Original Article

Prophylaxis protocols and their impact on bracket friction force

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ABSTRACT

Objective: To evaluate the effect of two different prophylaxis protocols on the friction force in sliding mechanics during in vivo leveling and alignment.

Materials and Methods: The sample comprised 48 hemi-arches divided into three groups according to the prophylactic protocol adopted. Group 1 consisted of patients undergoing prophylaxis with sodium bicarbonate, group 2 consisted of patients submitted to prophylaxis with glycine, and group 3 consisted of patients without prophylaxis, as a control. All patients received hygiene instructions and, with the exception of group 3, prophylaxis was performed monthly. After 10 months, the brackets were removed from the oral cavity and submitted to friction force tests and qualitative analysis by scanning electron microscopy. Analysis of variance followed by Tukey tests was performed for intergroup comparison regarding the friction force.

Results: The experimental groups presented significantly smaller friction forces than the group without prophylaxis. Accordingly, qualitative analysis showed greater debris accumulation in the group without the prophylactic procedures.

Conclusions: Prophylactic blasting with sodium bicarbonate or glycine can significantly prevent an increase of the friction force during sliding mechanics. (*Angle Orthod.* 2019;89:883–888.)

KEY WORDS: Orthodontic friction; Dental prophylaxis; Orthodontics; Corrective

INTRODUCTION

During orthodontic mechanics, the amount of force transmitted to the teeth is associated with the sliding resistance of the wire in the bracket slots.[1,2] This resistance is directly affected by the coefficient of friction created by the bracket-wire-ligature system,[3] which depends on the surface roughness of the component materials and the force connecting the wire into the slot.[4,5]

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It is essential to understand the impact of the friction force between the wire and bracket in order to apply the appropriate force and obtain an adequate biological response, preventing any undesirable effects[6,7] and thus improving patient comfort and treatment efficiency.[8]

The friction force can be divided into two components: static friction, in which movement of the bodies has not begun since the friction force is equal to or greater than the applied force, and kinetic or dynamic friction, which acts during sliding of the bodies when the applied force surpasses the static friction.[1,9]

Many variables can influence the amount of friction generated between the bracket-wire-ligature system.[10,11] The most common factor is accumulation of debris and plaque, which increases the surface roughness of orthodontic materials, primarily brackets, that have the tendency to remain until the end of orthodontic treatment.[11]

Prophylaxis regimens, including educational/motivational instructions or professional oral hygiene procedures, have been described as an important resource for the control of debris and plaque on the surface of brackets and teeth.[12,13] It could be argued that these approaches may play an important role in the reduction of friction during orthodontic mechanics.

Few studies[14,15] have evaluated the influence of prophylaxis (air-powder polishing) on the friction force of brackets at the end of orthodontic treatment. Their findings indicated that this technique reduces debris and decreases the friction levels. However, other in vitro studies demonstrated that prophylaxis showed negative effects, increasing bracket surface roughness and friction during sliding mechanics.[16,17] These results may be influenced to some degree by the use of as-received brackets without considering other in vivo clinical features.

In this context, the current evidence available is controversial regarding the influence of prophylaxis during orthodontic treatment. Therefore, it seems necessary to perform studies evaluating the effect of prophylaxis in the friction force during orthodontic treatment, especially concerning sliding mechanics when friction could influence treatment efficiency. Thus, the purpose of this study was to evaluate the impact of monthly prophylaxis performed with sodium bicarbonate and glycine on the friction force in sliding mechanics during in vivo leveling and alignment.

MATERIALS AND METHODS

This study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo, Brazil. The sample size was calculated based on an alpha significance level of 5% and a beta of 20%, to detect a mean difference of 0.52N (Newtons), with a standard deviation of 0.24N in the friction force after clinical use.[18] Although a minimum sample of 6 brackets was required in each group, 16 brackets per group were used to increase the precision of the results.

