UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

MURILO MATIAS

Comparison of deflection forces of esthetic wires combined with esthetic brackets

Comparação das forças de deflexão de fios estéticos em braquetes estéticos

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“Antes de entrar numa batalha, é preciso acreditar no motivo da luta”

Sun Tzu

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"Combati o bom combate,
Terminei minha corrida,
Guardei a fé."

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ABSTRACT

ABSTRACT

Comparison of deflection forces of esthetic wires combined with esthetic brackets

Coated wires and ceramic brackets have been developed to improve esthetics during orthodontic treatment. The aim was to compare the deflection force in coated nickel-titanium (NiTi) and esthetic wires in esthetic brackets. Four coated NiTi wires (Reflex Nickel Titanium and Aesthetic NiTi, by TP Orthodontics; Flexy NiTi, by Orthometric and Spectra, by GAC), one esthetic wire (Optis, by TP Orthodontics) and three different esthetics brackets (Inspire Ice, by Ormco; Mystique, by GAC and Clarity, by 3M/Unitek) were used. The specimens were set up on a clinical simulation device and evaluated in a Universal Testing Machine (Instron). In an acrylic resin plate, similar to parable form, 10 devices were fixed, in which the brackets were bonded. Three of these models were prepared for attach each set of attachment tested. Acrylic device representative of the right maxillary central incisor was activated on the bucco-lingual movement with record from 0.5 mm to 3 mm. Speed of the testing machine to the deflection was 2 mm/min. ANOVA and Tukey tests were used at $P<0.05$ to compare different wires and brackets.The lowest forces were generated by Spectra wire with Clarity bracket. The highest forces were generated by Flexy NiTi wire with Inspire Ice bracket. In the deflection of 3 mm, Optis wire experienced cracking and produced an extremely low force in 2; 1 and 0.5 mm unloading. Esthetic brackets and wires, when used together, can exhibit very different patterns of forces due to bracket composition and type of wire coating.

Key words: Orthodontic wires. Orthodontic brackets. Esthetics. Coating. Bending

Resumo

RESUMO

Comparação das forças de deflexão de fios estéticos em braquetes estéticos

Fios recobertos e braquetes cerâmicos têm sido desenvolvidos a fim de melhorar a estética durante o tratamento ortodôntico. O objetivo deste trabalho foi comparar as forças de deflexão em fios de Níquel-Titânio (NiTi) recobertos e fios estéticos em braquetes estéticos. Foram avaliados quatro tipos de fios de NiTi recobertos (Reflex Nickel Titanium e Aesthetic NiTi, da marca comercial TP Orthodontics; Flexy NiTi, da marca Orthometric e o fio Spectra, da GAC), um tipo de fio puramente estético (Optis, da marca TP Orthodontics) e três diferentes braquetes estéticos (Clarity, da marca 3M/Unitek; Mystique, da GAC e o Inspire Ice, da Ormco). Os corpos de prova foram montados em um modelo de simulação clínica e avaliados em uma máquina de ensaio universal (Instron). Em uma placa de resina acrílica foram fixados 10 dispositivos, também em acrílico, onde foram colados os braquetes de modo a assemelharem-se ao posicionamento dos dentes no arco superior. Foram confeccionados três destes modelos para a colagem de cada conjunto de acessórios a ser testado. O dispositivo de acrílico representante do incisivo central superior direito foi movimentado no sentido vestíbulo-lingual, em ativações de 0,5 a 3 mm, com velocidade constante de 2,0 mm/min. Os resultados foram avaliados por meio da análise de variância (ANOVA) e teste de Tukey, com nível de significância de 5% ($P<0,05$) para comparação entre os diferentes fios e braquetes. As menores médias de força foram apresentadas pelo fio Spectra em conjunto com o braquete Clarity. As maiores médias de força foram apresentadas pelo fio Flexy NiTi quando empregado com o braquete Inspire Ice. Numa deflexão de 3mm, o fio Optis apresentou uma deformação plástica na sua estrutura, comprometendo seu desempenho elástico e produzindo forças extremamente baixas em 2mm; 1mm e 0,5mm em descarga. Fios e braquetes estéticos, quando empregados em conjunto, podem exibir diferentes padrões de força, devido, principalmente, ao material de composição do braquete e ao tipo de cobertura estética do fio de NiTi.

Palavras-chave: Fios ortodônticos. Braquetes ortodônticos. Estética. Deflexão

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1 Introduction

1 INTRODUCTION

In recent years, esthetic has been evaluated by patients seeking orthodontic treatment as a significant factor. Main materials used in fixed orthodontics are brackets and wires. The use of an esthetic orthodontic wire with an esthetic bracket, which is not yet common place in orthodontics, is likely the next step to enhance the esthetics of orthodontic appliances (SPENDLOVE *et al.*, 2014).

Much progress has been made in the development of esthetic clear and translucent brackets. Invention of composite and ceramic brackets solved the problem (RUSSELL, 2005). Ceramic brackets are manufactured by aluminum oxide (Al_2O_3), referred to as polycrystalline or monocrystalline alumina, the latter also known as sapphire (JOHNSON; WALKER; KULA, 2005). They are commercially available in two types: conventional and metal reinforced, designed to provide less frictional force against alloy wires (DICKSON; JONES, 1996; CACCIAFESTA *et al.*, 2003).

