

Evaluation of Frictional Forces between Different Aesthetic Brackets and Arch Wires during Leveling and Alignment Stage

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الخلاصة

الاهداف: لمقارنة قوى الاحتكاك بين أنواع مختلفة من الحاصرات الجمالية والأسلاك القوسية المصنوعة من النيكل تيتانيوم خلال مرحلة التسوية والمحاذاة من مراحل المعالجة التقويمية. **المواد والطرق:** شملت عينة الدراسة ثلاثة أنواع من الحاصرات السيراميكية: الحاصرات السيراميكية متعددة الكريستالات ذاتية الربط، الحاصرات السيراميكية متعددة الكريستالات المزودة باحدود معدني والحاصرات السيراميكية أحادية الكريستالات. هذه الحاصرات تم اختبارها مع أسلاك مصنوعة من النيكل تيتانيوم بحجم 0.014 و 0.016. إنج. يشمل إعداد الاحتكاك نموذجاً صمم خصيصاً من ثلاث حاصرات غير مستوية وغير متحاذاة. أجريت جميع الاختبارات في الحالة الجافة على جهاز اختبار شد رقمي. لقد تم تحليل البيانات باستخدام الاختبارات الإحصائية الوصفية والاستنتاجية عند مستوى الدلالة ($p > 0,05$). **النتائج:** أظهرت النتائج وجود فروق ذات دلالة إحصائية بين المجموعات المدروسة من الحاصرات والأسلاك القوسية عند مستوى ($p > 0,05$). **الاستنتاجات:** تبين أن تركيب الحاصرات السيراميكية متعددة الكريستالات ذاتية الربط والأسلاك المصنوعة من النيكل تيتانيوم بحجم 0.014. إنج لديه أقل قوة احتكاك في مرحلة التسوية والمحاذاة فضلاً عن الحاصرات السيراميكية متعددة الكريستالات المزودة باحدود معدني والذي يعتبر بديلاً جيداً من أجل حل مشكلة الاحتكاك.

ABSTRACT

Aims: To compare the frictional forces between different types of aesthetic brackets and Nickel Titanium (NiTi) arch wires during leveling and alignment stage of orthodontic treatment. **Materials and Methods:** The sample of the study included three types of ceramic brackets: active self-ligating, monocrySTALLine and polycrySTALLine with metal slot in combination with 0.014" and 0.016" NiTi arch wires. The friction setup includes a custom-designed model with three nonleveled and nonaligned brackets. All tests were carried out in a dry state on a digital tensile testing machine. The data were analyzed using the descriptive and inferential statistical tests at ($p < 0.05$) significance level. **Results:** The results demonstrated that there were statistically significant differences between the studied groups of brackets and arch wires ($p < 0.05$). **Conclusions:** The combination of the active self-ligating ceramic bracket with 0.014" NiTi arch wire has the least frictional force in the leveling and alignment stage as well as the ceramic bracket with metal slot is a good alternative to solve the problem of friction. **Key words:** Frictional forces, aesthetic brackets, leveling and alignment.

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INTRODUCTION

Nowadays, aesthetically pleasing appliances are one of the most preferred aspects of orthodontic treatment. Aesthetic brackets are currently produced and used with great regularity, therefore, it is necessary for orthodontists to offer esthetic alternatives to metal brackets to accomplish treatment objective today.^(1,2) Self-ligating brackets are increasingly replacing conventional brackets due to their proposed reduced friction compared with conventional brackets especially when joined with smaller arch wires used in the initial leveling and alignment stage.^(3,4) Determining the approximate magnitude of frictional force associated with those esthetic and self-ligating brackets in different clinical

situations can assist in identifying the actual force employed in moving teeth, thus enabling the orthodontists apply light forces to the periodontium while stimulating maximal biological forces in the tooth being moved and minimal bone remodeling in the anchorage teeth.⁽⁵⁾

In most previous studies,^(4,6,7,8,9) there were limitations in study design because they investigated nonleveled brackets only, nonaligned brackets only or dealt with both malalignments separately, in addition, most of them investigated metal brackets only. Just one study has included both non leveled and non aligned brackets simultaneously to measure frictional forces.⁽¹⁰⁾ Hence further investigation of frictional forces of aesthetic

brackets during alignment and leveling is essential.

This work aims to evaluate and compare the values of the frictional forces of three types of ceramic brackets (conventional and self ligating) coupled with 0.014" and 0.016" NiTi arch wires during leveling and aligning stage.