A prospective sample of patients was recruited between 2015 and 2017 from a private practice (Volta Redonda, RJ, Brazil) based on the following inclusion criteria: patients who would begin orthodontic treatment, with all permanent teeth up to the second molars, and absence of previous orthodontic treatment. Those with a history of periodontal disease and smokers were excluded from the sample. All patients signed informed consent and agreed to participate in the study. The initial sample comprised 16 patients (64 hemi-arches) treated with conventional fixed appliances (Kirium-Abzil, São José dos Campos, SP, Brazil) with a slot size of 0.022×0.028 inches.

At the beginning of orthodontic treatment, all patients were instructed with the same oral hygiene and dietary guidelines and received equal oral hygiene products (Colgate toothbrush and Colgate Maximum Protection with 1450 ppm fluoride dentifrice). Then, the 64 hemi-arches were randomly allocated into three different groups, based on the type of prophylaxis protocol that would be performed:

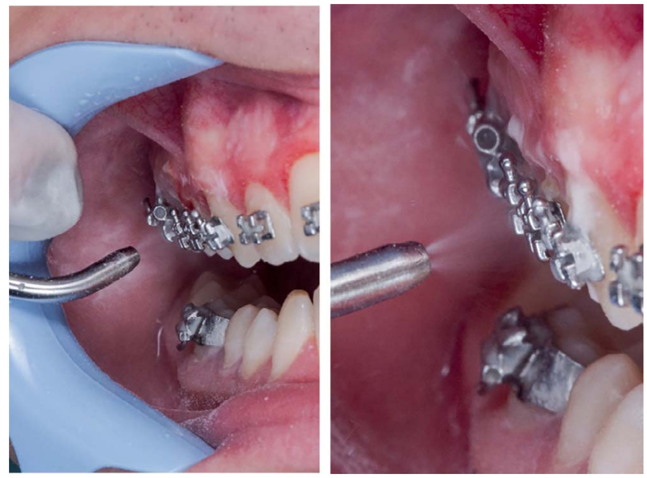

Figure 1. Prophylaxis (air-powder polishing) performed monthly.

Group 1 (G1): Monthly cleaning with sodium bicarbonate air-powder (Polident, Polidental, Cotia, SP, Brazil), performed by the orthodontist, without the archwire.

Group 2 (G2): Monthly cleaning with glycine air-powder (Clinpro Prophy Powder, 3M, Seefeld, Germany), performed as mentioned above.

Group 3 (G3): Without prophylaxis, serving as a control group.

The split-mouth experimental model was performed so that, for each patient of the sample, two hemi-arches from the same side were allocated for G3 and the remaining two hemi-arches for groups 1 or 2. Sixteen hemi-arches from G3 were randomly excluded to equalize the number of brackets per group. Thus, the final sample included 48 hemi-arches, with one second premolar bracket each.

For 10 months, the brackets underwent intraoral exposure during leveling and alignment. This treatment time was standardized for all patients. During this period, monthly, the wires were removed and the brackets of G1 and G2 received air-powder polishing cleaning with sodium bicarbonate and glycine, respectively, using an appropriate device (Practical Jet, Kondortech, São Carlos, SP, Brazil; Figure 1). Each bracket was blasted for 10 seconds, at a distance of 5 mm, with the jet perpendicular to the bracket surface.[12,16,17]

After the leveling and alignment phase, the second premolar brackets were carefully removed by the same operator using a thin cutting plier (Orthopli Corporation, Philadelphia, Penn) close to the base of the brackets.[15,18] The effect of intraoral exposure on the brackets was analyzed quantitatively with a friction test and evaluated qualitatively using scanning electron microscopy (SEM).

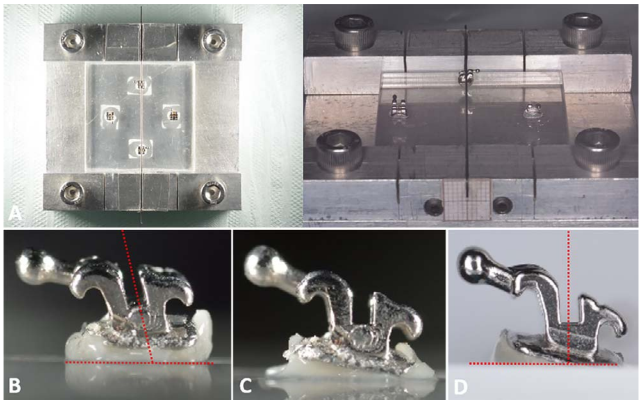

Figure 2. Friction test preparation. (A) Acrylic base with four bonded brackets. (B) Bracket positioning with composite without photocuring. (C) Bracket perpendicularly aligned to the base using a 0.021 × 0.025-inch stainless steel wire, without photocuring. (D) Bracket with the inclination and angulation corrected, after photocuring.

