Friction force on brackets generated by stainless steel wire and superelastic wires with and without IonGuard

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Abstract

Objective: The aim of this study was to evaluate the friction forces on brackets (Roth, Composite, 10.17.005, 3.2 mm, width 0.022x0.030-in, torque -2° and angulation +13°, Morelli®, Brazil), with stainless steel orthodontic rectangular wire (Morelli®, Brazil) and nickel-titanium superelastic Bioforce wires with and without IonGuard (Bioforce, GAC®, USA). **Methods:** Twenty-four brackets/segment of wire combinations were used, distributed into 3 groups according to the orthodontic wire. Each bracket/segment of wire combination was tested 3 times. The tests were performed in a universal testing machine EMIC DL2000®. The data was submitted to ANOVA one way followed by Tukey's post hoc test ($p<0.05$). **Results:** The rectangular orthodontic Bioforce wire with IonGuard presented significantly lower resistance to sliding than Bioforce without IonGuard. There was no statistical difference among the other groups. However, the coefficient of variation of Bioforce with and without IonGuard was lower than that of the stainless steel wire. **Conclusion:** The rectangular orthodontic Bioforce wire with IonGuard presented lower resistance to sliding than Bioforce without IonGuard, with no difference to the stainless steel wire.

Keywords: Orthodontic appliance design. Friction. Orthodontic wires.

INTRODUCTION AND LITERATURE REVIEW

The sliding mechanics is one of the most common methods of tooth movement and consists of controlled movement of teeth obtained by conducting the brackets along an arch. During this procedure, the bracket comes into contact with the wire, promoting friction between their surfaces. The friction between the bracket and orthodontic wire may reduce in half the force used to move the tooth.[5] As a result, the desired tooth movement is retarded or even inhibited. Therefore, it is desirable for orthodontic wires and brackets to have the lowest possible coefficient of friction.

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Among the various wires used in orthodontics, stainless steel wires have proven to be efficient and are used up until today. Nevertheless, new materials are being introduced, among them heat-activated and nickel-titanium (NiTi) wires. Heat-activated wires are characterized by the light and physiological distribution of forces and are indicated for various stages of active mechanotherapy. NiTi wires, due to their superelastic properties, enable the force to be more uniform due to the diminishment in deflection during tooth movement. Therefore, light and continuous forces are produced, allowing more physiological and effective tooth movement.[1,4,10] This wire is indicated, mainly for torque leveling and control, but the detailing and finalization must be done with stainless steel wires with the appropriate shape and size.[1,10]

The great disadvantage of wires made of beta-titanium or titanium-molybdenum alloy, known as TMA, is high friction, up to eight times higher than that of stainless steel,[6] and it is also higher than that of NiTi.[8] The wires made of titanium-niobium alloy have properties similar to those of TMA, with the advantage of resilience associated with moderate formability, but are not recommended for the retraction mechanics or closing spaces by sliding, due to the higher coefficient of friction.[6]

With the aim of reducing the friction between the bracket and NiTi wires, alternative surface treatments on these alloys have been recommended, such as ion implantation, a technique in which the metal substrate is hardened by the implantation of high energy ions in a very thin surface layer.[5]

Orthodontic wires are components that will determine the quantity of force distributed and the level of stress generated in the supporting structures of teeth throughout the active stage of orthodontic therapy. Due to the importance of the selection of metal wires on the success and speed of orthodontic treatment, the purpose of this study was to evaluate the force of friction between metal brackets and stainless steel wires, and Bioforce with and without IonGuard.

MATERIAL AND METHODS

For this study the materials listed in Table 1 were used. With the objective of simulating the sliding mechanics of a fixed orthodontic appliance, a device was constructed to demonstrate the distal movement of a canine in a previously established area, based on the methodology described by Secco[13] and Kuramae.[7]

Test specimen preparation

In order to perform the tests, an acrylic plate was made with the following measurements: 4.0 cm wide x 14.0 cm long x 0.5 cm thick. Next, a groove measuring 1 cm x 1.2 cm was made 2 cm from one of the ends. Four brackets were placed on the acrylic plate, bonded at a distance of 2 mm from the groove, with a 14mm a distance between them, and 2 other brackets were bonded onto the opposite side of the groove. The distance between the 2 sets of brackets was 14 mm (Fig 1). For bracket fixation the light polymerizable adhesive Adper Single Bond 2 (3M/ESPE Dental Products, St Paul, MN, USA) and resin composite Filtek Z100™ (3M/ESPE Dental Products, St Paul, MN, USA) were used. Before polymerization was performed, a 0.021 x 0.025-in wire was fit into the

