**In vitro evaluation of frictional forces of two ceramic orthodontic brackets versus a stainless steel bracket in combination with two types of archwires**

*Valiollah Arash, Mahmoud Rabiee¹, Vahid Rakhshan²³, Sara Khorasani and Farhad Sobouti⁴*

**ABSTRACT**

**Purpose:** The aim of this study was to compare frictional forces between monocrystalline alumina (MA), polycrystalline alumina (PA), and stainless steel (SS) brackets with two SS wires: Rectangular and round.

**Materials and Methods:** In this *in vitro* study, 60 0.022” brackets [20 PA (0° torque, Forestadent, Germany) and 20 MA (0° torque, Ormco, California, USA)] brackets plus 20 SS brackets (0° torque, Foretadent, Germany) and 60 SS archwires (30 rectangular 0.019” ×0.025” archwires and 30 round 0.018” archwires, Orto Technology, USA) were used in subgroups of 10 from the combination of all brackets and all archwires. A universal testing machine (Instron, Model STM 250, Germany) was used to investigate the static frictional resistance. The angulation between the bracket and wire was 0°, and the wires were pulled through the slots at a crosshead speed of 10 mm/min. Two-way and one-way analyses of variance (ANOVA) and Tukey tests were used to analyze the data.

**Results:** Mean (SD) static frictional force for each group was as follows: MA + round: 3.47 (0.38); MA + rectangular: 4.05 (0.47); PA + round: 4.14 (0.37); PA + rectangular: 4.45 (0.65); SS + round: 3.28 (0.22); and SS + rectangular: 4.22 (0.61). Significant effects of bracket types (*P* = 0.001) and archwire types (*P* = 0.000) on the friction force were detected using ANOVA. Tukey test indicated significant differences between PA brackets with both SS and MA brackets (*P* < 0.05), but not between SS and MA brackets. The two archwires as well had significantly different effects (Tukey *P* = 0.000).

**Conclusions:** Based on the present in-vitro study, the PA brackets might create higher frictional forces compared to both SS and MA brackets. The rectangular 0.019” ×0.025” archwire might create greater forces than round 0.018” archwire.

**Key words:** Artificial saliva, ceramic bracket, rectangular arch wire, round arch wire, stainless steel bracket, static friction

**INTRODUCTION**

Orthodontic tooth movement relies on sliding mechanics usually achieved by sliding the wire through the brackets.¹⁻³ Sliding causes friction, which is a force resisting the relative motion of two contacting objects.²⁻⁴⁻⁵ Static frictional resistance exhausts up to 60% of the exerted force for the tooth movement.²⁻⁶ Frictional resistance is undesirable in orthodontic tooth movement, as it might lock the bracket position and disallow tooth movement; in addition, it might bow the archwire and tilt the tooth, or lead to unwanted tooth movements or space losses through anchorage interference.³⁻⁷⁻¹⁰ Therefore, variables that might increase the friction are of interest.

Stainless steel (SS) brackets are still the most useful brackets in orthodontic practice because of their superior working qualities.
The only drawback of these brackets is their appearance.\textsuperscript{[11]} Because of the growing number of adult patients, the esthetic aspect of orthodontic therapy is becoming increasingly important.\textsuperscript{[12]} In an effort to overcome the esthetic problem of orthodontic appliances, ceramic brackets were manufactured in two forms: Polycrystalline alumina (PA) and monocrystalline alumina (MA). These are made of aluminum oxides, which have many advantages such as biocompatibility, good aesthetics, and resistance to temperature and chemical changes.\textsuperscript{[12]} The most apparent difference between polycrystalline and monocrystalline brackets is in their optical clarity. Single crystal brackets are obviously clearer than polycrystalline brackets, which might be translucent and more esthetic.\textsuperscript{[12, 13]} Although these brackets have solved the problem of esthetic, they can cause enamel abrasion, fracture more easily and have a higher coefficient of friction, increasing resistance to sliding mechanics. Ceramic brackets have been found to produce significantly more friction than SS ones. Moreover, the efficacy of tooth movement using ceramic brackets is significantly lower than that of metal brackets.\textsuperscript{[3, 7, 14–17]} Besides, despite their superior aesthetics, monocrystalline brackets are suggested to create higher frictional forces than polycrystalline brackets do.\textsuperscript{[18, 19]}

A decrease in frictional resistance results in a better response of hard and soft tissues. Studies have shown that approximately 50\% of force required for movement of the teeth is used to overcome the frictional force.\textsuperscript{[20]} Factors that affect frictional resistance include type of the bracket, physical properties, size, and alloy of arch wires, saliva, angulation of the wire to the bracket, method of ligation, contact angles, size and design of bracket slot, and the method of wire-bracket ligation.\textsuperscript{[3, 7, 17, 21–27]} Many studies have compared the frictional resistance of different brackets but studies on friction of newly introduced ceramic brackets are controversial.\textsuperscript{[12, 28–30]} Moreover, archwires as well should have a low friction,\textsuperscript{[31]} which necessitates the need to assess the frictional force of different archwires.