On the other hand, metallic wires coated with polymer materials, such as Teflon™ (tetrafluoroethylene) and epoxy resin, have also been developed (HUSMANN *et al.*, 2002; ELAYYAN; SILIKAS; BEARN, 2008), but not with the same efficiency. The epoxy coating is manufactured with a depository process that plates the base wire with an epoxy resin of approximately 0.002 in thick. Thus, a strong adhesion is achieved between the epoxy coating and the wire (CLOCHERET *et al.*, 2004).

The first esthetic transparent nonmetallic orthodontic wire contained a silica core, a silicone resin middle layer, and a stain-resistant nylon outer layer, the Optiflex by Ormco(TALASS, 1992). Fallis and Kusy subsequently developed an esthetic wire containing glass fibers (Owens Corning, Toledo, Ohio) embedded in a polymeric matrix formed from bisphenol A–diglycidylether methacrylate and triethylene glycol dimethacrylate (FALLIS; KUSY, 2000). Another research group has also developed a fiber-reinforced polymer wire (IMAI *et al.*, 1999). Although these polymer-based esthetic wires have an excellent appearance, they have not been clinically popular because of their brittle character.

There are different opinions in the literature concerning coated wires. Husmann et al. (HUSMANN *et al.*, 2002) evaluated their sliding properties and the adherence of the coating to the archwires. They found that plastic coating decreased friction between wires and brackets. Other authors have experienced some difficulties with these coated wires, claiming that the color tends to change with time and that the coating splits during use in the mouth, exposing the underlying metal (POSTLETHWAITE, 1992; LIM; LEW; TOH, 1994; KUSY, 1997).

There are no studies in the literature which had assessed the mechanical properties of coated wires against esthetic brackets, which seems reasonable to be used together. Thereby, *in vitro* studies try to aid orthodontists to design and select a mechanic that is not only efficient and biologically safe, but also has a pleasant esthetic appearance to patients. So, the aim of this study was to compare the load-deflection properties of esthetic and coated archwires in conventional and metal-insert ceramic brackets.

2 ARTICLE

2 ARTICLE

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Comparison of deflection forces of esthetic wires combined with esthetic brackets

Abstract

Introduction: Coated wires and ceramic brackets have been developed to improve esthetics during orthodontic treatment. Our aim was to compare the deflection force in coated nickel-titanium (NiTi) and esthetic wires in association with esthetic brackets. **Methods:** Esthetics and coated NiTi wires (Reflex NiTi, Aesthetic NiTi and Optis, by TP Orthodontics; Spectra, by GAC and Flexy NiTi, by Orthometric) and different esthetics brackets (Inspire Ice, by Ormco, Mystique, by GAC and Clarity, by 3M/Unitek) were tested. The specimens were set up on a clinical simulation device and evaluated in a Universal Testing Machine (Instron). In an acrylic resin plate, similar to parable form, 10 devices were fixed, in which the brackets were bonded. Three of these models were prepared to attach each set of attachment tested. Acrylic device representative of the right maxillary central incisor was activated on the bucco-lingual movement with record from 0.5 mm to 3 mm. Speed of the testing machine to the deflection was 2 mm/min. ANOVA and Tukey tests were used at $P<0.05$ to compare different wires and brackets. **Results:** The lowest forces were generated by Spectra wire combined Clarity bracket. The highest forces were generated by Flexy NiTi wire combined Inspire Ice bracket. In the deflection of 3 mm, Optis wire experienced cracking and produced an extremely low force in 2; 1 and 0.5 mm unloading. **Conclusion:** Esthetic brackets and wires, when used together, can exhibit very different patterns of forces due to bracket composition and type of wire coating.

Key words: Orthodontic wires. Orthodontic brackets. Esthetics. Coating. Bending.

Introduction

In modern society, esthetic aspect of orthodontic appliances is important, particularly due to more adult patients seeking for orthodontic care.[1] Two main groups of materials used in fixed orthodontics are brackets and archwires. The use of esthetic orthodontic archwires in association with esthetic brackets, which is not yet common routine in orthodontics, is likely the next step to enhance the esthetics of orthodontic appliances.[2] In a recent study, the combination of esthetic archwires and sapphire brackets was considered the second better esthetic option by lay adults, after clear aligners.[3]

Although esthetics are desired by patients and by orthodontists as well, proper and efficient function of the appliance is mandatory.[4] In terms of archwires, a number of alternatives have been explored to create an esthetic archwire that would allow efficient orthodontic treatment. Metal wires, particularly nickel-titanium (NiTi) alloys, have been coated with either tooth-colored polymers or inorganic materials. Although these wires might be considered more esthetic, a number of problems have been identified. They lack the translucency and the ideal transparency of an esthetic arch. Furthermore, the outer coating can wear or peel, and bending of the wire is limited.[5]

The materials traditionally used to coat wires are synthetic fluoropolymers such as polytetrafluoroethylene (PTFE), epoxy resins or a combination of them. Disadvantages in durability and surface properties such as tearing and color changing of these coatings in clinical conditions have been reported.[6] Efforts have been made to research and develop fiber-reinforced composite archwires suitable for use in clinical orthodontics,[7-9] but commercial availability has been progressing slowly.

