Original Article

Frictional forces in stainless steel and plastic brackets using four types of wire ligation*

Vanessa Nínia Correia Lima**, Maria Elisa Rodrigues Coimbra***, Carla D'Agostini Derech****, Antônio Carlos de Oliveira Ruellas*****

Abstract

Objective: This in vitro study evaluated and compared the frictional resistance of stainless steel and polycarbonate (PC) composite brackets tied with metal wire and elastomeric ligation. **Methods:** Four stainless steel and four polycarbonate composite brackets for premolars were placed in a universal testing machine for the traction of a piece of 0.019 x 0.025-in wire at 0.5 mm/min and total displacement of 8 mm. Ligations were performed according to the following alternatives: metal ligation with Steiner tying pliers; metal ligation using Mathieu tying pliers; Morelli™ elastomeric ligation; and TP Orthodontics™ elastomeric ligation. **Results and Conclusions:** Elastomeric modules generated more friction than the metal ligations, and the ligation with the Mathieu tying pliers caused less friction than all the other conditions under study. PC brackets generated less friction than metal brackets, but the choice of material to be used in clinical conditions should take into consideration other variables, such as resistance to shearing and to fractures, as well as color stability and microorganism adherence.

Keywords: Friction. Orthodontic ligation. Metal bracket. Plastic bracket.

INTRODUCTION

Orthodontics is based on the movements of teeth within the alveolar bone bed due to the forces applied. This process may be facilitated or complicated by the subsequent response of tissues and the appropriate and rational use of the mechanical resources available.[8] Frictional forces pose clinical challenges: they should be understood and controlled because their increase may be an advantage when used for anchorage, but harmful because of their effects in sliding mechanics.[12]

The nature of friction in orthodontics depends on several factors and is determined by mechanical and biological factors:[1,3,9]

Physical/mechanical factors

- Properties of the orthodontic wire: material, cross section, thickness, surface texture and hardness.

* Study conducted as a requisite of the Scientific Initiation Program of the Department of Orthodontics, School of Dentistry, Universidade do Brasil, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil.

** DDS, Rio de Janeiro, Brazil.
*** Master in Orthodontics, UFRJ. PhD in Material Sciences, IME, Rio de Janeiro, Brazil.
**** PhD in Orthodontics, UFRJ. Professor, Graduate Course in Orthodontics, Universidade Federal de Santa Catarina (UFSC), Florianópolis, Brazil.
***** PhD, Professor, Department of Orthodontics, UFRJ, Rio de Janeiro, Brazil.

• Type of ligation between wire and bracket: material and ligation, and type of instrument used.

• Properties of the bracket: material, surface treatment, manufacturing process, slot dimensions, number of wings.

• Orthodontic apparatus: interbrackets distance, difference in height between brackets and force applied for retraction.

Biological and environmental factors

• Saliva, bacterial plaque, acquired film.

• Corrosion.

In summary, the force generated depends primarily on the materials used in the system, their physical properties, their interactions with the environment and their application, including their ligation.

Esthetic brackets have been focused by the orthodontic material industry. Several materials have been tested: zirconium, porcelain and polycarbonate. They are currently produced with small changes in their structures, depending on the manufacturer. Although clear brackets are more esthetic than metal brackets, they have a series of disadvantages, such as the high incidence of fracture and damage to the enamel during debonding in the case of porcelain, and lack of stability of color, little resistance to wear and failure in incorporating the torque forces in the case of plastic brackets.

However, esthetic brackets are part of our current practice, and their future in orthodontics seems clear. Therefore, this study evaluated their mechanical properties, particularly frictional forces, in association with the following variables: type of bracket material (metal or polycarbonate composite), type of ligation (metal or elastomeric) and instrument used (Mathieu or Steiner tying pliers).

MATERIAL AND METHODS

Eight twin brackets for premolars were used; four were made of stainless steel (Fig 1) and four, of polycarbonate composite (PC) reinforced with 30% glass fiber (Fig 2), whose slots measured 0.022 x 0.030-in. The brackets were bonded with epoxy resin to a metal support and the set was placed in a universal testing machine for traction of the stainless steel wire segment with a rectangular section of 0.019 x 0.025-in, at 0.5 mm/min at a total of 8.0 mm displacement in dry medium (Fig 3).