The aim of this in vitro study was to evaluate frictional forces produced by three types of brackets combined with two common SS wires. The null hypotheses were that there would be no difference between the frictional forces of the brackets as well as between the frictional resistances of the two archwires.

**MATERIALS AND METHODS**

This in vitro experimental study was performed on 60 Roth 22 prescription 0.022\" slot lower incisor brackets and 60 archwires. The brackets were divided into three groups of \( n = 20 \), each: Two ceramic brackets: MA (0\° torque, Ormco, California, USA) and PA (0\° torque, Foretadent, Germany) and one SS metal bracket (0\° torque, Foretadent, Germany). The archwires were two groups of \( n = 30 \) each: both SS wires, rectangular (0.019\" × 0.025") and round (0.018") (Ortho Technology, USA).

All the brackets were immersed in artificial saliva (Bioxtra, Belgium) for 5 min to simulate oral conditions.\textsuperscript{[30]} In order to stabilize each bracket in a standard vertical position during frictional tests, the bonding surface of each saliva-soaked bracket was glued to a metal surface, which would act as a base for the bracket-wire setup in the next steps. After fixing the brackets on metal bases, the wires were secured into the bracket slots by elastomeric O-rings (Ortho Technology, USA).

Bracket-wire combinations were divided into six subgroups \( (n = 10) \) of three bracket types and two wire types:
- MA + round wire
- MA + rectangular wire
- PA + round wire
- PA + rectangular wire
- SS + round wire
- SS + rectangular wire

**Measurement of Frictional Forces**

A universal testing machine (Instron, Model STM 250, Germany) with a maximum load of 50 kg was used to measure frictional forces. The metal base was adapted to the testing machine, and the wires were pulled through the slots at a speed of 10 mm/ min while the angulation between the bracket and wire was 0°. The test was repeated 10 times for the 10 specimens in each subgroup. Based on the diagram obtained from the movement of the wire into the bracket, the average of the highest recorded force was considered as the static friction [Figure 1].

**Statistical Analysis**

Descriptive statistics were calculated for the groups. According to the Kolmogorov–Smirnov test, all groups were normally distributed. One-way and two-way analyses of variance (ANOVA) and Tukey post hoc test of SPSS (version 20, IBM, USA) were used to evaluate the results. The significance level was predetermined as 0.05.

**RESULTS**

The lowest mean frictional forces with round wire belonged to the SS bracket, and then polycrystalline and monocrystalline
The highest mean frictional forces recorded with rectangular wire belonged to the polycrystalline, and then SS and monocrystalline brackets [Table 1].

The null hypotheses were rejected. Two-way ANOVA indicated significant effects of bracket types (P < 0.001) and archwire types (P = 0.000) on the friction force. The interaction was nonsignificant [P = 0.120, Table 1].

The Tukey post-hoc test indicated significant differences between polycrystalline brackets with both metal and monocrystalline brackets, but not between metal and monocrystalline brackets [Figure 2, Tables 2 and 3]. The two archwires as well had significantly different effects [Tukey P = 0.000, Table 3].

One-way ANOVA indicated an overall statistically significant difference between subgroups (P < 0.001). The Tukey test showed the fewest significant differences between monocrystalline-rectangular and all other subgroups while the metal-round subgroup showed the greatest number of significant differences with other subgroups [Table 4].

**DISCUSSION**

The present study compared frictional forces between two ceramic brackets and one SS bracket with two different sizes and shapes of SS wires. In this study, friction produced by polycrystalline bracket was higher than that produced by monocrystalline which had a frictional resistance similar to SS bracket, supporting some previous studies and contrasting some others stating that monocrystalline might generate greater friction.