MATERIALS AND METHODS

An experimental model shown in Figure (1) reproducing the right buccal segment of the maxillary arch was designed to measure the frictional force generated by three types of aesthetic brackets: active self ligating ceramic brackets (Sensation™ Roth brackets, Orthotechnology, Tampa, Florida, 33647, USA), monocrystalline ceramic brackets

(Pure™ Roth brackets, Orthotechnology, Tampa, Florida, 33647, USA) and polycrystalline ceramic brackets with metal slot (Encore™ Roth brackets, Orthotechnology, Tampa, Florida, 33647, USA) in combination with 0.014" and 0.016" straight arch wires NiTi (Greenwood G&H® Orthodontics, Indiana, 46131, USA). All brackets used in this study had a 0.022" × 0.028" slot. The experimental model consists of a rigid frame made from a clear acrylic material with dimensions of (510 mm length × 50 mm width × 15 mm thickness). The model contains three holes of 8 mm in diameter and 10 mm in depth where three cylinders of mild steel are inserted in them. The middle cylinder is 10 mm height while the two other cylinders are 11 mm in height.



Figure (1): Setup of Experimental Model on the Tensile Testing Machine

Three brackets: maxillary right canine, maxillary right first and maxillary right second premolars have been bonded on the upper surfaces of the three cylinders. The experimental model represents the maxillary right quadrant during leveling and aligning stage. From the top view, the middle cylinder has been displaced 1 mm in the horizontal plane which simulates the apical malalignment as shown in Figure (1b). Besides that, from the side view, the middle cylinder is 1 mm inferior than the other cylinders to simulate palatal displacement of the middle bracket. The interbracket distance measured from the centers of brackets is 11 mm in accordance with.^(6,7)

In order to ensure that all brackets are

mounted in the same orientation and level before bonding them into the cylinders, a special mounting device has been designed. The device is made from a clear acrylic material and contains two holes, one has 10 mm length for the 10 mm cylinder and the other has 11 mm length for the 11 mm cylinder.

On its upper surface, each cylinder has a cross sign to be used as a guide for correct positioning of the cylinder in the mounting device which has vertical and horizontal lines to match this cross sign in the cylinder during mounting as shown in Figure (2). After achieving the correct position of the cylinder, it has been tightly screwed to the device using an L-key.

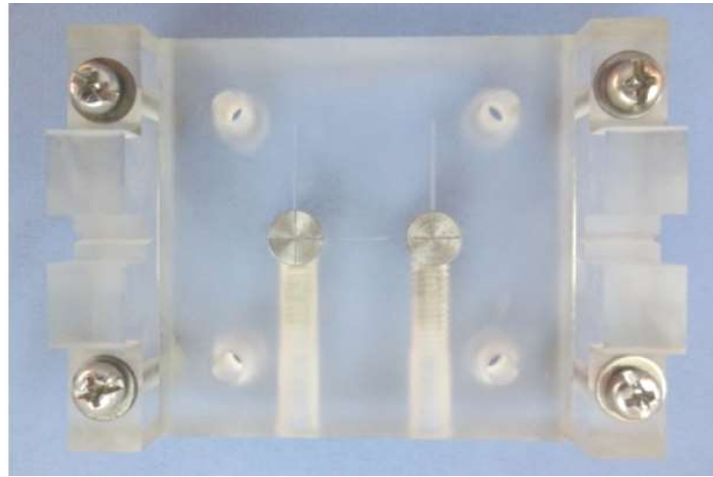
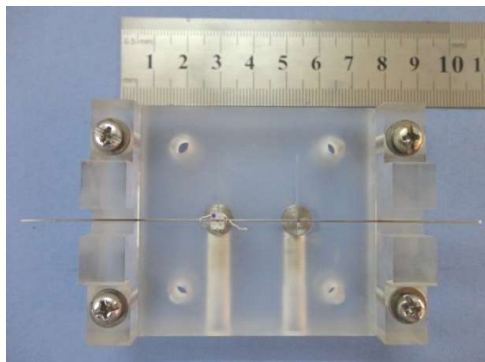


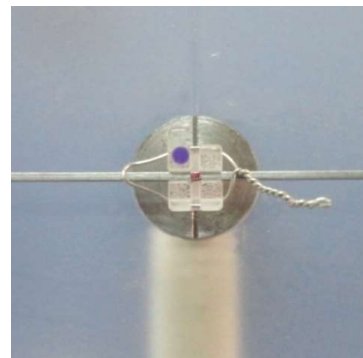
Figure (2): Top View of the Mounting Device

Positioning of the bracket slot onto cylinders was achieved by a stainless steel jig of 0.016" × 0.022" as described by Thomas et al.⁽¹¹⁾ The jig is parallel to the upper edge of the mounting device and passes over the centers of the two cylinders and situate on two groove exist on right and left walls of the device as shown in Figure (3a). The jig was used so that the largest cross-section size 0.022" occupies the entire slot height which assists in eliminating the various tip

and torque values of the different bracket prescriptions which could affect the frictional characteristics. The correct positioning of the bracket on a cylinder was done by matching the center of the bracket with the center on the cross sign and red point plotted on the jig as shown in Figure (3b). Prior to bonding, a metal ligature was used to attach the bracket to the jig to bring it into contact with the base of the slot to ensure that all brackets are in the same level.