Friction Force

The friction test was performed using acrylic plates (area of 6.0 × 6.0 cm and thickness of 0.4 cm).[18,19] Four brackets were bonded to each base with conventional composite resin (Opallis, FGM, Joinville, Brazil) and, before photocuring, the brackets were perpendicularly aligned to the bases using a 0.021 × 0.025-inch stainless steel (SS) wire to obtain 0° of angulation and inclination in the friction test device[20] (Figure 2). All wires were cleaned with 70% alcohol before each friction test to eliminate any debris or oiliness that could interfere with the results.[19]

The second premolar brackets from the three groups were tested using an Instron universal testing machine (model 3342, Instron Corp, Canton, Mass) simulating 5-mm sliding on 6-cm segments of 0.019 × 0.025-inch SS wires[21] (Figure 3). The speed of the tests was 5 mm/min, and the force levels were registered by a 10N load cell.[11,22] The ligation system was standardized using 200 g of force with a device adapted to the universal machine, as previously reported.[20] This device provided a constant 100 g of force on each side (mesial and distal) of the bracket (Figure 4). The tests were performed in a dry environment, and each bracket and wire was used only once.[23]

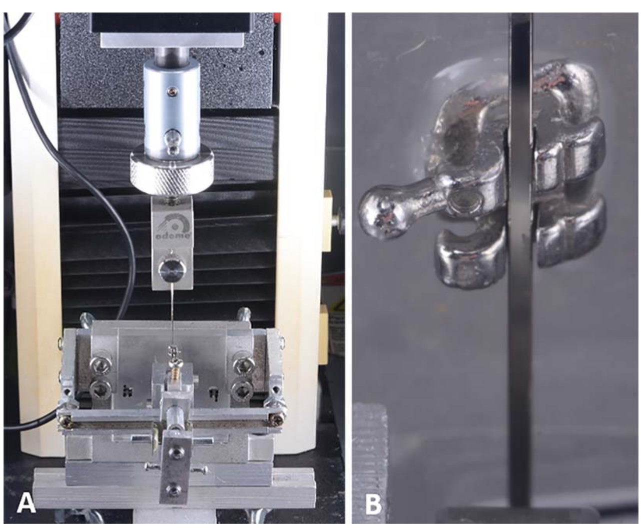

Figure 3. (A) Instron Universal Testing Machine, model 3342. (B) Friction test with 6-cm segments of 0.019 × 0.025-inch stainless steel wire.

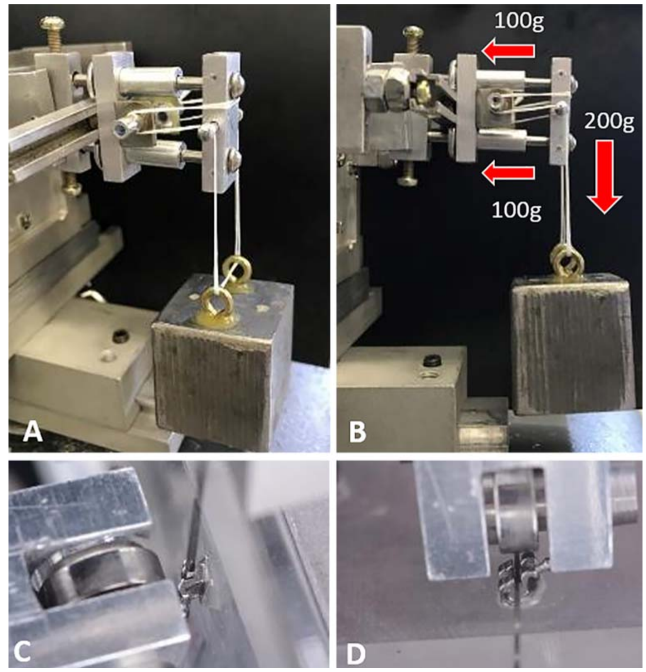

Figure 4. (A–D) Device developed to control the ligation force between the bracket and wire.