Kusy[4] stated that these coatings are succumbed to mastication forces and oral enzymes. In a study conducted by Elayyan et al.,[10] loss of these coatings and increased roughness were reported after clinical use. Coatings are also vulnerable to mechanical and thermo cycling stresses in vitro.[5] On the other hand coating of archwires may influence over their mechanical properties. Husmann et al.,[11] showed that coatings decreased frictional force. Elayyan et al.,[12] found that epoxy resin coated archwires produced lower frictional force compared to uncoated wires of the same dimensions.

Considering the difficulty to directly evaluate the periodontal ligament stresses, the only way to estimate these parameters is by knowing the magnitude of forces applied to the teeth. Thereby, *in vitro* studies try to aid orthodontists to design and select a mechanic that is not only efficient and biologically safe, but also has a pleasant esthetic appearance to patients. The aim of this study was to compare the load-deflection properties of esthetic and coated archwires in conventional and metal-insert ceramic brackets.

Material and Methods

Material

Three clinical simulation devices were used in this study. Each of them received a different type of conventional esthetic bracket, varying according to the composition. All brackets had 0.022-in slot size and were ligated by elastomeric ligature (Super Slick Tie SST by TP Orthodontics) with outer diameter of 3.23mm in conventional way ("O" shaped). In these devices, four different NiTi wires (with and without esthetic coating) and one translucent wire, with superelastic and mechanical properties similar to NiTi wire, manufactured with a reinforced polymeric composite of plastic resin and fiberglass were used (Table I).

The archwires, brackets and elastomeric ligatures used were the same batch. All archwires evaluated had 0.016-in round and the same format (Standard or Medium). The specimens were divided in 15 groups using 10 wires per group, totaling 150 tests.

Methods

In order to standardize the tests of international order and as adequately as possible, this study followed the standard ISO 15841.[13]

The wire deflection was performed by a clinical simulation device representative of the right maxillary central incisor, composed of an acrylic resin plate with parabola shape where structures which represent the maxillary teeth were affixed (Fig 1). It was based on other author's papers that employed it in their studies.[14,15]

Brackets were bonded from second premolar to second premolar on the acrylic resin plate with cyanoacrylate adhesive on acrylic structures and positioned and aligned such that the mesiodistal slot axes were all contained in the same plane, using a 0.021x0.025-in archwire. These structures were fixed by means of threaded screw in the bottom of the acrylic resin plate. Different from the others, moving acrylic structure was not screwed, enabling its bucco-lingual movement. It received a hole, in which a metal cylinder was placed allowing its activation. The acrylic structure attached to the testing machine had a rounded cut to fit the metal cylinder (Fig 2).

The inter-brackets distance was kept constant at 6 mm,[16] corresponding the average distance between slots considering the size of the bracket and the average size of dental crowns mesiodistally, since the relation force/deflection is dependent, among other things, on this distance. The speed of the testing machine to the deflection was 2 mm/min.

To evaluate of the wire deflection a universal testing machine Instron 3342 (Norwood, MA, USA) with load cell 10N(1kgf) was used (Fig 3). Its accuracy speed is ± 0.2% and position accuracy (extension) is ≤ 0.02 mm or 0.05% of reading.[17]

An acrylic box with water was adapted in the test machine,[16,18-20] at 36±1°C maintained with a submersible electric resistance connected to a digital thermostat (TIC 17RGTi/9 model, Full Gauge Controls, Canoas/RS, Brazil) previously scheduled to stay in the desired temperature range (Fig 4).

Before each test, load cell calibration was achieved by Bluehill Lite software (v.2.25, 2005). Assessments of deflection wires in unloading were performed beginning in 3,1mm, and from this point, generated values could be measured in 3; 2; 1 and 0.5mm.

Statistical Analysis

Normal distribution of the variables was evaluated with Kolmogorov-Smirnov test, indicating that the parametric statistical tests could be applied.

Descriptive statistics including means and standard deviations values were calculated for each archwire-bracket combination.

To choose the size of sample in this research was used the standard ISO 15841 which recommends 6 specimens of each sample. However, to minimize the chance of any technical error and increase reliability of the results, a number of 10 specimens have been chosen for each group. Therefore, there was no need for sample size calculation.

ANOVA and Tukey tests were used to compare different wires and brackets.

All statistical analyses were performed with Statistica software (Statistica for Windows – Release 7.0 - Copyright Statsoft, Inc. Tulsa, Okla), at the $P<0.05$ level of significance.

Results

For all deflections studied (0.5; 1; 2 and 3 mm) there was statistically significant difference among the brackets, wires and on the interaction between both ($P<0.05$); the test showed that when evaluating the influence of the wire separately, it was observed that it has a significant effect on the magnitude of the forces generated, as well as when evaluating the bracket by itself. Similarly, when analyzing the wire/bracket interaction, it was observed its influence on the magnitude of the forces generated, especially in smaller deflections (Table II).

For Reflex Nickel Titanium wire, used as control in this research, it was observed that on the unloading of 3 mm deflection, Inspire Ice bracket presented the statistically highest mean force, with statistically significant difference from Clarity and Mystique brackets. In 2 mm unloading, this wire presented a totally opposite behavior, showing significantly lower force values (Table III).

During the tests with Flexy NiTi wire**,** it was observed that in 3, 1 and 0.5 mm unloading the Inspire Ice bracket has also presented the highest mean force, with statistically significant difference from Clarity and Mystique brackets. In 2 mm unloading, there was no statistical difference among the three types of brackets (Table IV).