Material	Composition	Prescription	Manufacturer
Canine bracket	Stainless steel	Roth: 3.2 mm wide, slot 0.022 x 0.030-in, Torque -2° and angulation +13°	Morelli (Sorocaba/SP, Brazil)
Maxillary central incisor bracket	Stainless steel	Edgewise: slot 0.022 x 0.030-in	Morelli (Sorocaba/SP, Brazil)
Rectangular wire 0.019 x 0.025-in	Stainless steel	-	Morelli (Sorocaba/SP, Brazil)
Rectangular wire 0.019 x 0.025-in	nickel-titanium - without IonGuard - Bioforce	-	GAC (Central Islip, New York, USA)
Rectangular wire 0.019 x 0.025-in	nickel-titanium - with IonGuard - Bioforce	-	GAC (Central Islip, New York, USA)

TABLE 1 - Materials used in the study.

bracket slots, guaranteeing their alignment. Right after polymerization with light activation appliance Light Cure Unit Cl-K50 Kondortech (São Carlos, SP, Brazil), this wire was removed. Elastic ligatures were used to fix the wire segments onto the acrylic plate.

Test bracket model

A 14 mm long and 1 mm thick wire, representing the root of a canine tooth was bonded to each of 24 metal brackets (Morelli®), at the center of the base and perpendicular to the bracket slot. On this wire, 10 mm from the center of the bracket slot, a small groove was made using a carborundum disk at low speed, which marked and represented the center of resistance of the root, on which a load of 50 g was applied to create the normal force between the bracket slot and orthodontic wire, to generate friction during the tests.

The test bracket was placed on the wire, and a 50 g counterweight was inserted on a previously made groove, with the objective of creating a force and generating friction during the tests. The fixation of the test brackets on the wires was performed with a firmly adjusted metal tie, which was loosened until the bracket slid on the wire under its own weight when the acrylic plate was placed perpendicular to the ground on the testing machine grip (Fig 2).

Test to determine the sliding and friction force

For the sliding and friction tests, the samples were divided into 3 groups, according to the wire used. Each group consisted of 8 bracket/wire segment sets, and each set was tested 3 times to obtain a mean value. The ends of the wires were tightly bent against the brackets so that the wires would not slide through the bracket slots.

For the friction test the acrylic plate mounted with the wire segment was vertically fixed to the grip at the base of the EMIC DL2000® machine (EMIC, equipamentos e sistemas de ensaio LTDA, São José dos Pinhais, PR, Brazil) so that the wire that passed through the bracket slot would be aligned with the center of the load cell at the top part of the machine.

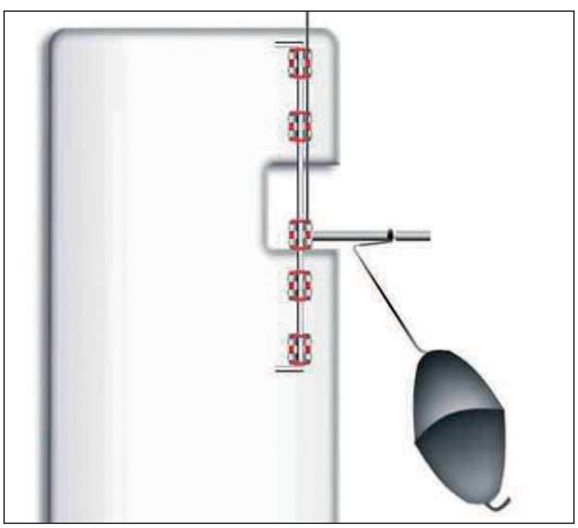

FIGURE 1 - Plate with wire segment and the test bracket that simulated the canine tooth in sliding mechanics, placed vertically to adjust the tie of the test bracket, on the Universal Testing Machine EMIC DL2000®.

FIGURA 2 - Acrylic plate perpendicularly positioned to the ground on the grip of the testing machine.

A 0.025-in stainless steel wire bent into a "U" shape, with the ends measuring 14 cm and the base 0.5 cm, was placed with its base supported on the mesial surface of the test bracket and its two ends fixed onto the load cell.

The readout of the sliding force and friction between the brackets and the different types of wires was performed in a universal testing machine EMIC DL2000® at a speed of 5 mm/min, for a distance of 8 mm. The force necessary to conduct the bracket through the wire was recorded in the form of a force x time graph.

The data was submitted to the Analysis of Variance and the Tukey test at a level of significance of 5%.

RESULTS

The means and standard deviation of the friction force for the different bracket/wire segment sets are shown in Table 2. The results showed that the Bioforce wire without IonGuard presented the highest friction force (1.597±0.147), significantly higher than the Bioforce wire with IonGuard (1.377±0.086), which presented the lowest friction force values. There was no significant difference among the other groups (P>0.05).