Two friction forces were considered during tests: static friction (maximum initial force before the sliding movement) and kinetic friction (mean friction force measurements between the second and third millimeter of sliding). The first and the last 2 mm were disregarded.[11,22]

Superficial Roughness

Two samples of first premolar brackets from each group were selected and directly examined by SEM (Aspex Express, Fei Europe, Eindhoven, the Netherlands). Frontal and lateral images at 25× and 100× magnifications were captured, respectively.[16]

Statistical Analyses

Normal distribution of the variables was checked and confirmed through Kolmogorov-Smirnov tests. Analysis of variance followed by Tukey tests was used to evaluate intergroup differences regarding static and

Table 1. Intergroup Comparisons Regarding Static and Kinetic Friction (Analysis of Variance, Followed by Tukey Tests)

	G1: Sodium Bicarbonate		G2: Glycine		G3: Without Prophylaxis		
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	*P*
Static friction, N	0.232 A	0.061	0.230 A	0.092	0.352 B	0.170	.006*
Kinetic friction, N	0.221 A	0.086	0.223 A	0.070	0.304 B	0.136	.039*

* Different letters indicate statistically significant intergroup differences at $P < .05$.

kinetic friction. Statistical tests were performed with Statistica software (Statistica for Windows, version 7.0, StatSoft, Tulsa, Okla), with a level of significance set at $P < .05$.

RESULTS

The groups submitted to prophylaxis with sodium bicarbonate and glycine demonstrated significantly smaller static and kinetic friction when compared with the group without prophylaxis (Table 1). Both experimental groups showed similar friction values.

The SEM images showed accumulation of debris and plaque in all groups submitted to intraoral exposure. However, group 3 showed greater debris and plaque accumulation than the groups exposed to prophylaxis in the frontal and lateral views (Figures 5 and 6).

DISCUSSION

Generally, studies evaluating the friction force in brackets after intraoral aging use a control group composed of as-received brackets.[11,18,22,24] The comparison between as-received and as-retrieved brackets showed greater friction values after intraoral aging, which is well established in the literature. In this context, this study aimed to evaluate the impact of different prophylaxis protocols on the friction force during sliding mechanics. Therefore, a control group of brackets submitted to intraoral aging without prophylaxis was more suitable for clinical simulation.[25]

This study included an in vivo clinical phase, and the brackets were analyzed with a strict in vitro methodology. In addition, to reduce the number of variables that could interfere with the results and introduce bias, some precautions were taken regarding orthodontic treatment and in vitro analysis.

SEM was performed on first premolar brackets because this test affected the bracket surface and would interfere with the subsequent in vitro test. Therefore, the second premolar brackets were used exclusively for the friction force evaluation.

Orthodontic Treatment Characteristics

Previous studies[5,6] confirmed differences regarding surface roughness on orthodontic brackets of different brands, models, and materials. Thus, the same brand and bracket material (Kirium-Abzil) was used in this study. In addition, the patients were treated by the same experienced orthodontist, and the wire sequence during the leveling and alignment phase was also standardized as follows: 0.014, 0.016, 0.018, and 0.016 $\times$ 0.022-inch and 0.019 $\times$ 0.025-inch nickel-titanium superelastic archwires, using elastic or metallic ligation. During this phase, only two brackets from two patients experienced adhesive failures.

The prophylaxis methodology performed in groups 1 and 2 was based on the recommendation of other studies[12,17] that compared different angulations, distances, and blasting times. These factors were controlled during the prophylactic procedure to maintain the bracket integrity and retention.[12,16]

Removal of the brackets for subsequent in vitro evaluation was performed with a thin cutting plier, which has previously been reported as an effective method to prevent bracket distortion.[18,26] In general, every possible effort to standardize the in vivo period was performed to prevent interference with the in vitro tests.

