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# Evaluation of Tensile and Friction Resistance of Various Orthodontic Elastomeric Ligatures

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors MBL and WJSU designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors KRF, RK and AGJ managed the literature searches and did the statistical analysis. Authors RDG and SBG managed the experimental tests. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** This work evaluated the friction resistance and tensile strength of different colors of various commercial brands of orthodontic elastomeric ligatures with different types of wires.
**Study Design:** Laboratory experimental investigation.
**Place and Duration of Study:** Department of Dentistry, Dental School, University of North Paraná between January and December, 2015.
**Methodology:** Seven colors of elastomeric orthodontic ligatures (yellow, blue, light pink, dark pink, purple, green and red) from different commercial brands (GAC and Morelli) were compared for

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tensile strength. Three wires (NiTi, TMA and Steel 0.019X0.025-in) from GAC were also compared when friction was evaluated. For the tensile test, the ligatures were tested on a universal testing machine at 1 mm/min. For the friction test, 10 observations were made for each combination archwire-bracket. The friction test used a special apparatus fixed on a universal testing machine, and the specimens were tested at 5 mm/min with 10 mm of displacement. The results were recorded, and the means (N) were submitted to analysis of variance and Tukey's tests at 5% significance.

**Results:** For tensile strength, GAC showed higher resistance with statistical difference for all colors compared to Morelli, except by the dark pink color, which showed no differences. It was verified that steel orthodontic wire (0.67N±0.36) showed lower friction compared to TMA (1.84N±0.81) and NiTi (1.53N±0.96). Regarding the brands, GAC (1.13N±0.76) showed lower friction compared to Morelli (1.56N±0.97). The pigments of the ligature interfered with the friction properties, verifying that purple (1.36N±0.72), light pink (1.05N±0.65) and dark pink (0.84N±0.53) showed less friction when compared to the other colors.

**Conclusion:** The pigmentation of the ligatures influences friction with the wires and the properties of resistance.

*Keywords: Orthodontics; elastomers; friction; tensile resistance; pigments; wires.*

## 1. INTRODUCTION

An expressive number of patients have been searching for orthodontic treatment in the last decade, in order to improve esthetic and function, encouraged by advances in dentistry [1]. Orthodontics, in a special way, plays an important role in the rehabilitation of patients [2]. Recently, there is a report that the hip joint mobility was improved by orthodontic treatment [3]. Therefore, orthodontic treatment may play a important role to improve the systemic conditions, too. The orthodontic sliding mechanic is one of the most common methods to translate a tooth mesiodistally. In this technique, mesiodistal tooth movement is accomplished by guiding a tooth along a continuous arch wire with the use of an orthodontic bracket [4]. The major disadvantage of this latter mechanism is the friction generated between the support and the arch, which tends to resist the movement of the bracket and tooth in opposite directions [4].

The friction is only part of the resistance movement when the wire slides over the slots [5,6] and is determined by the wire type and size, type of angulation between the arch and the slot and ligature method. Because this force works in the opposite direction of the cell body, it is important that the frictional forces are eliminated or minimized when the orthodontic tooth movement is being planned [4,7,8]; otherwise, the friction will result in a delay of tooth movement, an increase of the anchoring requirements or both [7,9].

Tooth movement may occur when the forces applied overcome the friction in the slot-arch support [10]. If a high level of frictional force between the slots and the arch occurs, it can cause connection between the two components, resulting in little or no dental movement [11].

Conventional braces usually use metallic or elastomeric ligatures to fix the archwire with the brackets. Due to their commercial appeal, these elastomeric ligatures come in different colors, which are made by the incorporation of different stains. This can interfere with the properties of the ligatures and generate more or less friction with the archwire.

There are few reports in the literature regarding the influence of pigments in the resistance and friction of elastomeric ligatures during orthodontic movement. Furthermore, little is known if this pigmentation interferes in the same way with different types of wire alloys. Thus, the aim of this study was to evaluate the tensile bond strength of elastomeric orthodontic ligatures of different colors from various commercial brands and to compare the friction of these materials with three types of wire alloys.

