BJOS Brazilian Journal of Oral Sciences

Original Article

Volume 18
2019
e191605

Evaluation of friction on self-ligating and conventional brackets associated with different types of archwires submitted to sliding mechanics

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Received: March 29, 2019
Accepted: August 23, 2019

Aim: The aim of this study was to verify the frictional force during sliding mechanics in orthodontic tooth movement, using conventional metal brackets of the active and passive self-ligating types with stainless steel and copper nickel titanium archwires. **Methods:** This experimental *in vitro* study was conducted with conventional metal (Morelli, Sorocaba, SP, Brazil) brackets, active self-ligated (SLI Morelli, Sorocaba, SP, Brazil) and passive self-ligated (SLP Morelli, Sorocaba, SP, Brazil), with slot 0.022 x 0.028 inches and Roth prescription. The brackets were tested with rectangular section 0.019 x 0.025 inch copper nickel titanium and stainless steel archwires. For each type of bracket, 10 sets of plate/bracket/archwire segment (n=10) were fabricated. Non-parametric Kruskal Wallis and Dunn tests were used for comparison between types of brackets and Wilcoxon tests for comparison between types of archwires. **Results:** The results showed that the frictional force values were higher with copper nickel titanium than with stainless steel archwires ($p<0.05$). When copper nickel titanium archwires were used, the active self-ligating brackets showed higher frictional force values than the other types, followed by the conventional brackets. Lower frictional force values were observed with passive self-ligating brackets. For stainless steel archwires, no difference was observed between conventional and active self-ligating brackets, the passive self-ligating type presented lower frictional force values than the others. **Conclusion:** It was concluded that the higher frictional force was observed when active self-ligating brackets were associated with copper nickel titanium archwires. Lower frictional force was verified between passive self-ligating brackets combined with stainless steel archwires.

Keywords: Orthodontic brackets. Friction. Orthodontic appliance design.

Introduction

The frictional resistance present when performing orthodontic sliding mechanics results from interactions between the bracket, arch and method of ligation[1-9].

A high frictional coefficient may reduce the force used for orthodontic movement by half, diminishing the speed of tooth movement and making it difficult to control anchorage. The frictional force should be as low as possible with the goal of achieving greater mechanical efficiency; that is, the force applied must be sufficient to break the static friction and enable tooth movement[2,6,9,10-13].

The frictional force may vary according to the materials used, and whether the environment is wet or dry, type of brackets, archwires and ligations. Self-ligating brackets may be divided into active and passive types; the active types have a spring clip that invades the bracket slot putting pressure on the archwire, while in the passive system, the clip does not invade the slot, it only covers the slot without putting pressure on the archwire[1-5,7,10,12,14-19].

Among the various wires used for making orthodontic arches, stainless steel wires are outstanding as they have a polished surface[14,20]. However, the technological evolution has led to new archwires being used, among them the nickel titanium type with the addition of copper (CuNiTi)[17,21]. The incorporation of copper has resulted in these archwires having more defined thermoactive properties than the superelastic NiTi archwires, therefore, they exert more homogeneous forces throughout the arch, providing faster, more effective movement, in an optimal system of forces, with greater control of tooth movement; they may be used in different orthodontic treatment protocols, as they achieve more biologically compatible results by releasing more physiological force and shortening the time of treatment[2,4,10,21-23].

The frictional forces between conventional and (passive and active) self-ligating brackets, associated with archwires that have different section and compositions have been studied[2,6,12,24]. However, no reports were found of studies comparing the frictional force between active and passive self-ligating brackets with rectangular 0.019 x 0.025 inch sections of copper nickel titanium and stainless steel, in a wet environment at a temperature of 36.5^0 C.

The hypothesis under study was that metal self-ligating brackets would produce lower frictional force than that of conventional metal brackets; and copper nickel titanium archwires would produce higher frictional forces than those of stainless steel archwires.

Thus the aim of this study was to verify the frictional force during sliding mechanics in orthodontic tooth movement, using conventional metal brackets of the active and passive self-ligating types in combination with stainless steel and copper nickel titanium archwires.

Materials and Methods:

This experimental *in vitro* study was conducted with 30 sets of plate/bracket/archwire segments that were divided into three Groups according to the brackets used, i.e., conventional metal (Ref. 10.10.901, Morelli, Sorocaba, SP, Brazil), active self-ligating metal (Ref. 10.14.900, SLI/ Morelli, Sorocaba, SP, Brazil) and passive self-ligating metal brackets (Ref. 10.13.900, SLP/ Morelli, Sorocaba, SP, Brazil). For each bracket type, 10 sets of plate/bracket/segment (n=10) were fabricated[6,16,25]. The brackets were tested with rectangular section 0.019 x 0.025 inch copper nickel titanium (Ref. 50.62.154, Morelli, Sorocaba, SP, Brazil), and stainless steel archwires (Ref. 50.62.004, Morelli, Sorocaba, SP, Brazil)[2,3,11].

