraging the in-vivo testing of the parameters ascertained in this study to assess their promising applicability in dynamic clinical conditions. Contemporary and latest archwire and ligature materials with different combinations of bracket series may be used to yield better results.

## 7. Conclusions

1. Self-ligating metal bracket combinations with different archwires showed significantly smaller values of friction than self-ligating ceramic, metal and ceramic bracket combinations.
2. Ceramic bracket combinations demonstrated the maximum value of FR (frictional resistance) in contrast to other combinations.
3. In general, Teflon-coated archwires in combination with different brackets and ligature systems generated lesser resistance values on comparing with SS (stainless steel) wire combinations.
4. Teflon-coated ligature combinations possess less friction in comparison with conventional elastomeric module combinations.
5. The combination of using steel brackets on the molar and premolar teeth (for anchorage) and ceramic brackets on the incisal teeth (for esthetics) can produce differences in friction that could lead to the undesirable shift of posterior teeth into the extraction spaces, primarily preserved for the retraction of the anterior teeth during sliding mechanics, the aftermath of which would be anchorage burnout and encroachment of the extraction space. Additional measures to reinforce the anchorage must be used in such cases.

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## 9. Conflict of Interest

None.

## References

1. Bednar JR, Gruendeman GW, Sandrik JL. A comparative study of frictional forces between orthodontic brackets and arch wires. *Am J Orthod Dentofac Orthop*. 1991;100(6):513–35.
2. Kim TK, Kim KD, Baek SH. Comparison of frictional forces during the initial levelling stage in various combinations of self-ligating brackets and archwires with a custom-designed typodont system. *Am J Orthod Dentofac Orthop*. 2008;133(2):187–202.
3. Marques IS, Araújo AM, Gurgel JA, Normando D. Debris, roughness and friction of stainless steel archwires following clinical use. *Angle Orthod*. 2010;80(3):521–8.

4. Dholakia KD, Bhat SR. Clinical efficiency of nonconventional elastomeric ligatures in the canine retraction phase of preadjusted edgewise appliance therapy: an in-vivo study. *Am J Orthod Dentofac Orthop*. 2012;141(6):715–37.
5. Kaur G, Goyal S, Rajpal S, Gera A. Comparative evaluation of frictional forces of conventional and self-ligating brackets systems: an in vitro study. *J Indian Orthod Soc*. 2013;47(4):339–81.
6. Kannan MS, Murali RV, Kishorekumar S, Gnanashanmugam K, Jayanth V. Comparison of frictional resistance of esthetic and semi-esthetic self-ligating brackets. *J Pharm Bioallied Sci*. 2015;7(5):116–36.
7. Angle EH. The latest and best in orthodontic mechanism. *Dent Cosmos*. 1928;70:1143–58.
8. Articolo LC, Kusy RP. Influence of angulation on the resistance to sliding in fixed appliances. *Am J Orthod Dentofac Orthop*. 1999;115(1):39–51.
9. Aryadne W. 9.Aryadne cipreste mascarelo, ana paulagodoia , vivianfurlettia , William custódioa , heloisa cristina valdrighi in Evaluation of friction in metal, ceramic and self-ligating brackets submitted to sliding mechanics. . *Rev Odontol UNESP*. 2018;47(4):244–8.
10. Monteiro M, Silva LE, Elias CN, Vilella OV. Frictional resistance of self- ligating versus conventional brackets in different bracket archwire-angle combinations. *J Appl Oral Sci*. 2014;22(3):228–62.
11. Hain M, Dhopatkar A, Rock P. The effect of ligation method on friction in sliding mechanics. *Am J Orthod Dentofac Orthop*. 2003;123(4):416–38.
12. Tecco S, Iorio D, Nucera D, Festa G, Bisceglie D, Cordasco B. Evaluation of the friction of self-ligating and conventional bracket systems. *Eur J Dent*. 2011;5(3):310–7.
13. Kumar S, Singh S, Hamsa AS, Bhatnagar A. Evaluation of friction in orthodontics using various brackets and archwire combination-an in vitro study. *J Clin Diagn Res*. 2014;8(5):33–9.
14. Nagesh S, Praveen N, Sumitra R. Comparison of Frictional Resistance between four types of brackets in combination with stainless steel and beta-titanium archwires. *APOS Trends Orthod*. 2020;10(4):231–8.
15. Pillai AAR, Gangadharan A. Comparison of the frictional resistance between archwire and different bracket system. *J Pharm Bioallied Sci*. 2014;6(1):150–6.
16. Kusy R, Whitley J, Gurgel J. Comparisons of surface roughness's and sliding resistances of 6 titanium-based or TMA-type archwires. *Am J Othod Dentofac Orthop*. 2004;126(5):589–603.
17. Kusy RP, Whitley JQ. Whitley in Friction between different wire-bracket configurations and materials in Seminars in Orthodontics. *Semin Orthod*. 1997;3(3):166–83.
18. Greenberg R, Halperin G, Etsion I, Tenne R. The Effect of WS2 Nanoparticles on Friction Reduction in Various Lubrication Regimes. *T Lett*. 2004;17(2):179–86.

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