FIGURE 1 - Metal bracket used in the study.

FIGURE 2 - Polycarbonate composite (plastic) bracket used in the study.

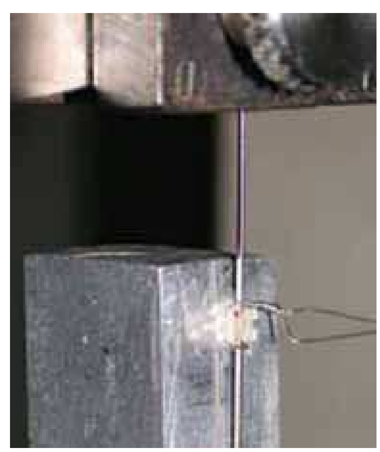


FIGURE 3 - Detail of the metal wire tied to the plastic bracket bonded to the metal support and placed in the universal testing machine.

According to information provided by manufacturers, the polycarbonate composite brackets are injected parts with a density of 1.4 g/cm^3 and typical hardness of 74 in the Shore scale; and conventional or unsintered metal brackets had a density of 7.4 to 7.9 g/cm^3.

The instruments for ligation were the Steiner or the Mathieu tying pliers, which were used, for each experimental situation, by the same operator using a 0.010-in-thick stainless steel wire (10 loops). Elastic tying was simple, around the bracket wings, and performed with two types of elastomeric ligations: TP Orthodontics™ and Morelli™. The ligation was positioned using an adaptor for elastomeric ligations.

Fifteen repetitions were performed for each of the 8 conditions or groups (Table 1).

TABLE 1 - Characteristics of the 8 sample groups.

GROUP	Bracket	Tying
PL Steiner	plastic	metal with Steiner pliers
PL Mathieu	plastic	metal with Mathieu pliers
PL Morelli	plastic	Morelli elastomeric ligation
PL TP	plastic	TP elastomeric ligation
Met Steiner	metal	metal with Steiner pliers
Met Mathieu	metal	metal with Mathieu pliers
Met Morelli	metal	Morelli elastomeric ligation
Met TP	metal	TP elastomeric ligation

Results were described as mean, standard deviation, minimum and maximum values. Analysis of variance (ANOVA) was used to assess the significance of statistical differences between groups, and the Tukey test was used for multiple comparisons between pairs at a 95% confidence interval ($p < 0.05$). The pairs studied were: PL Steiner x PL Mathieu; PL Morelli x PL Steiner; Met Steiner x Met Mathieu; Met Morelli x Met TP; PL Steiner x Met Steiner; PL Mathieu x Met Mathieu; PL Morelli x Met Morelli; PL TP x Met TP.

RESULTS

Table 2 describes mean frictional forces (gf) generated during the mechanical trial in the 8 conditions studied, as well as their standard deviations and minimum and maximum values.

The analysis of variance (ANOVA) revealed statistically significant differences between means in the 8 groups ($p < 0.05$). Similarly, when the variable bracket type was kept constant and the type of tying was changed, a statistically significant difference was also found, both for the metal and the plastic brackets ($p < 0.05$).

The Tukey test revealed that all the pairs under evaluation had statistically significant differences ($p < 0.05$) in frictional forces generated, except the PL Mathieu x Met Mathieu pair, whose results were statistically similar.

TABLE 2 - Descriptive statistics: means, standard deviations (SD), minimum and maximum values of friction generated in gram-force in the various conditions analyzed (n = 15).