The results obtained with the Aesthetic Nickel Titanium wire were the only ones to show statistically significant difference in all tested deflections. In 3 mm unloading, Inspire Ice bracket presented the statistically highest mean. In 2 mm unloading, this wire showed higher means in combination with Mystique and Clarity brackets. In smaller deflections, this wire showed the highest mean in combination with Mystique brackets (Table V).

Table VI shows that Spectra wire presented greater stability of mean values within the deflections studied. Only in 3 mm unloading, it was observed a statistically higher mean by Inspire Ice. For 2, 1, and 0.5 mm, all brackets presented similar means.

Optis esthetic wire presented the lowest force values for all deflections. In 3 mm of unloading, statistically higher forces were found, when used in combination with Inspire Ice bracket. From this point, the wire produced permanent deformation (crack), producing an extremely low force, near zero, meaning that the wire stopped exerting force (Table VII).

Discussion

Due to the lack of scientific studies in the literature on the mechanical properties of esthetic wires available in the market, there is still doubt whether coated metal and esthetic wires (FRP), have mechanical properties similar to the original alloy wires, thus being able to replace them and meet the requirement of esthetics required by patients. Therefore, in this paper we analyzed the mechanical behavior of these wires, in order to fill that gap in terms of knowledge production, aimed to evaluate the characteristics of force-deflection of esthetic wires available in the market, employing a clinical simulation device, comparing them to NiTi wire employed during alignment and leveling of the orthodontic treatment.

Sample and Methodology

By presenting fewer confounding variables than clinical tests, *in vitro* comparisons between different brackets and wires, as performed in this research, ensure lower discrepancy of individual responses and more fair and reliable results.[21,22].

There is no consensus in the literature about the number of specimens employed for each type of wire. Silva et al. [23] employed 5 samples for each type of wire, and Iijima[24] employed only one. The international standard[13] indicates a sample higher or equal to six specimens for each type of wire. The present study as well as previously reported[12,25,26] employed 10 samples for each type of wire studied, as shown in the above requirement. Importantly, all wires tested in this study were employed only once in the clinical simulation device.

From a practical standpoint, the load corresponds to the applied force to the tooth when the clinician deflects the wire and the wire bonds to the bracket, whereas the unloading refers to tooth movement while the wire returns to its original shape,[27] or it represents the forces that promote tooth movement during the orthodontic treatment.[28,29]

Although the elastic deflection test in the three point machine is widely used by several authors,[10,24,26] this research employed a clinical simulation device, as reported by other authors[8,12,23,25,30] who seeking to enhance or modify the deflection tests in the three point machine, including to these variables as brackets and elastomeric ligatures in order to best reproduce the clinical environment, where situations such as the friction may influence the magnitude of the force, increasing the loading force, but decreasing the unloading force.[31]

Moreover, as many variables are introduced, reproducibility of the results is more difficult, limiting comparisons with other works[21,22,24,26,30] Despite the efforts to reproduce a clinical situation, each study provides its particularities in the evaluation of the mechanical properties of the wires. Therefore, it is suggested that a greater emphasis should be given to the order of magnitude of the forces produced by the wires and not the numerical value of the amount of force released by wire during deflection tests.[20]

The type of ligation affects the seating force of the archwire. A previous study found higher archwire seating forces with elastic ligation than with steel ligation, and lower seating forces with loose stainless steel ligation than tight stainless steel ligation.[32]

In the present study it was used a super slick elastomeric modules able to generate significantly less static friction at the module/archwire interface than do regular modules when tied normally.

Results

Despite extensive research on the optimal force to promote tooth movement,[15,33] there is still no consensus in the literature. For Schwarz[34] during orthodontic treatment, ideal force should not exceed blood capillary pressure (20 to 26 g/cm^2). Thus, Reitan[35] noted that the right amount of force to be applied varies with the involved tooth and the type of movement performed.

Although there is some difficulty in knowing the exact value of an ideal force to produce a rapid tooth movement, without causing damage to the periodontium, it is known that wires which release light and continuous forces are biologically the most acceptable.[35] It is speculated that these forces would range from 25g and 250g[35] or from 150g to 500g.[15]

The use of a NiTi wire without esthetic coating, as the Reflex Nickel Titanium evaluated in this research, was necessary for representing, theoretically, a parameter to be followed by the other wires, since, with exception of Optis wire, all the other NiTi wires were coated with some type of esthetic material.

When tested with Inspire Ice bracket, in 3 mm deflection, 460.48g force was produced, the second largest force of all tests performed, differing from the results obtained with the other brackets, which produced lower forces. On the other hand, in 2 mm deflection, this wire presented a totally opposite behavior, showing significantly lower force values and not showing a defined pattern of behavior when employed with Inspire Ice bracket (Table III).

Flexy NiTi wire (Rhodium plated) presented the highest mean forces, particularly in 3 mm deflection and combined with the Inspire Ice bracket (Table IV).

This wire is plated by Rhodium, a noble and ductile metal and silver white coloring. Accurate data about the manufacturing process and conditions of this wire were not available by the manufacturer. It is suggested that its esthetic cover layer with low friction characteristics, should contribute to release higher forces during unloading. However, in a recent work[36] NiTi wire Rhodium plated(High Esthetic, by Dentsply GAC) showed the highest surface roughness, greater elasticity and strength during activation, but not on unloading. In addition, it has also showed the highest corrosion rate between the tested wires.