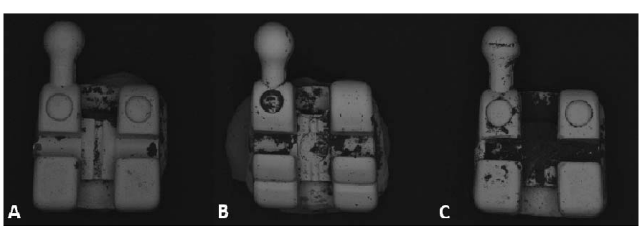

Figure 5. SEM micrograph frontal images. (A) Bracket treated with sodium bicarbonate air-powder. (B) Bracket treated with glycine air-powder. (C) Bracket without prophylaxis.

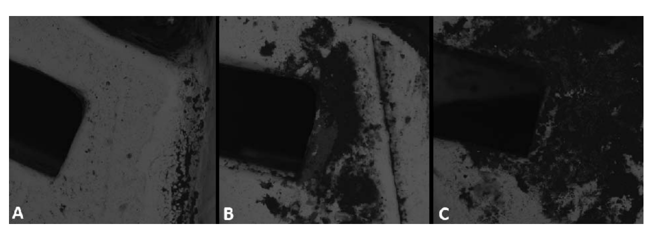

Figure 6. SEM micrograph profile images. (A) Bracket treated with sodium bicarbonate air-powder. (B) Bracket treated with glycine air-powder. (C) Bracket without prophylaxis.

In Vitro Test

After removal, the brackets were tested after a few hours. Differently from previous studies,[11,22,27] which performed bracket cleaning after removal, the friction force was tested in a dry environment without cleaning, to preserve the bracket conditions.[23]

A device associated with a 0.021 × 0.025-inch SS wire was used to avoid any angulation and inclination effect produced by the brackets, thereby preventing friction originating from binding and notching effects that could interfere in the results[22] (Figure 2). The friction test was performed using a single 0.019 × 0.025-inch SS wire for each bracket tested, with both tested only once to prevent any possible damage to the sliding structures, increasing surface roughness and consequently the coefficient of friction[6,28] (Figure 3B). Even though care was taken to avoid any failure, one bracket from the control group failed during the in vitro analysis and was discarded.

Another variable controlled during the in vitro tests was the intensity of the ligation force applied between the bracket and wire. Instead of using an elastic or metallic ligation force, which are unstable[29] or operator dependent,[30] a device capable of applying an exact ligation force of 200 g was developed for the present study, as previously suggested (Figure 4).[20]

Prophylaxis and Friction Force

Accumulation of calcified and noncalcified plaque within the bracket slot is one of the main factors responsible for increasing the friction force during orthodontic therapy.[22,31] Thus, satisfactory control of oral hygiene is important because plaque accumulation not only decreases the effectiveness of the sliding mechanics by increasing the friction force but also promotes higher cariogenic potential.[32] Although many hygiene protocols could be investigated, only prophylactic methods were compared in this study since they are the most effective and common procedures clinically performed in orthodontics.[12,33]

The groups treated with both prophylaxis protocols exhibited effective hygiene control, resulting in significantly smaller friction values when compared with the group without prophylaxis (Table 1). Similar results were found in previous investigations[14,15]; however, this study followed a standardized clinical protocol and in vitro methodology to reduce the incorporation of possible biases. Nevertheless, it should be considered that the impact of prophylaxis on the friction force is still controversial. Some studies showed that the prophylactic procedure with sodium bicarbonate may compromise the bracket surface and increase the amount of friction during sliding mechanics.[16,17]

Even though prophylaxis may cause changes in the surface of the bracket slots, this study demonstrated that, clinically, the effect of the procedure was positive regarding friction, considering that the presence of debris and plaque promoted a significantly greater increase in the friction force (group 3) than the possible damage caused by prophylaxis (groups 1 and 2). Another concern that should be considered is the abrasiveness of sodium bicarbonate on the enamel. However, this damage can be reduced by applying the prophylactic blast carefully only in the bracket slots.