The results of this study regarding the higher frictional forces produced by MA compared to MA and SS brackets were in contrast to those of Cha et al., in which the difference between PA and MA was not significant and friction in polycrystalline brackets was lower than SS brackets. Similarly, De Franco et al. reported that the frictional force between mono- and polycrystalline brackets were the same, which contrasted our results. As well, Saunders and Kusy did not show any differences in frictional force between mono- and polycrystalline brackets. Guerrero et al. showed that the highest frictional force was produced by monocrystalline bracket (Inspire) with 0.019” x0.025” SS wire, and the lowest one was produced with SS bracket and SS wire (0.019” x0.025”). Several factors such as different bracket and wire brands, different methods of manufacturing the brackets, different intersections of the base and walls of the slot, and the kind of artificial saliva used in the experiment might explain the differences. The metal slot has a smoother surface than ceramic and therefore it will create less frictional resistance to sliding. This agrees with many previous investigations that have shown frictional resistance was reduced by lining the slots of conventional ceramic brackets with SS inserts.

In general, increasing the size of the bracket and using rectangular wire instead of round wire can increase friction. In addition, in some cases when there is bracket-wire angulation and binding, the friction in round wire may be greater than that in rectangular wire. The reason can be the bite into the round wire at one point, including an indentation in the wire. However, with a rectangular wire, the force is distributed over a larger area, resulting in less pressure and, therefore, less resistance to movement. Friction in rectangular wire used in this study was more than that in round wire. The difference was significant except in polycrystalline bracket, resembling previous studies. However, it should be noted that the wires were different not only in shape but also in the size of their cross-section, which disallows making strong conclusions regarding the wire type.

In interpreting the findings of the study the limitations of the in-vitro studies should be considered. In the present study, artificial saliva was used to simulate the oral condition. Lubricants depending on the alloy type have different

![Figure 2: Comparison of frictional forces between the brackets and wires. Different letters indicate statistically significant differences (P < 0.05) between the groups](image)

| Bracket type    | Archwire | Mean (SD) | Minimum | Median | Maximum | 95% CI       |
|-----------------|----------|-----------|---------|--------|---------|--------------|
| Monocrystalline| Round    | 3.479 (0.3894) | 3.055  | 3.354  | 4.341  | 3.176-3.782  |
|                 | Rectangular | 4.056 (0.4723) | 3.237  | 4.237  | 4.67   | 3.753-4.359  |
| Polycrystalline| Round    | 4.147 (0.3723) | 3.458  | 4.194  | 4.697  | 3.845-4.450  |
|                 | Rectangular | 4.454 (0.6549) | 3.458  | 4.531  | 5.371  | 4.151-4.756  |
| Metal           | Round    | 3.283 (0.2244) | 3.029  | 3.213  | 3.66   | 2.980-3.586  |
|                 | Rectangular | 4.222 (0.6119) | 3.384  | 3.992  | 5.273  | 3.919-4.524  |

SD – Standard deviation; CI – Confidence interval for the mean
In SS alloys, lubricants react with the chromium oxide layer, which provides the wire with a lower coefficient of friction, changing their surface tension and producing an adhesive effect. The important point in simulating is to choose a material with the same viscosity as that of natural saliva. Human saliva might lead to higher frictional forces than forces produced in artificial saliva but close to frictional forces measured in dry condition. Artificial saliva might have a lower viscosity and a higher wettability than natural saliva. However, salivary lubrication might have an inconsistent and controversial effect such as being invalid (if artificial saliva is used), increasing the friction, or playing an insignificant role.

**CONCLUSIONS**

Within the limitations of this in vitro study, it was concluded that polycrystalline brackets might create higher frictional forces compared to both SS and monocrystalline brackets.

The rectangular (0.019" × 0.025") archwire can create greater frictional forces compared to the round (0.018") wire.

### Table 2: Results of Tukey post hoc test, comparing friction in bracket types

| (I) Bracket type   | (J) Bracket type     | Mean difference (I-J) | P     | 95% CI            |
|--------------------|----------------------|-----------------------|-------|-------------------|
| Monocrystalline    | Polycrystalline      | -0.53310*             | 0.002 | -0.897 (-0.169)   |
| Metal              |                      | 0.01515               | 0.994 | -0.349 -0.379     |
| Polycrystalline    | Monocrystalline      | 0.53310*              | 0.002 | 0.169-0.897       |
| Metal              |                      | 0.54825*              | 0.002 | 0.185-0.912       |
| Metal              | Monocrystalline      | -0.01515              | 0.994 | -0.379-0.349      |
| Polycrystalline    |                      | -0.54825*             | 0.002 | -0.912 (-0.185)   |