Aesthetic Nickel Titanium wire showed statistically higher force values only in 2, 1 and 0.5 mm deflection with Mystique bracket. Only in 3mm deflection, the highest force was presented by sapphire bracket (Table V).

These findings show an atypical behavior of this wire, especially in greater deflections, possibly caused by the surface of the esthetic coating, influencing on the resistance to sliding while measuring the forces at unloading. However, when compared with the uncoated NiTi wire of the same dimension and same manufacturer, Kaphoor[25] found no statistically significant difference in force values of this epoxy resin coated wire, showing a better behavior than found in this study.

Only in 3 mm unloading, Spectra coated wire showed statistically significant difference, and once again Inspire Ice bracket showed larger values. For the other deflections, there has been a lack of standard for the different brackets evaluated (Table VI).

Among all tested alloy wires, with and without coating, Spectra showed the lowest force values for all deflections. This may be related to increased friction arising from its coating material, since the greater the friction at the wire/bracket interface, the lower is the force generated during unloading, because friction consumes part of the accumulated initial force during the wire activation. Only from the moment that it exceeds the static friction, the wire will actually express its stored energy.

This result reinforces the findings by Elayyan,[12] Alavi[31] and Kaphoor[25] that found lower force generated by the epoxy resin coated wire.

Although recent studies[25] have shown that coated wires may now be able to generate forces similar to the noncoated wires, as the Spectra wire, this did not occur in the present study.

In the present research, purely esthetic wire presented the lowest force values for all deflections. From 3 mm of deflection, the wire produced permanent deformation (crack), meaning that the wire stopped exerting force (Table VII) and (Fig 5).

Cracking is defined as a region of ultrafine cracks in the resin phase leading to the appearance of a white band[37] It is noticed by a significant drop in force values. Even with the cracking, the wires still exert some force, but they are much lower than without cracking.[38]

This FRP wire (Fiber Reinforced Polymer) is manufactured with translucent composite material comprising a polymer matrix methylmethacrylate (PMMA) and glass fiber for reinforcement, in order to obtain a final product not only esthetic, but also able to reproduce the mechanical properties of the coated NiTi wires. It should display satisfactory springback to provide an adequate tooth movement, in other words, wire should return to its original format after tied to the teeth.

During its manufacturing process, the fiber content which comprise the structure, influences the force variability and rigidity.[7] The size and amount of fiber filaments determine alterations in rigidity of the produced wire, also altering the elasticity modulus and the elastic limit;[7] Thus, it is suggested that 0.016-in FRP wire evaluated in this research has an internal fiber configuration unable to withstanding 3 mm elastic deflection and keep their original shape without losing the stiffness and elasticity.

A similar result found in this study was obtained by Spendlove[2] who found fracture of the wires and decrease of force released in 2 mm unloading. Likewise, Chang[38] observed microcracks in the structure of 30% of the esthetic wires samples, stored in water for 30 days, warning for its limited clinical employment, as a viable clinical orthodontic wire. Also Huang[39] tested a new fiber glass wire, which similarly fractured under a slightly larger than 2 mm deflection.

Differently, Imai[7,40] and Ballard et al.[26] reported no fracture or permanent cracks in the FRP wires. Factors related to the methodology of these studies may explain this result. Tests were performed on a three point bending and not in a clinical simulation device, thus in the absence of brackets. The wires used had 0.018-in or 0.020-in and were tested in smaller deflections to those performed in the present study.

The clinical applicability of these fiber-reinforced composite archwires may be limited as they are unable to sustain deflections of 2 mm without experiencing cracking and loss of force delivery. Future studies performing a microscopic analysis of failures seem to be interesting to investigate the cause of wire fractures, and thus associate them with falling load values in unloading.

It has been reported that the frictional force of the ceramic brackets is greater, due to its rough surface.[41] Furthermore, the chemical characteristic of alumina on the ceramic surface may cause adherence on the wire surface. This may generate a high friction and reduce the orthodontic force from 12% to 60%.[42] Due to these problems, a metal-insert has been developed in order to reduce the friction force generated by the ceramic brackets.

Three types of conventional esthetic brackets exhibited influence on the results of the different wires, assessed in all deflections studied. This fact suggests that the interpretation of the load-deflection values, presented by the various specimens of wires, should not be done isolated and quantitatively, because a determined part of this generated force, reflects a greater or lower contribution of the bracket, depending on the friction generated by its insert, result from different materials composition.

For all deflections evaluated, three different types of esthetic brackets showed statistically significant difference and clearly defined pattern of force by different wires, regardless of the bracket used. In general, the highest mean forces were presented by Flexy NiTi wire and lower mean forces by Optis wire (Tables VIII, IX and X).

Bednar[43] and Ireland[44] report that in general, the ceramic brackets produce less friction than stainless steel. Alavi[31] showed that conventional ceramic brackets produced higher frictional force compared to metal-insert type. Also Suwa[45] found higher friction in polycrystalline brackets when used with FRP wires. However, Kusy[41] found no significant differences in friction between metal-insert and ceramic brackets, because although polycrystalline alumina bracket is harder and rougher than a stainless steel bracket and the fracture toughness of the brittle polycrystalline is 30 times lower than for the ductile stainless steel, it was not expected that frictional force of these material combinations performed similarly. Furthermore, Ireland[44] found a lower friction coefficient in ceramic brackets, despite the higher surface roughness.