## 2. MATERIALS AND METHODS

Seven different colors of elastomeric orthodontic ligatures: yellow, blue, light pink, dark pink, purple, green and red, from different commercial brands GAC (Denstply GAC International Inc, New York, NY, USA) and Morelli (Dental Morelli Ltda, Sorocaba, SP, Brazil) and three wires: nickel-titanium (NiTi) (Denstply GAC International Inc), titanium-β (TMA) (Denstply GAC International Inc) and steel (Denstply GAC International Inc) with 0.019X0.025-in were used.

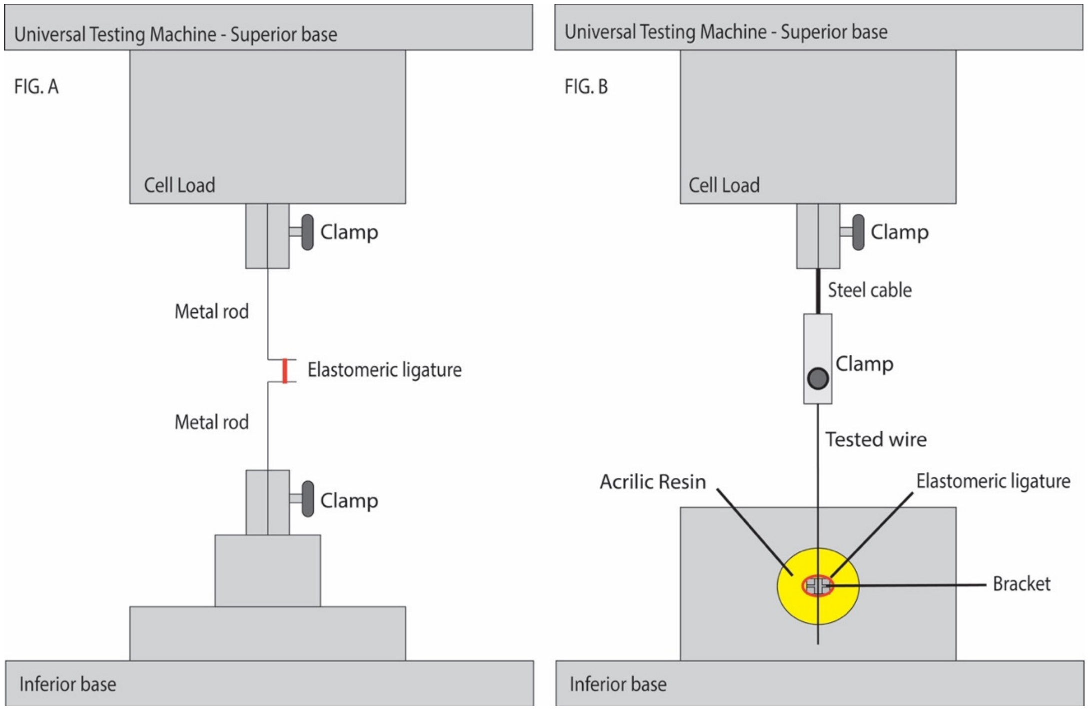


**Fig. 1. A. Representative scheme of tensile resistance device and B. Representative scheme of friction device**

For the tensile resistance test, the elastomeric ligatures were positioned on a special apparatus that held the ligatures at two points in opposite directions. The apparatus, which consisted of two rods with a 90-degree end (Fig. 1A) was fixed to a universal testing machine (DL200, Emic, São José dos Pinhais, PR, Brazil) with a 5 Kgf cell load, and the load was applied at 0.5 mm/min.