CI – Confidence Interval. *P<0.05

### Table 3: Descriptive statistics for friction caused by archwires and brackets

| Tested material | Mean     | 95% CI       |
|-----------------|----------|--------------|
| Bracket         |          |              |
| Monocrystalline | 3.767    | 3.553-3.981  |
| Polycrystalline | 4.301    | 4.087-4.515  |
| Metal           | 3.752    | 3.538-3.966  |
| Archwire        |          |              |
| Round           | 3.636    | 3.462-3.811  |
| Rectangular     | 4.244    | 4.069-4.418  |

CI – Confidence Interval

### Table 4: Pairwise comparisons between subgroups, using Tukey test

| (I) Subgroups     | (J) Subgroups          | Mean difference (I-J) | P     | 95% CI            |
|-------------------|------------------------|-----------------------|-------|-------------------|
| Monocrystalline-round | Monocrystalline-rectangular | -0.577               | 0.091 | -1.208-0.054     |
| Polycrystalline-round | Monocrystalline-rectangular | -0.6684*             | 0.032 | -1.299 (-0.038)  |
| Polycrystalline-round | Polycrystalline-rectangular | -0.9749*             | 0.000 | -1.606 (-0.344)  |
| Polycrystalline-round | Metal-round             | 0.196                 | 0.940 | -0.435-0.826     |
| Polycrystalline-round | Metal-rectangular      | -0.7426*             | 0.012 | -1.373 (-0.112)  |
| Monocrystalline-rectangular | Monocrystalline-round      | 0.577                | 0.091 | -0.054-1.208     |
| Polycrystalline-rectangular | Monocrystalline-round      | -0.091               | 0.998 | -0.722-0.539     |
| Polycrystalline-rectangular | Polycrystalline-round      | -0.398               | 0.435 | -1.028-0.233     |
| Polycrystalline-rectangular | Metal-round            | 0.7729*              | 0.008 | 0.142-1.404      |
| Polycrystalline-rectangular | Metal-rectangular      | -0.166               | 0.971 | -0.796-0.465     |
| Monocrystalline-round | Monocrystalline-round      | 0.6684*              | 0.032 | 0.038-1.299      |
| Monocrystalline-round | Polycrystalline-round      | 0.091                | 0.998 | -0.539-0.722     |
| Monocrystalline-round | Polycrystalline-rectangular | -0.307              | 0.705 | -0.937-0.324     |
| Monocrystalline-round | Metal-round             | 0.8642*              | 0.002 | 0.234-1.495      |
| Monocrystalline-round | Metal-rectangular      | -0.074               | 0.999 | -0.705-0.556     |
| Polycrystalline-round | Monocrystalline-round      | 0.9749*              | 0.000 | 0.344-1.606      |
| Polycrystalline-round | Monocrystalline-round      | 0.398                | 0.435 | -0.233-1.028     |
| Polycrystalline-round | Polycrystalline-round      | 0.307                | 0.705 | -0.324-0.937     |
| Polycrystalline-round | Metal-round             | 1.1707*              | 0.000 | 0.540-1.801      |
| Polycrystalline-round | Metal-rectangular      | 0.232                | 0.884 | -0.398-0.863     |
| Metal-round | Monocrystalline-round      | -0.196               | 0.940 | -0.826-0.435     |
| Metal-round | Monocrystalline-round      | -0.7729*             | 0.008 | -1.404 (-0.142)  |
| Metal-round | Polycrystalline-round      | -0.8642*             | 0.002 | -1.495 (-0.234)  |
| Metal-round | Polycrystalline-rectangular | -1.1707*            | 0.000 | -1.801 (-0.540)  |
| Metal-round | Metal-rectangular      | -0.9384*             | 0.001 | -1.569 (-0.308)  |
| Metal-rectangular | Monocrystalline-round      | 0.7426*              | 0.012 | 0.112-1.373      |
| Metal-rectangular | Monocrystalline-round      | 0.166                | 0.971 | -0.465-0.796     |
| Metal-rectangular | Polycrystalline-round      | 0.074               | 0.999 | -0.556-0.705     |
| Metal-rectangular | Polycrystalline-rectangular | -0.232              | 0.884 | -0.863-0.398     |
| Metal-rectangular | Metal-round             | 0.9384*              | 0.001 | 0.308-1.569      |

