In vivo comparison of the friction forces in new and used brackets

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Studies that evaluate frictional force on orthodontic brackets usually compare ligature, archwire size, bracket alloys, and systems. However, these studies do not simulate in vitro specific conditions of in vivo situations. Aiming to evaluate some conditions not created in vitro, 30 used standard edgewise brackets (30.7 months) collected from patients in the end of treatment (group 1) and 20 as-received brackets (group 2) of the same brand were compared. The brackets used in vivo were carefully removed to avoid deformation. Frictional resistance tests of both groups were performed in a universal testing machine using a system that standardizes normal force. Five brackets from each group were analyzed with scanning electron microscopy (SEM). Student t tests were used to compare the frictional force between groups 1 and 2 and showed a statistically difference (32.91 and 21.22 g, respectively). The Mann-Whitney test showed that group 1 had more organic matter attached to the slot surface compared with group 2 (P < .05). However, a comparison of topography between the groups did not show a statistically significant difference. SEM analysis showed a statistically high correlation (r = 0.73) between organic matter adhesion to the slot surface and frictional resistance. However, the results were not significant. These results indicate the clearance of brackets and wires during sliding mechanics. ORTHODONTICS (CHIC) 2012;13:e44–e50.

Key words: brackets, corrosion, friction, scanning electron microscopy

Many studies have been developed to evaluate possible mechanical and biologic factors related to frictional resistance. Among the mechanical factors cited are bracket width and angulations, slot dimension, surface roughness, wire size and cross-section, ligature material, and pressure. Biologic factors include saliva, biofilm, acquired coating, and corrosion. Scanning electron microscopy (SEM) has been commonly used to qualitatively show these changes in bracket surface.
The food, debris, and biofilm accumulation on the bracket slot–archwire interface is another aspect that compromises sliding mechanics. It is well-known that any obstruction on this interface can delay or even block tooth movement.

To the authors’ knowledge, there are no in vivo studies that evaluate surface topography and friction resistance of orthodontic metallic brackets before and after treatment. Besides that, studies in vitro have evaluated surface roughness and friction resistance on as-received brackets\textsuperscript{1,4–8,11,12} without being submitted to any degradation or food debris and biofilm accumulation simulating in vivo conditions.

Therefore, the present study aims to compare friction resistance between new and used brackets in vivo. The organic matter adhesion and surface topography of these brackets was also compared qualitatively with SEM.

**METHODS**

Thirty premolar edgewise stainless steel brackets removed from patients whose orthodontic treatments were complete (group 1) and 20 new premolar edgewise brackets of the same brand (standard edgewise 0.022 × 0.030-inch, Dental Morelli) (group 2) were tested. The patients underwent orthodontic treatment at the Department of Orthodontics, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil. The group 4 brackets remained in situ for a mean ± standard deviation (SD) of 30.7 ± 4.2 months. The possible higher variability of group 1 explains its larger sample size.

The brackets were removed by ligature cutter plier positioned in the interface between the composite and bracket base, avoiding the slot damage that can occur with conventional debonding instruments. These brackets were stored in closed sterilized containers of distilled water. The internal and external bracket slot dimensions (Fig 1) were analyzed with a light stereoscope binocular (Carl Zeiss KL 1500 LCD) and a digital camera (Pixelink) with 25× magnification to observe whether any deformation occurred.\textsuperscript{20} Any brackets with visible deformation were eliminated from the sample).

**SEM**

Five brackets from each group were randomly chosen and analyzed in an SEM (JEOL JSM 5.800) operated at 20 kV and magnifications of 100×, 500×, and 1,000×) twice. The microphotographs used to evaluate the surface topography were taken on the background slot surface, at 500× magnification, by a calibrated single examiner.

Brackets in group 1 were stored in distilled water after removal. The first analysis evaluated food debris and biofilm presence on the slot surface. The following scores were used, according to previous published methods\textsuperscript{14,21}: 0, total absence of debris; 1, some debris, involving less than 1/4 of the image analyzed; 2, moderate presence of debris involving 1/4 to 3/4 of the image; 3, presence of a large amount of debris involving more than three-fourths of the image examined.\textsuperscript{14}

Before the second evaluation, the five specimens from group 1 were submitted to three 30-minute cycles in an ultrasonic washer (Maxiclean 1400A, Unique Company), with the samples immersed in enzymatic detergent (Endozime Plus, DFL) to remove organic matter\textsuperscript{22} and allow evaluation of the surface topography. Each of the 10 microphotographs was evaluated according to a previous study\textsuperscript{23} with eight characteristics of surface topography classification: presence of streaks; mottled or spotted aspect; presence of depressions, pores, ridges, or grains less than 1/3 of the surface; presence of depressions, pores, ridges, or grains in 1/3 of the surface; presence of circumferential depressions, ridges,
pores, or grains in 2/3 of the surface; presence of depressions or pores in whole surface; aspect alveolated; or presence of indentations. The overall topography surface index was calculated by the sum of the number of characteristics exhibited by each analyzed bracket (a maximum of 8).

**Friction test**

The remaining brackets were individually bonded with cyanoacrylate adhesive to a circular acrylic plate, which fit in a device designed especially for this purpose (Fig 2). This device was then attached to a universal testing machine, so that the slot of the bracket was perpendicular to the base of the machine.