A



B

Figure (3): Bracket Bonded on a Cylinder inside the Mounting Device

Epoxy steel glue was used to bond the brackets onto the cylinders where the glue mixed according to the manufacturer instructions with a setting time of four minutes. After setting of the glue, the cylinders with their brackets unscrewed and removed from the mounting device and screwed to the experimental model in such away the cross sign on the cylinders coincide with the vertical lines on the model. By this method, the correct positions of brackets with their cylinders will be guaranteed in all three dimensions.

After assembling the three cylinders with their brackets on the experimental model,

the arch wire ligated to the brackets with elastomeric ligature in conventional brackets or by closing clip in active self-ligating brackets. The experimental model has been attached to the upper clamp of the universal tensile testing machine while the wire has been attached to the lower clamp as shown in Figure (1a). The upper clamp moved upward at a speed of 10 mm/min during the tests which carried out in a dry condition and at a temperature of 29±3 oC.

The universal tensile testing machine was set up to document the amount of the maximum force which represents the static frictional force.⁽¹²⁾

The statistics of the results included; the descriptive (mean, standard deviation, minimum and maximum values), the analysis of variance and Duncan's Multiple Range Test at ($p < 0.05$) significance level.

RESULTS

Descriptive statistics of frictional forces are reported in Tables (1 and 2) for all bracket and wire combinations. Inferential statistics (Duncan Multiple Analysis Range Test) are reported in Tables (3 and 4). The 0.014" NiTi wire and active self-ligating bracket had significantly lower values of frictional

force as compared to the other combinations, whereas the combination of the 0.016" NiTi monocrySTALLine bracket and elastic ligature displayed significantly greater values of frictional force when compared with other combinations as shown in Figure (4). Wire dimension significantly influenced the frictional forces in the three bracket non-aligned and nonleveled system for all types of ceramic brackets used at ($p < 0.05$). The 0.016" NiTi arch wire generated the higher friction level than the 0.014" NiTi for all brackets used in the study.

Table (1): Descriptive Statistics of Static Frictional Forces of Aesthetic Brackets with 0.014" NiTi Arch Wire

Bracket material	Arch wire material	No. of tests	Mean	Standard deviation	Minimum	Maximum
Active self-ligating	0.014" NiTi	10	0.4580	0.0439	0.3900	0.5200
Polycrystalline with metal slot	0.014" NiTi	10	1.7190	0.1236	1.5700	1.900
MonocrySTALLine	0.014" NiTi	10	2.9620	0.0764	2.830	3.090

Table (2): Descriptive Statistics of Static Frictional Forces of Aesthetic Brackets with 0.016" NiTi Arch Wire

Bracket material	Arch wire material	No. of tests	Mean	Standard deviation	Minimum	Maximum
Active self-ligating	0.016" NiTi	10	0.9330	0.0718	0.7800	1.0000
Polycrystalline with metal slot	0.016" NiTi	10	2.1300	0.1122	2.0000	2.3100
MonocrySTALLine	0.016" NiTi	10	3.3980	0.1176	3.2200	3.5300

Table (3): Duncan's Statistics of Static Frictional Forces of 0.014" NiTi Arch Wires

Bracket material	Arch wire material	No. of tests	Mean	Standard deviation	Duncan's analysis
Active self-ligating	0.014" NiTi	10	0.4580	0.0439	A
Polycrystalline with metal slot	0.014" NiTi	10	1.7190	0.1236	B
MonocrySTALLine	0.014" NiTi	10	2.9620	0.0764	C

ANOVA Test: $F = 2040.564$, $p < 0.05$; Different letters mean significant difference

Table (4): Duncan's Statistics of Static Frictional Forces of 0.016" NiTi Arch Wires

Bracket material	Arch wire material	No. of tests	Mean	Standard deviation	Duncan's analysis
Active self-ligating	0.016" NiTi	10	0.9330	0.0718	A
Polycrystalline with metal slot	0.016" NiTi	10	2.1300	0.1122	B
MonocrySTALLine	0.016" NiTi	10	3.3980	0.1176	C