An important aspect to be considered is the difficulty in extrapolating the findings obtained in the laboratory regarding frictional forces to the clinical environment due to many different factors such as occlusal forces, which by tightening or loosening the wire in brackets during treatment, may have different force values, with significant clinical relevance.[46]

Final considerations

Due to the above stated, the results of this study do not allow a thorough comparison with previous studies since aspects such as wire size, deflection values, brackets and elastomeric rings and temperature are variables in this type of research which need to be taken into consideration.[7,12,23-25,30,40]

The intrabatch variation may have influenced by the quality of manufacture, in particular concerning alloy and covering compositions. The bracket material will affect the bracket/wire surface interaction.[14] This in turn will affect the friction between the wire and bracket, and thus the force delivered to the tooth.[47]

The optimal deflection occurs at clinically useful displacements between 1 and 2.5 mm. These are the movements that predominate during leveling and aligning with the low dimension wires. This unloading region is the force value most likely to be applied in the clinical situation as soon as some movement of the teeth has occurred within the periodontal ligament.[14] Thus, it is suggested that a deflection above this range may be clinically excessive and not show a reliable behavior with 0.016-in NiTi coated wire, as observed in this search, where all wires tested in 3 mm deflection showed statistically significant values, regardless wire/bracket interaction.

Friction generated among bracket, wire and elastomeric ring is very important in the amount of force released by the wire, and as the deflection increases, so does the emergence angle of the bracket/wire, becoming more acute. Thus, a higher frictional force is generated and probably leads to further damage to the coating material. During activation, friction increases the amount of force generated while in the unloading, the frictional force produced by the wires decreases.[12]

Wires coated by different esthetic materials may present different diameters specified by the manufacturer in its package; this an extremely important factor when analyzing the mechanical performance of these wires, because it can result either in a decrease in the size of the internal NiTi wire, as in an excessive increase in the amount of coating material.

Reduction in the internal dimensions of NiTi wire, to compensate for the coating thickness seems to be the responsible for the major changes in mechanical properties of the esthetic wires,[23,25] particularly in elastic deflection forces as observed in this study.

It was observed that esthetic wires employed in this work presented mostly deflection forces compatible to those obtained by uncoated NiTi wires (Reflex Nickel Titanium). Special attention should be given to Optis wire, which despite being highly esthetic presented a permanent crack in 3 mm deflection. This means that when the glass fiber wire is employed in moderate to severe crowding, it may undergo a permanent bending interrupting tooth movement. Although light forces during unloading are desirable, they cannot be effective if they are below the range of optimal orthodontic force for tooth movement.

Since there are few published works on the mechanical properties of esthetic wires, additional studies need to be conducted, so that these mechanical properties are consistent with the desired force levels to induce tooth movement.

Furthermore, additional investigation is necessary to clarify whether the above observed differences reflect the real influence of the coating material or if they are influenced by the coating manufacturing process.

Conclusions

- The lowest forces were generated by Spectra wire in combination with Clarity and Mystique brackets, for all deflections studied;
- The highest forces were generated by Flexy NiTi wire in combination with Inspire Ice bracket;
- Optis wire experienced cracking and produced an extremely low force in 2; 1 and 0.5 mm of unloading, resulting into extremely low forces, non-compatible to the mean forces generated by the other tested wires;
- Inspire Ice bracket presented the highest mean forces in unloading, regardless the wire employed;
- Esthetic brackets and wires, when used together, can exhibit very different patterns of forces due to bracket composition and type of wire coating.

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FIGURE LEGENDS

Fig 1. Acrylic resin plate with the structures in position and brackets bonded; acrylic device representative of the right maxillary central incisor and cylindrical metal structure.

Fig 2. Tip of the universal testing machine moving bucco-lingually the acrylic structure.

Fig 3. Instron universal testing machine and load cell 10N.

Fig 4. Clinical simulation device.

Fig 5. Crack generated by Optis wire during deflection.