A segment of 20-cm 0.019 × 0.025-inch stainless steel archwire was positioned into the slot of the brackets and maintained in the slot by a pressing apparatus attached to a 120-g weight (approximately the force generated by an elastic ligature). The tests were realized under wet conditions (distilled water placed in the slot-wire interface). The upper end of the wire was inserted into a tension 2 kg load cell of the testing machine. Each wire was drawn through the bracket at a constant speed of 3 mm/min for a distance of 2 mm. The friction force was recorded at point 1 (0.5-mm wire displacement) and at point 2 (1-mm wire displacement), and the maximum friction force was recorded. A graphic curve was generated for each test.

**Statistical analysis**

All statistical analysis was performed using software SPSS 16.0 (IBM). The Shapiro-Wilk test confirmed normal distribution for the friction test groups. The Student unpaired t test compared the means of groups 1 and 2. The Mann-Whitney nonparametric test was used to compare food debris and biofilm levels as well as the topography surface of groups 1 and 2. The Spearman correlation was used to evaluate the frictional resistance, food debris and biofilm levels, and topography surface relationships (α = .05).
RESULTS

Comparison tests
The mean friction resistance was 32.91 ± 1.36 g and 21.22 ± 1.66 g for groups 1 and 2, respectively. Group 1 showed higher frictional resistance than group 2 ($P < .001$) (Table 1). The Mann-Whitney test showed that group 1 had higher levels of food debris and biofilm than group 2 ($P < .01$) (Table 2). The same test did not show statistically significant differences between the topography surfaces of groups 1 and 2 (Table 2).

Correlation tests
Spearman analysis showed strong correlation ($r = 0.73$) between friction resistance and food debris and biofilm level variables ($P < .05$). However, the topography surface and frictional resistance correlation showed little association between them ($P > .05$) (Table 3).

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<th>Table 1</th>
<th>Comparison of frictional resistance</th>
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<td>Group</td>
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<td>1</td>
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<td>2</td>
<td>20</td>
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*Student unpaired t test. SD, standard deviation.

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<th>Table 2</th>
<th>Comparison of food debris and biofilm and topography surface</th>
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<td>Group</td>
<td>Mean rank</td>
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<tr>
<th>Table 3</th>
<th>Spearman correlation among frictional resistance, food debris and biofilm, and topography surface</th>
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<td>Spearman test</td>
<td>Frictional resistance</td>
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<td>Frictional resistance</td>
<td>Correlation coefficient ($r$)</td>
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<td>Significance (two-tailed)</td>
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<td>Food debris and biofilm</td>
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Comparison of friction forces in new and used brackets

**DISCUSSION**

Group 1 (32.91 ± 1.36 g) showed statistically higher friction resistance than group 2 (21.22 ± 1.66 g) \( (P < .001) \) (see Table 1). Clinically, this result is expected. Since the used normal force and contact area was the same, the friction resistance variation is due to a friction coefficient \( (\mu) \) that can be changed by the corrosion and food debris and biofilm adhesion metallic brackets and wires are exposed to in the oral environment.

According to these results, the analysis of food debris and biofilm adhesion showed that group 1 presented statistically significantly more organic matter adhered to slot surfaces than group 2 \( (P < .01) \) (see Table 2). Group 2 did not show organic matter adhered to the slot surface, in contrast to group 1, which exhibited scores 2 or 3 for all brackets. Therefore, the Spearman correlation showed a positive relationship between frictional resistance and organic matter analysis \( (r = 0.73) \) (see Table 3). These results are in concordance to a previous study\(^\text{14}\) that exposed wires to an oral environment for 8 weeks.

Surface topography analysis did not show a statistically significant difference between groups 1 and 2 \( (P > .05) \). This result was not expected because of the long period of time in the oral environment. Despite knowledge of the corrosion resistance of stainless steel alloy, this study evaluated the surface degradation over a mean time of 30.7 months in the mouth. The qualitative topography surface analysis of group 2 slot surfaces showed superficial irregularities, in addition to cracks and grooves that make the corrosive process easier (Fig 3).

However, the irregularities of group 1 brackets seem to have disappeared, probably because of the sliding of metallic bracket and wire surfaces against each other, leaving a scratched surface aspect (Fig 4). However, cracks and grooves seem to have increased because of corrosion (Fig 5).
It is known that SEM photomicrographs are limited compared with other analyses and are more indicated for evaluation of the surface topography. However, this method is still largely used and provides enough information for this objective. The authors assume this fact and believe that atomic force microscopy or rugosimeter could complement such results.

These results show two important aspects in the control of orthodontic forces during treatment. The first is the commercial brand used should have a good surface polish and satisfactory corrosion resistance. The second important aspect is ensuring the removal or adhered organic matter.

CONCLUSION

Based on these results, it is concluded that the brackets used during orthodontic treatment have more resistant frictional forces than new brackets, principally due to the accumulation of food debris and dental biofilm.

Cleaning archwires and brackets during orthodontic treatment and choosing high-quality orthodontic brackets and wires will help provide satisfactory sliding mechanics.

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REFERENCES