ANOVA Test: $F = 1442.693$, $p < 0.05$; Different letters mean significant difference

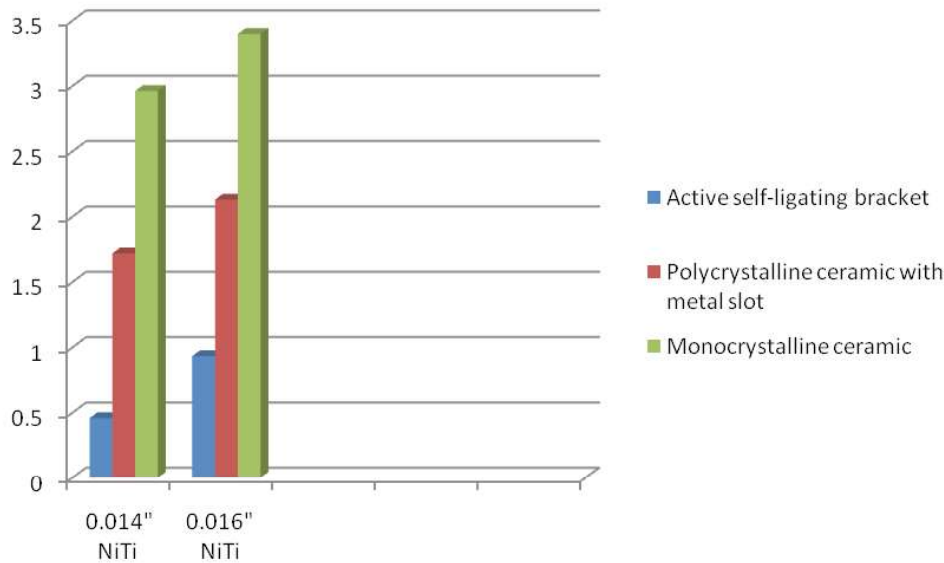


Figure (4): Bar Diagram Representing the Mean of the Static Frictional Forces of Three Different Bracket Types with Two Sizes of NiTi Arch Wires

DISCUSSION

The monocrystalline twin bracket (Pure) with a ceramic slot demonstrated significantly ($p < 0.05$) greater friction than all other esthetic brackets examined. The polycrystalline conventional twin ceramic bracket (Encore) with a metal slot insert demonstrated significantly less friction than (Pure), and the polycrystalline active self-ligating bracket (Sensation) displayed the least amount of frictional forces. Studies that evaluated the frictional force produced by different brackets and wires diverged a great deal because of the variety of methodologies^(3,13) and alloys tested from different companies. This makes it difficult to compare results. However, the present study showed results similar to those of other investigators who pointed to self-ligating brackets as the ones producing the lowest frictional forces.⁽²⁾ This is attributable to the decreased ligation forces of these brackets which caused the corresponding decrease in frictional forces displayed in these systems.

The work of this study agreed with other previous studies that compared different types of ceramic brackets and found that the monocrystalline brackets had the highest frictional forces⁽¹⁴⁾ while the ceramic bracket with metal reinforced slot had a lower frictional force value than did the traditional ceramic bracket^(15,16). Although these studies investigated aligned brackets with rectangular arch wires of $0.019'' \times 0.025''$, high frictional force associated with conventional

ceramic brackets could be attributed to some ceramic bracket characteristics such as hardness and stiffness. Manufacturing procedure, finishing and polishing are difficult to do; this might lead to the granular and pitted surface of the ceramic brackets. The ceramic brackets with metal reinforced slot showed the intermediate values of the frictional force, probably because its smoother bracket slot surface in which the arch wires could slide through⁽¹⁴⁾. The cross-sectional size of the NiTi arch wire used in this study significantly affected the frictional forces. Wires with larger cross-sections showed rising in the frictional forces. Similar results have been obtained from previous studies.⁽⁶⁾

The main reason for the increase in friction as the wire size increased can be attributed to an increase in the stiffness of the wire.⁽¹⁷⁾ Another contributing factor to the greater friction with larger arch wire is from the force of ligation. The larger arch wire would demand a greater stretch of the elastomeric ligature which would subsequently impart a larger normal force and hence more friction.⁽¹⁸⁾

CONCLUSIONS

Self-ligating ceramic bracket is a good choice when aesthetic treatment is desired. The conventional twin ceramic bracket with the metal slot is a suitable alternative because it is relatively cheaper and better in term of less frictional force.

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