In this study, the brackets were evaluated after leveling and alignment since, after this phase, greater sliding mechanics could be expected. However, further research should be performed with similar methodology to confirm these findings and to better understand this multifactorial phenomenon.[25]

In summary, available evidence suggests that professional oral hygiene instructions only are not sufficient to prevent the accumulation of debris and bacterial plaque inside the bracket slot.[13] The SEM images from group 3 confirm these findings and emphasize of the importance of prophylactic cleansing (Figures 5 and 6). Orthodontists should consider the positive clinical effects that prophylaxis can produce during sliding mechanics, characterized by a decrease in the static and kinetic friction forces.

It must be considered that in vivo evaluation of resistance to sliding is not plausible so far. Although this study showed significant effects of the two prophylaxis protocols on friction force reduction, the main concern is related to the impact that this friction decrease would have on treatment efficiency and whether it would be considered clinically significant or not. Future clinical studies should be performed to answer this matter.

CONCLUSION

- Prophylactic blasting with sodium bicarbonate or glycine can significantly prevent an increase of the friction force in sliding mechanics during leveling and alignment.

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REFERENCES

1. Articolo LC, Kusy RP. Influence of angulation on the resistance to sliding in fixed appliances. *Am J Orthod Dentofacial Orthop*. 1999;115:39–51.