GROUP	Mean	SD	Minimum value	Maximum value
PL Steiner	93.93	10.94	75.00	107.15
PL Mathieu	41.43	4.28	33.93	46.43
PL Morelli	95.72	11.84	82.15	108.93
PL TP	72.56	7.68	60.18	80.05
Met Steiner	125.34	22.49	104.80	167.28
Met Mathieu	46.85	4.30	39.81	52.29
Met Morelli	177.52	17.18	149.77	199.98
Met TP	254.63	24.51	215.19	283.77

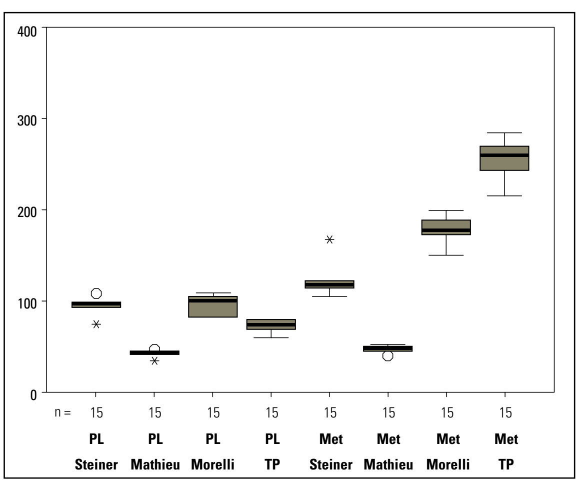
DISCUSSION

There was great variation in the generation of frictional forces (41.43 gf to 254.63 gf), and the greatest variation was found when the metal bracket and wire were tied using the TP Orthodontics elastomeric ligation, and the lowest, for the plastic bracket, metal wire and Mathieu pliers.

In general, frictional forces generated in the groups of metal brackets were greater than the ones for the plastic brackets and metal ligation. The groups in which Mathieu pliers were used had the lowest friction, with either a plastic or a metal bracket.

The sequence of groups in growing order of friction generated was: PL Mathieu, Met Mathieu, PL TP, PL Steiner, PL Morelli, Met Steiner, Met Morelli, Met TP.

Graph 1 shows that metal brackets generated greater friction than plastic brackets in this study. Previous studies showed that surface irregularity of polycarbonate brackets is significantly lower than that of other esthetic materials, such as porcelain.[14] However, when compared with metal (stainless steel) brackets, findings in the literature have shown that plastic brackets generate greater friction during sliding, probably due to their deformation when tied.[11,13] It may be inferred that, in our tests, there was not enough deformation of plastic brackets to increase friction between brackets and the metal wire.



GRAPH 1 - Box graph of friction force (gf) in the eight situations under analysis.

Although plastic brackets generated less friction than the metal brackets, the choice of material to be used in clinical settings should take into consideration other variables, such as the resistance to shearing, fracture, and deformation, as well as color stability and microorganism adherence.

Ligations may range from 50 to 300 gf and the elastomeric modules generate about 225 gf with gradual decrease due to relaxation.[9] In this study, elastic ligation tended to generate more friction than the metal ligation, in agreement with findings by Berdnar, Gruendeman and Sandrik,[2] in 1991. However, Omana, Moore and Bagby,[10] in 1992, opportunely added that, although theses procedure generated less resistance, it is difficult to standardize the force employed.[10] It is important to keep in mind that lubricated elastomeric ligations generate less friction than the ones that are not lubricated, as used in this study.[4,7]

The Mathieu pliers, as a tying instrument, produced less friction than the Steiner pliers when used with metal or plastic brackets, which was already expected, because light metal tying produces less friction than when adjusted.[7,9]

Classically, the standard surface of sliding mechanics is metal, particularly stainless steel. However, other orthodontic materials have satisfactory results, or better than in previous trials, particularly when using plastic brackets, which, in this study, had a better frictional result than metal brackets. However, as materials are modified or replaced, the constant investigation of friction generated by new and update materials is fundamentally important.[5,6]

CONCLUSIONS

1. Frictional forces varied considerably between the eight conditions under study; such variation is positive because it provides several options in orthodontic mechanics and more or less friction according to the needs for each case.

2. Plastic brackets generated less friction than metal brackets.

3. Elastomeric materials generated more friction than metal ligations, and the ligation with the Mathieu tying pliers caused less friction than all the other conditions under study.

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Submitted: February 2008
Revised and accepted: October 2009

Contact address
Carla D'Agostini Derech
Av. Rio Branco, 333/306 – Centro
CEP: 88.015 201 – Florianópolis, Brazil
E-mail: carladerech@hotmail.com