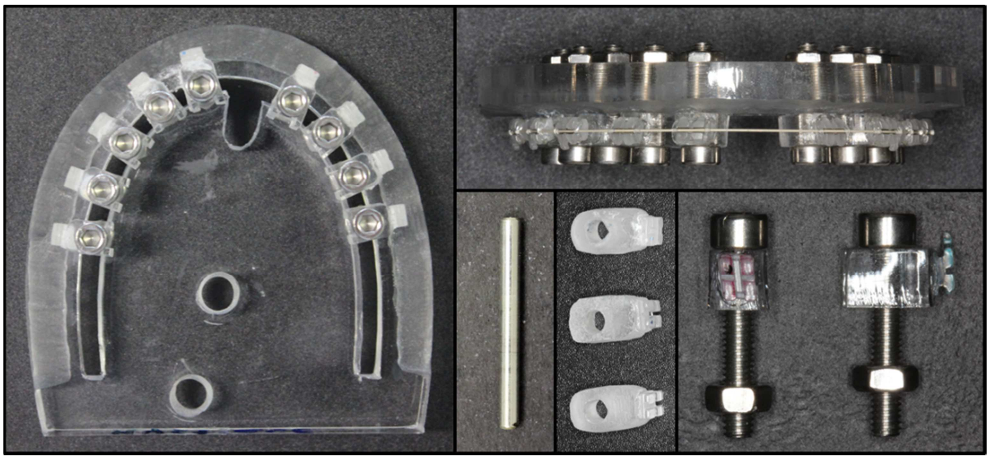

Fig 1

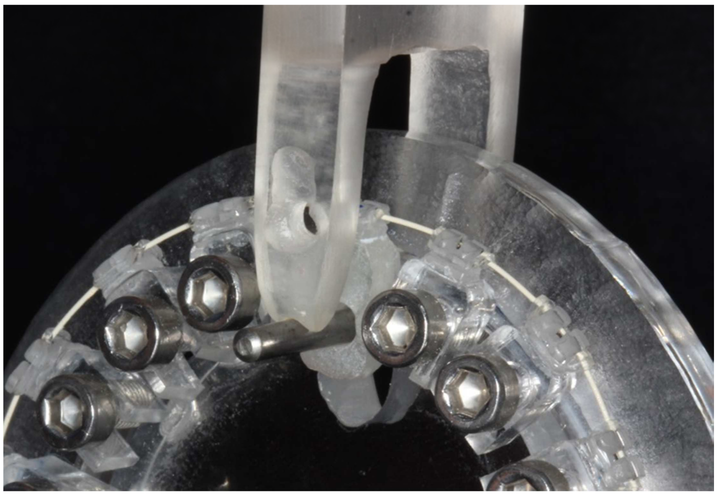

Fig 2

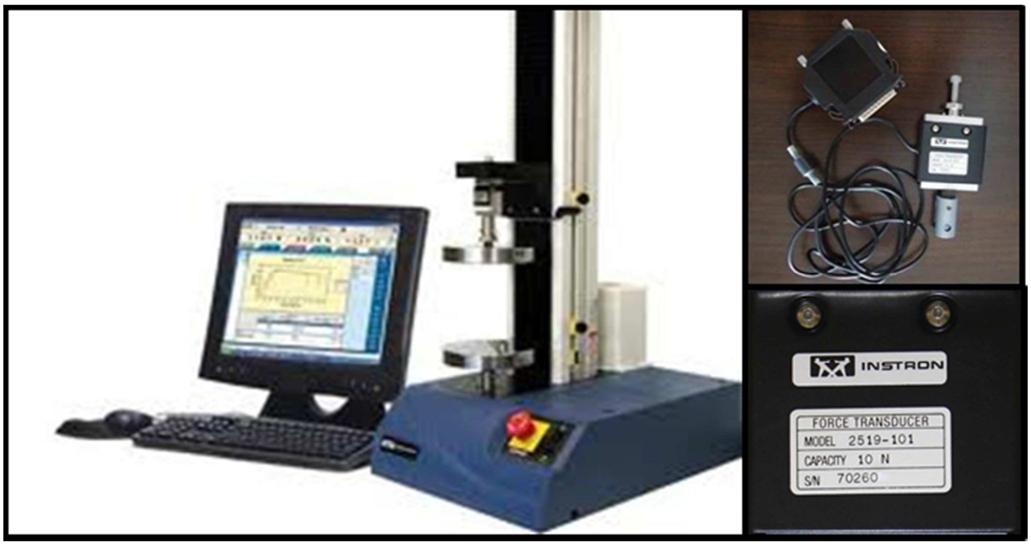
INSTRON
FORCE TRANSDUCER
MODEL 2519-101
CAPACITY 10 N
S/N 70260

Fig 3

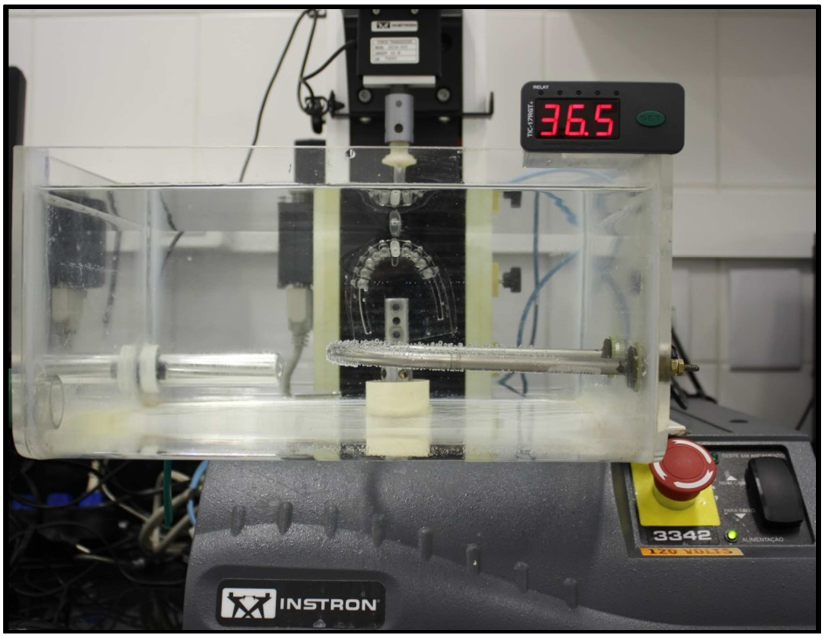

Fig 4

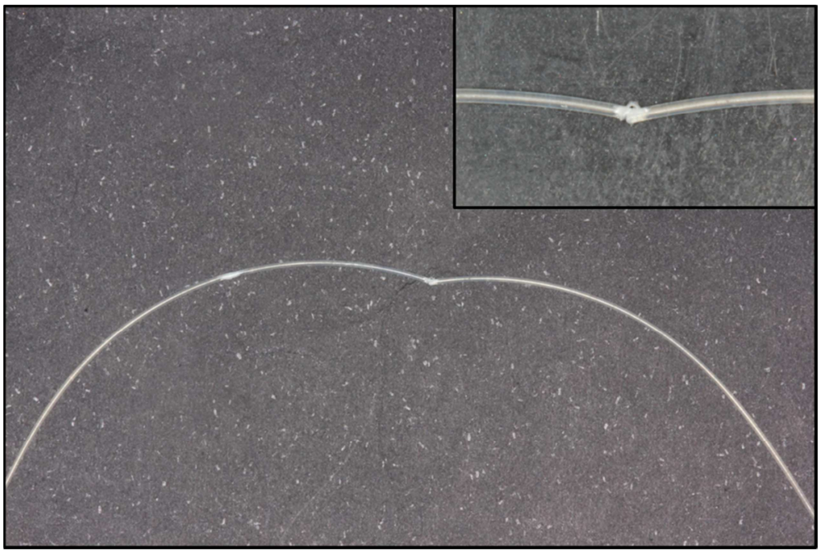

Fig 5

Table I. Experimental groups of wires (0.016-in) and brackets

Wire	Brand/Manufacturer	Coating	Batch
NiTi	Reflex Nickel Titanium/(TP Orthodontics (La Porte – USA)	No coating	23213012SMS
NiTi coated (only labial surface)	Aesthetic Nickel Titanium/TP Orthodontics (La Porte – USA)	Epoxy resin	21213069AKLB
NiTi plated	Flexy NiTi/Orthometric (Marília – Brazil)	Rhodium	0413040161
NiTi coated	Spectra/GAC (Bohemia – USA)	Epoxy resin	253584
FRP (Fiber Reinforced Polymer)	Optis/TP Orthodontics (La Porte – USA)	No coating	080505
Bracket	**Brand/Manufacturer**	**Type**	**Batch**
Polycrystalline ceramic	Clarity/3M Unitek (St Paul - USA)	Conventional/ metal- insert	EM40M
Polycrystalline ceramic	Mystique/GAC (Bohemia – USA)	Conventional	141902
Monocrystalline ceramic (sapphire)	Inspire Ice/Ormco (Orange, USA)	Conventional	290513

Table II. ANOVA Two-way test to analyze the influence of bracket, wire and interaction bracket/wire in force generated in different deflections.

Source of variation	SS	DF	MS	F	P	Deflection
Interaction	5676	8	710	1.20	0.305	3 mm
Bracket	55429	2	27715	46.80	**0.000***	3 mm
Wire	799487	4	199872	337.53	**0.000***	3 mm
Error	72835	123	592			
Interaction	5341	8	668	1.75	0.094	2 mm
Bracket	6449	2	3225	8.43	**0.000***	2 mm
Wire	1244587	4	311147	813.36	**0.000***	2 mm