DISCUSSION

Friction, defined as the force that is resistant or opposed to movement, in which one surface slides over another, has a multifactorial nature. Friction can be static or dynamic and both types represent resistance to movement when orthodontic force is applied. There are various factors that influence the magnitude of friction between the bracket and wire, among them: The material of the wire and bracket, shape and caliber of the wire, ligature material, size of the bracket slot, bracket width and angulation, the point of force application in relation to the center of resistance, surface roughness, force applied and lubrication by saliva.[3] To determine the influence of the wire and the parameters involved in diminishing the force, the variation factor in this study was only the type of wire used, as the other factors were kept constant. Consequently, the differences found in the friction force are due to the wire characteristics.

The results obtained in this study indicated that the Bioforce wire without IonGuard presented higher friction force (1.597±0.147), significantly higher than that of Bioforce with IonGuard (1.377±0.086).

There was no significant difference between the stainless steel wire and the other groups (p>0.05). These results corroborate the reports of Viazis,[15] who verified that the second generation of square or rectangular Bioforce wires is versatile as initial arches because they allow alignment, leveling and closing spaces simultaneously. Studies that compared stainless steel, NiTi and beta titanium wires, have shown that beta titanium wire produced higher friction forces than NiTi,[3,8] but no significant difference was observed between NiTi and stainless steel wire, in agreement with the results of this study.[8]

Because NiTi wires presented better elasticity and resistance to corrosion, it began to be used in orthodontic therapy at the end of the 1960s.[2] The use of wires made of nickel-titanium has advantages such as: 1) Reduced chair time; 2) Application of light and continuous force;

TABLE 2 - Friction force values (N) of Bioforce wires with IonGuard, Bioforce without IonGuard and stainless steel wire.

	Bioforce with IonGuard	Bioforce without IonGuard	Stainless steel wire
Mean	1.377[b]	1.597[a]	1.573[ab]
Standard Deviation	0.086	0.147	0.214
Minimum Force	1.240	1.420	1.200
Maximum force	1.480	1.800	1.820
Coefficient of Variation (%)	10.62	10.94	22.41

Distinct letters represent statistically significant difference with a level of significance of 95%.

3) reduced time required for tooth alignment and leveling, which can frequently be performed with a single arch and; 4) working within acceptable biological limits.[9] The main advantage of using friction mechanics is the fact that in general, there is no need for complicated configurations on the wire, and less time is consumed to perform the initial wire placement. However, one cannot overlook it's greater efficiency when compared with mechanics without friction, since the presence of friction diminishes the movement of the tooth along the wire.[14]

With the objective of reducing friction between wires and orthodontic brackets, the process of ion implantation, frequently used in the engineering field, was introduced. In this process, a substrate is refined by ionized atoms that adhere to radicals positively charged with high energy by means of a negative charge. The radicals penetrate into the substrate surface and unite with it. Therefore, is it not a coating, but a permanent modification produced in the surface composition. This process alters the composition of the wire surface, diminishing the friction forces produced during tooth movement.[12] A 3 µm layer of nitrogen, achieved with ion bombardment on the wire surface, allows the force of friction to be reduced, increases the fracture resistance and diminishes the release of nickel in the mouth, which is responsible for allergic processes in some patients.[15]

The most important characteristic of superelastic nickel titanium in the orthodontic clinic is the release of more constant forces for larger deflections.[17] The association of lighter and constant forces with a lower coefficient of friction of the Bioforce IonGuard wires is extremely important in facilitating and accelerating orthodontic treatment, allowing longer intervals between appointments and producing physiologic forces for tooth movement.

Therefore, it can be suggested that rectangular Bioforce IonGuard wires have an excellent clinical application, especially in the initial stages of orthodontic treatment; that is, in alignment and leveling, and can replace all the round wires, as well as some rectangular stainless steel wires.[1,10,11] These new alloys used in orthodontic wires present characteristics capable of filling the gaps left by orthodontic treatment performed with sequential stainless steel wires, which vary the force by the growing change in the cross-sectional caliber of the wires.[9] However, Wichelhaus et al[16] verified that after 4 weeks of clinical use there was a significant increase in the friction of the wires with ion implantation, concluding that the advantages of these materials occur in the initial periods of their use.

Based on this data, the particular properties of these wires allow their application in the various stages of treatment, largely replacing the use of classical stainless steel wires.[6] Therefore, in the sliding mechanics, the Bioforce IonGuard wire could generate less resistance due to friction than the Bioforce wire without IonGuard, allowing tooth movement with lower forces. Nevertheless, the detailing and conclusion of orthodontic treatment must be performed with stainless steel wires of appropriate shape and size.[1]

CONCLUSION

Based on the methodology used, test conditions, and according to the results obtained in this study, it was concluded that the type of wire has an influence on the result of friction force. The highest friction values were presented by the Bioforce wires without IonGuard and the lowest friction force by the Bioforce wire with IonGuard, this being a good alternative to the Bioforce wire without IonGuard, when more sliding is required in tooth movement. The stainless steel wire presented intermediate friction force in comparison with the other wires.

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