For the friction test, a ¾-in PVC tube with a height of 2 cm was filled with acrylic resin (Artigos Odontológicos Classico Ltda., Campo Limpo Paultista, SP, Brazil). Incisors standard edgewise brackets (Agile, Abzil 3M, São José do Rio Preto, SP, Brazil) with 0.022 in slots were fixed on the acrylic cylinder with cyanoacrylate and were positioned on a special apparatus (Fig. 1B) fixed on the universal testing machine (Emic) using a 5 Kgf cell load, with the bracket positioned perpendicular to the base. The wires were positioned inside of the slot and fixed on the upper part of the universal testing machine in such a way that the wire ran freely inside of the slot. The elastomeric ligatures were positioned on the bracket and tested at 5 mm/min with 10 mm of displacement; the results were then recorded. Ten test readings were taken for each group of elastomeric ligatures immediately after placement.

All tests were conducted in dry conditions. Each ligature and wire was tested only once to eliminate the possibility of surface-wear effects; that is, ten test readings were taken using seven different elastomeric ligatures in each group and seven different wire segments.

The results obtained for both tests were recorded, and the means (N) were submitted to one-way analysis of variance and Tukey's tests at 5% of significance after verifying their normality using the Kolmogorov-Smirnov test.

## 3. RESULTS AND DISCUSSION

Analyzing the elastomeric ligature tensile strength, GAC showed higher resistance with statistical difference for all colors compared to Morelli, except by the dark pink color, which showed no differences (Table 1). Analyzing the different colors inside the same brand group, differences were found between red (25.77N±1.52) and blue (20.24N±2.15) for GAC and dark pink (21.69N±1.60) and blue (15.33N±0.84), yellow (18.55N±2.92), light pink (17.80N±2.92) and purple (16.68N±1.15) for Morelli (Table 1).

**Table 1. Tensile strength (N)**

| Color | GAC | Morelli |
|---|---|---|
| Yellow | 22.91±1.43 A abc | 18.55±2.92 B bcd |
| Blue | 20.24±2.15 A c | 15.33±0.84 B e |
| Light pink | 22.58±1.23 A bc | 17.80±1.77 B cde |
| Dark pink | 22.61±1.81 A bc | 21.69±1.60 A a |
| Purple | 23.32±1.34 A abc | 16.68±1.15 B de |
| Green | 23.55±4.11 A ab | 20.06±2.38 B abc |
| Red | 25.77±1.52 A a | 21.36±1.37 B ab |

**Different capital letters in a line or lower column differ statistically at 5% significance with Tukey's test*

The dental movement can occur when applied forces appropriately overcome the friction in the bracket–archwire system. In this experiment, when the wire factor was analyzed alone, the orthodontic steel wire had a statistically lower friction (0.67N±0.36) when compared to the TMA (1.84N±0.81) and NiTi (1.53N±0.96) wires, most likely due to its smoother surface compared to the others.

Analyzing the brands of the orthodontic ligatures factor alone, the Morelli model (1.56N±0.97) had statistically inferior results compared to the GAC model (1.13N±0.76), which showed less resistance to the orthodontic wire and slid where the rounded shape favored lower friction because the contact region was smaller.

The ligature pigments analyzed independent of other factors interfered in friction properties; purple (1.36N±0.72), orange (1.12N±0.86), light pink (1.05N±0.65) and dark pink (0.84N±0.53) had statistically lower friction when compared to the other colors.

When comparing the factors together, there were no statistical differences between colors and brands when steel wire was used (Table 2). When NiTi was analyzed, GAC (1.50N±0.43), showed less friction than Morelli (2.82N±0.76) only for green color and inside the same brand, GAC showed difference between red (2.07N±1.02) and blue (0.93N±0.74), light pink (0.87N±0.39) and dark pink (0.62N±0.30), Morelli showed differences between green (2.27N±0.52) and light pink (1.27N±0.47) and dark pink (1.22N±0.64) (Table 2). When TMA was analyzed, GAC (1.58N±0.51), showed less friction than Morelli (2.64N±0.62) only for red color and inside the same brand, GAC showed difference between green (2.51N±0.51) and dark pink (0.91N±0.29), light pink (1.26N±0.59) and purple (1.50N±0.44), Morelli showed differences between yellow (2.85N±0.42) and blue (1.81N±0.63), light pink (1.27N±0.47), dark pink (1.22N±0.64) (Table 2).