The test specimens were made up of a rectangular acrylic plate[3,5,10,14,25], measuring 8.5 cm long, 4 cm wide and 0.5 cm thick with metal brackets (conventional), slot 0.022 x 0.028 inches, from the maxillary right 2nd premolar to the maxillary right central incisor[5,14], combined with a segment of rectangular section 0.019 x 0.025 inches of copper nickel titanium and stainless steel (Morelli, Sorocaba, SP, Brazil)[3,5,25], as shown in Figure 1.

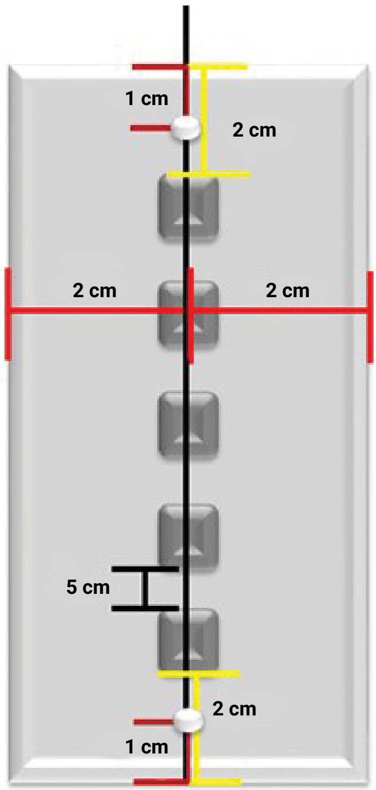

Figure. 1 - Schematic drawing of the acrylic plate (8.5 cm long, 4 cm wide and 0.5 cm thick). Metal brackets were positioned 0.5 mm distant from each other. The archwire was fixed on the brackets to frictional force evaluation.

The position of each bracket was demarcated on the plate and abraded with a spherical bur at low speed, cleaned with gauze imbibed in 70% alcohol, and dried with absorbent paper towels to prevent the presence of substances or dirt that could compromise the results obtained, thereby increasing the relationship of brackets and preventing these from debonding from the plate during the tests[11,13]. The brackets were aligned in parallel on in the most central region of the plate, so that the center of each bracket remained at a distance of 2 cm from the lateral borders and at a distance of 0.5 cm from each other. The brackets localized in the upper and lower extremities remained at a distance of 2 cm from the top and bottom edges of the acrylic plate[3,5,14,25].

After this, the brackets were fixed with cyanoacrylate adhesive (Super Bonder, Loctite Henkel, SP, Brazil), before a device was bonded on a 0.021 x 0.025 inch thick "U"-shaped[11] stainless steel archwire (Ref. 55.03.015, Morelli, Sorocaba, SP, Brazil), which was fitted into the channels of the brackets, and its extremities were fixed in holes made in the plate at a distance of 1 cm from its top and bottom edges. This was done to obtain the maximum level of standardization among the groups, to prevent any poorly positioned bracket from affecting the reliability of the results[11,14]. After the brackets were fixed, the rectangular archwire segments of copper nickel titanium and stainless steel, measuring 0.019 x 0.025 inches and 20 cm long were positioned[3,10,23,24].

The arch segments of 0.019 x 0.025 inches were fixed to the conventional metal brackets by conventional elastomeric ligatures (Ref. 60.06.101, Morelli, Sorocaba, SP, Brazil), in accordance with previously used methodology[5,14,25].

To simulate the conditions of the oral cavity, the tests were performed in a wet environment. The test specimens remained in a glass receptacle submersed in 12 liters of water at a temperature of 36.5 ^{o}C, because activation of the copper nickel titanium archwire occurs at 35 ^{o}C. The temperature of the water was controlled by two mercury thermometers[2,14,15,20].

Assay to determine the frictional force

To evaluate the frictional force, a Universal Test Machine (Instron model 4411, Buckinghamshire, England) with a 50 N load cell and 5 mm/min crosshead speed was used[25]. The archwire was moved 5 mm on the brackets and the friction evaluated. The results corresponding to the static frictional force were transmitted to the Bluehill 2.0 Materials Testing Software (Instron, Norwood, MA 02062- 2643, U.S.A.), coupled to the testing machine. The tests were repeated five times in each plate/bracket/archwire set up and the mean obtained. In the conventional metal brackets, the elastomeric ligatures were removed and replaced with new elastomeric ligatures in each test. For removal and insertion of the elastomeric ligatures in the conventional brackets, an elastic tie applicator was used (Ref. 75.01.001, Morelli, Sorocaba, SP, Brazil)[5,10,15.24].

The data did not comply with the presuppositions of a normal variance analysis. Therefore, the non-parametric Kruskal Wallis and Dunn tests were used for comparison between types of brackets and Wilcoxon tests for comparison between types of archwires. The Wilcoxon test was used because the same 30 test specimens were analyzed with the stainless steel archwires and those made of copper nickel titanium. The analyses were performed in the R Program (R Foundation for Statistical Computing, Vienna, Austria) considering the level of significance of 5%[1,11,13,14].