2. Drescher D, Bourauel C, Schumacher HA. Frictional forces between bracket and arch wire. *Am J Orthod Dentofacial Orthop*. 1989;96:397–404.
3. De Franco DJ, Spiller RE Jr, von Fraunhofer JA. Frictional resistances using Teflon-coated ligatures with various bracket-archwire combinations. *Angle Orthod*. 1995;65:63–72.
4. Bourauel C, Fries T, Drescher D, Plietsch R. Surface roughness of orthodontic wires via atomic force microscopy, laser specular reflectance, and profilometry. *Eur J Orthod*. 1998;20:79–92.
5. Pratten DH, Popli K, Germane N, Gunsolley JC. Frictional resistance of ceramic and stainless steel orthodontic brackets. *Am J Orthod Dentofacial Orthop*. 1990;98:398–403.
6. Kapur R, Sinha PK, Nanda RS. Frictional resistance in orthodontic brackets with repeated use. *Am J Orthod Dentofacial Orthop*. 1999;116:400–404.
7. Yee JA, Türk T, Elekdağ-Türk S, Cheng LL, Darendeliler MA. Rate of tooth movement under heavy and light continuous orthodontic forces. *Am J Orthod Dentofacial Orthop*. 2009;136:150.e151–150.e159.
8. Roscoe MG, Meira JB, Cattaneo PM. Association of orthodontic force system and root resorption: a systematic review. *Am J Orthod Dentofacial Orthop*. 2015;147:610–626.
9. Kusy RP, Whitley JQ. Friction between different wire-bracket configurations and materials. *Semin Orthod*. 1997;3:166–177.
10. Eliades T, Bourauel C. Intraoral aging of orthodontic materials: the picture we miss and its clinical relevance. *Am J Orthod Dentofacial Orthop*. 2005;127:403–412.
11. Regis S Jr, Soares P, Camargo ES, Guariza Filho O, Tanaka O, Maruo H. Biodegradation of orthodontic metallic brackets and associated implications for friction. *Am J Orthod Dentofacial Orthop*. 2011;140:501–509.
12. Barnes CM, Russell CM, Gerbo LR, Wells BR, Barnes DW. Effects of an air-powder polishing system on orthodontically bracketed and banded teeth. *Am J Orthod Dentofacial Orthop*. 1990;97:74–81.
13. Migliorati M, Isaia L, Cassaro A, et al. Efficacy of professional hygiene and prophylaxis on preventing plaque increase in orthodontic patients with multibracket appliances: a systematic review. *Eur J Orthod*. 2014;37:297–307.
14. Aragón ML, Lima LS, Normando D. Air-powder polishing on self-ligating brackets after clinical use: effects on debris levels. *Dental Press J Orthod*. 2016;21:90–94.
15. Leite BS, Fagundes NCF, Aragón MLC, Dias C, Normando D. Cleansing orthodontic brackets with air-powder polishing: effects on frictional force and degree of debris. *Dental Press J Orthod*. 2016;21:60–65.
16. Parmagnani EA, Basting RT. Effect of sodium bicarbonate air abrasive polishing on attrition and surface micromorphology of ceramic and stainless steel brackets. *Angle Orthod*. 2012;82:351–362.
17. Wilmes B, Vali S, Drescher D. In vitro study of surface changes in fixed orthodontic appliances following air polishing with Clinpro Prophy and Air-Flow. *J Orofac Orthop*. 2009;70:371–384.
18. Araujo RC, Bichara LM, Araujo AM, Normando D. Debris and friction of self-ligating and conventional orthodontic brackets after clinical use. *Angle Orthod*. 2015;85:673–677.
19. Marques IS, Araujo AM, Gurgel JA, Normando D. Debris, roughness and friction of stainless steel archwires following clinical use. *Angle Orthod*. 2010;80:521–527.
20. Nishio C, da Motta AFJ, Elias CN, Mucha JN. In vitro evaluation of frictional forces between archwires and ceramic brackets. *Am J Orthod Dentofacial Orthop*. 2004;125:56–64.
21. Alavi S, Farahi A. Effect of fluoride on friction between bracket and wire. *Dent Res J (Isfahan)*. 2011;8:S37–S42.
22. Dos Santos AA, Pithon MM, Carlo FG, et al. Effect of time and pH on physical-chemical properties of orthodontic brackets and wires. *Angle Orthod*. 2015;85:298–304.
23. Kusy RP, Whitley JQ. Influence of fluid media on the frictional coefficients in orthodontic sliding. *Semin Orthod*. 2003;9:281–289.
24. Liu X, Lin J, Ding P. Changes in the surface roughness and friction coefficient of orthodontic bracket slots before and after treatment. *Scanning*. 2013;35:265–272.
25. Tageldin H, Cadenas de Llano Perula M, Thevissen P, Celis J-P, Willems G. Quantifying resistance to sliding in orthodontics: a systematic review. *Br J Med Med Res*. 2016;17:1–30.
26. Ribeiro AA, Mattos CT, Ruellas AC, Araujo MT, Elias CN. In vivo comparison of the friction forces in new and used brackets. *Orthodontics (Chic.)*. 2012;13:e44–e50.
27. Mendes BAB, Ferreira RAN, Pithon MM, Horta MCR, Oliveira DD. Physical and chemical properties of orthodontic brackets after 12 and 24 months: in situ study. *J Appl Oral Sci*. 2014;22:194–203.
28. Choi SH, Kang DY, Hwang CJ. Surface roughness of three types of modern plastic bracket slot floors and frictional resistance. *Angle Orthod*. 2014;84:177–183.
29. Bednar JR, Gruendeman GW, Sandrik JL. A comparative study of frictional forces between orthodontic brackets and arch wires. *Am J Orthod Dentofacial Orthop*. 1991;100:513–522.
30. Hain M, Dhopatkar A, Rock P. A comparison of different ligation methods on friction. *Am J Orthod Dentofacial Orthop*. 2006;130:666–670.
31. Ahn SJ, Kho HS, Lee SW, Nahm DS. Roles of salivary proteins in the adherence of oral streptococci to various orthodontic brackets. *J Dent Res*. 2002;81:411–415.
32. Rosenbloom RG, Tinanoff N. Salivary *Streptococcus mutans* levels in patients before, during, and after orthodontic treatment. *Am J Orthod Dentofacial Orthop*. 1991;100:35–37.
33. Gerbo LR, Barnes CM, Leinfelder KF. Applications of the air-powder polisher in clinical orthodontics. *Am J Orthod Dentofacial Orthop*. 1993;103:71–73.