CI – Confidence Interval. *P<0.05

Effects of SS alloys, lubricants react with the chromium oxide layer, which provides the wire with a lower coefficient of friction, changing their surface tension and producing an adhesive effect. The important point in simulating is to choose a material with the same viscosity as that of natural saliva. Human saliva might lead to higher frictional forces than forces produced in artificial saliva but close to frictional forces measured in dry condition. Artificial saliva might have a lower viscosity and a higher wettability than natural saliva. However, salivary lubrication might have an inconsistent and controversial effect such as being invalid (if artificial saliva is used), increasing the friction, or playing an insignificant role.
The rectangular wire combined with polycrystalline bracket had the highest frictional force. SS bracket combined with round wire produced the lowest frictional resistance.

REFERENCES

1. Hosseinzadeh Nik T, Hooshmand T, Farazdagi H, Mehrabi A, Razavi ES. Effect of chlorhexidine-containing prophylactic agent on the surface characterization and frictional resistance between orthodontic brackets and archwires: An in vitro study. Prog Orthod 2013;14:48.

2. Nanda R. Biomechanics in Clinical Orthodontics. Philadelphia: WB Saunders; 1997. p. 50-1.

3. Williams CL, Khalaf K. Frictional resistance of three types of ceramic brackets. J Oral Maxillofac Res 2012;4:e3.

4. Hain M, Dhopatkar A, Rock P. The effect of ligation method on friction in sliding mechanics. Am J Orthod Dentofacial Orthop 2003;123:416-22.

5. Tecco S, Festa F, Caputi S, Traini T, Di Iorio D, D’Attilio M. Friction of conventional and self-ligating brackets using a 10 bracket model. Angle Orthod 2005;75:1041-5.

6. Drescher D, Bourauel C, Schumacher HA. Frictional forces between bracket and wire arch. Am J Orthod Dentofacial Orthop 1989;96:397-404.

7. Omont HN, Motze RN, Bagby MD. Frictional properties of metal and ceramic brackets. J Clin Orthod 1992;26:425-32.

8. Nicoll J. Frictional forces in fixed orthodontic appliances. Dent Pract Dent Rec 1968;18:362-6.

9. Kapila S, Angolkar PV, Duncanson MG Jr, Nanda RS. Evaluation of friction between edgewise stainless steel brackets and orthodontic wires of four alloys. Am J Orthod Dentofacial Orthop 1990;98:117-26.

10. Huffman DJ, Way DC. A clinical evaluation of tooth movement along arch wires of two different sizes. Am J Orthod 1983;83:453-9.

11. Nishih C, da Motta AF, Elias CN, Mucha JN. In vitro evaluation of frictional forces between archwires and ceramic brackets. Am J Orthod Dentofacial Orthop 2004;125:56-64.

12. Eslamian L, Borzabadi-Farahani A, Mousavi N, Ghasemi A. A comparative study of shear bond strength between metal and ceramic brackets and artificially aged composite restorations using different surface treatments. Eur J Orthod 2012;34:610-7.

13. Swartz ML. Ceramic brackets. J Clin Orthod 1988;22:82-8.

14. Kusy RP, Whitley JQ. Coefficients of friction for arch wires in stainless steel and polycrystalline alumina bracket slots. J. The dry state. Am J Orthod Dentofacial Orthop 1990;98:300-12.

15. Tanne K, Matsubara S, Shibaguchi T, Sakuda M. Wire friction from ceramic brackets during simulated canine retraction. Angle Orthod 1991;61:285-90.

16. Ghaafari J. Problems associated with ceramic brackets suggest limiting use to selected teeth. Angle Orthod 1992;62:145-52.

17. Keith O, Jones SP, Davies EH. The influence of bracket material, ligation force and wear on frictional resistance of orthodontic brackets. Br J Orthod 1993;20:109-15.

18. Karamouzos A, Athanasiou AE, Papadopoulos MA. Clinical characteristics and properties of ceramic brackets: A comprehensive review. Am J Orthod Dentofacial Orthop 1997;112:34-40.

19. Kusy RP, Whitley JQ. Friction between different wire-bracket configurations and materials. Semin Orthod 1997;3:166-77.

20. Ehsani S, Mandich MA, El-Bialy TH, Flores-Mir C. Frictional resistance in self-ligating orthodontic brackets and conventionally ligated brackets. A systematic review. Angle Orthod 2009;79:592-601.

21. Read-Ward GE, Jones SP, Davies EH. A comparison of self-ligating and conventional orthodontic bracket systems. Br J Orthod 1997;24:309-17.