Friction is an important consideration in sliding mechanics. During space closure, 60% of the applied force is spent on overcoming friction. There are multiple factors responsible for frictional resistance. Several variables exist that can directly or indirectly contribute to the frictional force levels between the bracket and the wire [12].

The force magnitude during orthodontic treatment will result in an adequate tissue response and fast orthodontic movement [13]. During mechanotherapy involving wire movement along the bracket, the archwire-bracket frictional interface can interfere with the appropriate forces on the support tissues [13]. This friction between the arches and brackets is determined by the ligature type and the connection procedure. The friction also increases as the guide-arch cross section increases [7,14, 15] and is influenced by the wire type, ligature, bracket width, resistance center position, surface roughness and applied orthodontic force [16].

The purpose of the ligature during the slip is to hold the archwires inside the bracket slots without pressing the arch [17]. There is a loss of control that is inherent from the absence. The lack of control of the binding force between bracket and arch make the frictional resistance unknown. The solution is based on the premise that short-duration forces should be resistant using an elastic material of high-strength resistance, and long-term strength can be accommodated by stress-relaxation characteristics in a properly developed ligation. However, there is no material that can meet all of these requirements, including polyethylene ligatures [12].

Frictional forces have two components; initial friction, also known as static friction, occurs between the arch and the bracket when strength is applied and must be overcome for movement to begin [18]. From the beginning of the movement of the teeth, the second friction component, called dynamical friction, begins to act, occurring when the arch moves towards the applied force, guided by the slot of the molar to the premolar [18].

The connection mode affects the friction produced [19]. The material and binding strength influence the frictional resistance between the bracket and arch. Loose steel ligatures show a lower frictional resistance compared to elastomeric ligatures [20], and rectangular wires generate more tension when compared to round wires [16]. Steel wires generate less friction than NiTi wires, which generate lower stress compared to TMA wires [16].

Clinically, lower friction is observed with the sliding of ligatures when rectangular wires were used. Lower friction can be considered both an advantage and a disadvantage depending on the situation; for example, during anterior retraction, lower friction is required in the lateral tracking of the dental arches, whereas in the final stabilization phase, higher friction is desirable in all slots [21].

The TMA wire showed higher friction compared to the NiTi wire and steel, which showed lower friction, corroborating the results of other studies [13,22-24]. This behavior is probably due to surface roughness, which maintains the same sequence [7,25]. The friction in the arch-bracket interface appears to be higher when TMA wires are used, whereas NiTi has a smoother surface, less friction, a lower modulus and improved resistance [12]. The literature unanimously reports that the force used over the steel ligature is subjective and varies according to the orthodontist [21]. Moreover, elastomeric ligatures lose elasticity over time and can change frictional force values [12].

When the color of the ligatures was analyzed, purple, orange, light pink and dark pink showed less friction ($p < .001$). Differences may be due to the various pigments between ligatures. However, the difficulty of obtaining access to the elastomeric ligature composition by manufacturers does not allow a full understanding and identification of substances that may influence the results.