Results

In Table 1, it was possible to observe that the frictional force values were higher with copper nickel titanium than they were with stainless steel archwires, for the same type of bracket ($p<0.05$). When copper nickel titanium archwires were used, the active self-ligating brackets showed higher frictional force values than the other types ($p<0.05$), followed by the conventional brackets. Lower frictional force values were observed with passive self-ligating brackets ($p<0.05$). For stainless steel archwires, no significant difference was observed between conventional and active self-ligating brackets ($p>0.05$), but the passive self-ligating type presented significantly lower frictional force values than the others ($p<0.05$).

Table 1. Median (minimum and maximum values) of frictional force (N) considering bracket and type of archwire

Bracket	Archwire	
	Copper Nickel Titanium	Stainless steel
Conventional	6.18 (4.38-6.86) Ab	4.96 (4.13-6.26)Ba
Active self-ligating	13.21 (10.58-15.35) Aa	9.56 (4.80-12.78)Ba
Passive self-ligating	0.52 (0.46-0.96) Ac	0.01 (0.00-0.02) Bb

Medians followed by different letters (capitals on horizontal lines and lower-case in vertical position) differ between them (p≤0.05)

Discussion

The hypothesis that self-ligated metal brackets would produce lower frictional force than conventional metal brackets was rejected. The hypothesis that the titanium nickel copper archwires would produce higher frictional force than the stainless steel wires was accepted.

The questions raised in our study reinforced the affirmations of other authors that the supposed advantage of lower friction in self-ligating brackets was still controversial, when compared with conventional brackets associated with archwires with rectangular sections, particularly when comparisons were made between active self-ligating brackets and the conventional types[4,11,14,16,26,27].

Our findings showed that the association of conventional and self-ligating active and passive brackets with copper nickel titanium archwires with rectangular 0.019 x 0.025 inch sections presented higher friction values in the active self-ligating brackets, followed by the conventional types. The lowest frictional force values were observed for the passive self-ligating brackets; these results corroborated the findings of previous studies that did not find lower frictional force with the use of self-ligating brackets.

The elasticity of the copper nickel titanium archwire, with a rougher and more irregular surface associated with the pressure exerted by the clip of the self-ligating brackets could increase the surface of contact between the wire and the internal part of the slot. Consequently this would increase the frictional force, in agreement with previous studies in which the composition of the copper nickel titanium archwire could increase the frictional force[17,22,23,28].

In conventional brackets associated with copper nickel titanium archwires, the friction would be lower due to the smaller area of contact of the ligature with the archwire, and also due to the lower pressure exerted by the elastic ligature on the archwire. These findings corroborated those of studies in which lower pressure exerted by the elastic ligatures were found, making the pressure smoother and diminishing the points of contact of the wire with the internal part of the slot[21].

The difference in composition between the material of the ligature and that of the clip could also have an influence on the friction. The lower friction values observed in the presence of passive self-ligating brackets would result from the smaller surface of contact between the archwire and internal part of the slot, resulting from the absence of pressure exerted by the clip of this bracket. The findings of this study corroborated those of previous studies in which it was proved that the increase in contact surface increased the friction[1,2,5,7,11,13,14,16,18,24].

The result of the present research showed that the combination between copper nickel titanium archwires associated with active self-ligating brackets generated higher frictional forces than those generated by the combination of this archwire with conventional brackets, disagreement with some reports in the literature, in which the low friction observed in self-ligating brackets was considered an advantage[3,5].

Our findings corroborated the results found by researchers when they made a comparison between self-ligating and conventional brackets, in which the lower frictional resistance would only be observed when these brackets were combined with wires with smaller diameters. These results would be justified by the reduction in the surface of contact between the slot and archwire[1,2,5,11,13,14,24,26,29].

The results of the present study revealed that active self-ligating brackets produced similar friction values when compared with conventional brackets with the use of stainless steel archwires with rectangular sections. This fact may be explained by the more polished, smoother surface and greater rigidity of this wire, so that in spite of the pressure exerted by the clips of the active self-ligating brackets, the contact surface of this wire would not be increased. In the case of conventional brackets, the elastic ligature would not produce sufficient force to increase the surface of contact at the bracket/archwire interface, corroborating the findings of previous studies in which the composition of the archwire and clip of the bracket were reported[2,11,16,18,19,21].

The lowest friction values in this study were observed in passive self-ligating brackets, irrespective of the archwire used. This result corroborated the findings in the literature[14,18]. The lower friction in these brackets would be explained because of the smaller number of contacts between the archwire and bracket slot, since this system ends up creating a tunnel in which the archwire remains relatively free, thus transforming the bracket into a tube. This also explains why lower frictional values were observed with archwires of smaller calibers; that is, the smaller the surface of contact, the lower would be the friction, reinforcing the results of previous researches[1,2,11,13,18,24].

The results of the present study contribute to the orthodontic practice of sliding mechanics, since the current literature does not show unanimity regarding the friction produced by wires of rectangular section of different compositions in self - ligating brackets. However, the results of this study have limitations because it is an in vitro study, suggesting that clinical studies are performed.

In conclusion, higher frictional forces were observed between copper and nickel titanium arches associated with active self-ligating brackets, while lower frictional forces were observed with the use of stainless steel arches associated with passive self-ligating brackets.

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