22. Pizzoni L, Ravnholt G, Melsen B. Frictional forces related to self-ligating brackets. Eur J Orthod 1998;20:283-91.

23. Schumacher HA, Bourauel C, Drescher D. The effect of the ligature on the friction between bracket and arch. Fortschr Kieferorthop 1990;51:106-16.

24. Henao SP, Kusy RP. Frictional evaluations of dental typodont models using four self-ligating designs and a conventional design. Angle Orthod 2005;75:75-85.

25. Thomas S, Sherriff M, Birnie D. A comparative in vitro study of the frictional characteristics of two types of self-ligating brackets and two types of pre-adjusted edgewise brackets tied with elastomeric ligatures. Eur J Orthod 1998;20:589-96.

26. Lombardo L, Wierusz W, Toscano D, Lapenta R, Kaplan A, Siciliani G. Frictional resistance exerted by different lingual and labial brackets: an in vitro study. Prog Orthod 2013;14:37.

27. Nucera R, Lo Giudice A, Materese G, Artemisia A, Bramante E, Crupi P, et al. Analysis of the characteristics of slot design affecting resistance to sliding during active archwire configurations. Prog Orthod 2013;14:35.

28. De Franco D, Spiller RE Jr, von Fraunhofer JA. Frictional resistances using Teflon-coated ligatures with various bracket-archwire combinations. Angle Orthod 1995;65:63-72.

29. Saunders CR, Kusy RP. Surface topography and frictional characteristics of ceramic brackets. Am J Orthod Dentofacial Orthop 1994;106:76-87.

30. Guerrero AP, Guariza Filho O, Tanaka O, Camargo ES, Vieira S. Evaluation of frictional forces between ceramic brackets and archwires of different alloys compared with metal brackets. Braz Oral Res 2010;24:40-5.

31. Chng CK, Foong K, Gandedkar NH, Chan YH, Chew CL. A new esthetic fiber-reinforced polymer composite resin archwire: A comparative atomic force microscope (AFM) and field-emission scanning electron microscope (FESEM) study. Prog Orthod 2014;15:39.

32. Bazakidov E. Evaluation of frictional resistance of esthetic brackets. [Thesis]: University of Oklahoma; 1995.

33. Cha JY, Kim KS, Hwang CJ. Friction of conventional and silica-insert ceramic brackets in various bracket-archwire combinations. Angle Orthod 2007;77:100-7.

34. Cacciafesta V, Sfondrini MF, Scribante A, Klersy C, Auricchio F. Evaluation of frictional forces between archwires and ceramic brackets with metal slot inserts. Angle Orthod Dentofacial Orthop 2003;124:403-9.

35. Kapur Wadhwa R, Kwon HK, Close JM. Frictional resistances of different bracket-wire combinations. Aust Orthod J 2004;20:25-30.

36. Jones SP, Amoah KG. Static frictional resistances of polycrystalline ceramic brackets with conventional slots, glazed slots and metal slot inserts. Aust Orthod J 2007;23:36-40.

37. Rajakulendran J, Jones S. Static frictional resistances of polycrystalline ceramic brackets with metal slot inserts. Aust Orthod J 2006;22:147-52.

38. Kusy RP, Whitley JQ, Prewitt MJ. Comparison of the frictional coefficients for selected archwire-bracket slot combinations in the dry and wet states. Angle Orthod 1990;61:293-302.

39. Al-Mansouri N, Palmer G, Moles DR, Jones SP. The effects of lubrication on the static frictional resistance of orthodontic brackets. Aust Orthod J 2011;27:132-8.

40. Kusy R, Saunders C. Surface textures and frictional characteristics of ceramic brackets. J Dent Res 1991;70:483.

41. Downing A, McCabe JF, Gordon PH. The effect of artificial saliva on the frictional forces between orthodontic brackets and archwires. Br J Orthod 1995;22:41-6.

42. Andreassen GF, Quevedo FR. Evaluation of friction force in the 0.022×0.028 edgewise bracket in vitro. J Biomech 1970;3:151-60.

How to cite this article: Arash V, Rabiee M, Rakhshan V, Khorasani S, Sobouti F. In vitro evaluation of frictional forces of two ceramic orthodontic brackets versus a stainless steel bracket in combination with two types of archwires. J Orthodont Sci 2015;4:42-6.

Source of Support: Nil, Conflict of Interest: None declared.