**Table 2. Frictional resistance (N) between elastomeric ligature colors and different brands**

| Wire | Color | GAC | Morelli |
|---|---|---|---|
| Steel | Yellow | 0.69±0.29 A a | 0.79±0.39 A a |
| | Blue | 0.57±0.20 A a | 0.81±0.30 A a |
| | Light pink | 0.50±0.23 A a | 0.81±0.18 A a |
| | Dark pink | 0.32±0.10 A a | 0.60±0.21 A a |
| | Purple | 0.70±0.35 A a | 1.20±0.47 A a |
| | Green | 0.86±0.28 A a | 0.75±0.20 A a |
| | Red | 0.36±0.07 A a | 0.60±0.18 A a |
| NiTi | Yellow | 1.53±0.37 A ab | 1.03±0.55 A e |
| | Blue | 0.93±0.74 A b | 2.43±1.08 A abcd |
| | Light pink | 0.87±0.39 A b | 1.62±1.05 A cd |
| | Dark pink | 0.62±0.30 A b | 1.38±0.55 A d |
| | Purple | 1.10±0.55 A ab | 1.83±0.81 A bcd |
| | Green | 1.50±0.43 A ab | 2.82±0.76 B a |
| | Red | 2.07±1.02 A a | 2.79±0.93 A ab |
| TMA | Yellow | 2.13±0.46 A ab | 2.85±0.42 A a |
| | Blue | 2.18±0.10 A ab | 1.81±0.63 A bc |
| | Light pink | 1.26±0.59 A bc | 1.27±0.47 A c |
| | Dark pink | 0.91±0.29 A c | 1.22±0.64 A c |
| | Purple | 1.50±0.44 A bc | 1.88±0.89 A abc |
| | Green | 2.51±0.35 A a | 2.27±0.52 A ab |
| | Red | 1.58±0.51 A abc | 2.64±0.62 B ab |

**Different capital letters in a line or small letters in a column for the same wire type differ statistically at 5% significance with Tukey's test*

Orthodontic elastomers biodegrade in the oral environment mainly by hydrolysis [26]. Their secondary bonds are broken, the result of which is relaxation [27,28], which is the main feature of orthodontic elastomer degradation. The consequence of relaxation is the lowering of the mechanical energy transmitted from the elastomeric ligature to the tooth, reducing the ability to maintain the wire into the slot and consequently the effectiveness of tooth movement [27-31]. This phenomenon is responsible for the constant clinical exchange of elastomeric ligatures. After relaxation, elastomers usually suffer from the effects of viscosity, consisting of plastic strain when the elastomer is subjected to strength below the plastic limit [32]. Permanent deformations are commonly seen in all ligatures in the oral environment; however, they are never stressed above the plastic limit [26]. The green and red elastomeric ligatures for both brands, purple for GAC and dark pink for Morelli showed the greatest resistance. In general, GAC ligatures showed higher resistance compared to Morelli. These elastomers are most likely those that maintain a higher active time period in the oral cavity.

Color degradation of the elastomeric modules can be caused by both liquid and food in the oral environment, and this is one of the known deficiencies of elastomer modules [33]. Clinically, esthetics are a significant reason for the selection of modules, and color pigmentation of the elastomeric modules is a concern for both clinicians and patients [33]. Orthodontic patients should be advised that various colors of orthodontics ligatures will suffer different degrees of color alteration. The esthetic considerations for improvement in color stability should play an important role in the selection of modules for clinical use [33].

When the elastomeric ligature is stretched, its surface changes, which may influence its reaction to the oral environment, such as increased staining [34]. The higher the elastomeric ligature resistance is, the less stretching there is, which can contribute to the lower staining of the ligature. More resistant ligatures (Table 1) most likely have a lower potential for staining. The same likely occurs with GAC ligatures when compared to those from Morelli (Table 1).

Different ligatures be preferred for different conditions [35], however, for the conditions of this study, the GAC modules had higher tensile strength and lower friction, making these ligatures more appropriate for orthodontic sliding mechanics.

## 4. CONCLUSION

Aside from the limitations of this experiment, the elastomeric orthodontic ligature brand, the type of orthodontic alloy wire and the ligatures' color pigments can interfere in the friction and the tensile resistance of the ligatures. GAC showed higher resistance for all colors compared to Morelli, except by the dark pink color, which showed no differences. It was verified that steel orthodontic wire showed lower friction compared to TMA and NiTi. The pigments of the ligature interfered with the friction properties, verifying that purple, light pink and dark pink showed less friction when compared to the other colors.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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