Error	47053	123	383			
Interaction	23076	8	2884	6.228	**0.000***	1 mm
Bracket	3815	2	1908	4.118	**0.018***	1 mm
Wire	431548	4	107887	232.930	**0.000***	1 mm
Error	56970	123	463			
Interaction	21177.9	8	2647.2	4.0570	**0.000***	0.5 mm
Bracket	4474.9	2	2237.4	3.4290	**0.035***	0.5 mm
Wire	44127.3	4	11031.8	16.9068	**0.000***	0.5 mm
Error	80258.8	123	652.5			

SS, Sum of Squares; DF, Degree of Freedom; MS, Medium Square; F, Variance Ratio.
*Statistical significance for P <0.05.

Table III. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests, when necessary, to evaluate the behavior of the brackets using **Reflex Nickel Titanium** wire (N=10)

Variable	Clarity	Mystique	Inspire Ice	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	405.69 (5.66) A	390.33 (18.67) A	460.48 (27.92) B	**0.000000***
2mm	268.38 (5.93) A	280.20 (9.80) A	259.80 (14.97) B	**0.001104***
1mm	176.29 (19.38)	174.99 (20.22)	195.09 (19.88)	0.055872
0.5mm	52.75 (30.05)	56.55 (25.37)	61.98 (28.51)	0.779911

*Statistically significant for $p<0.05$.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table IV. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests, when necessary, to evaluate the behavior of the brackets using **Flexy NiTi** wire (N=10).

Variable	Clarity	Mystique	Inspire Ice	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	428.49 (23.86) [A]	408.60 (37.42) [A]	465.88 (23.59) [B]	**0.000549***
2mm	308.59 (34.47)	303.04 (39.63)	277.31 (23.89)	0.100181
1mm	187.16 (13.70) [A,B]	173.20 (15.54) [A]	198.86 (12.74) [B]	**0.001489***
0.5mm	24.42 (15.40) [A]	52.91 (27.38) [B]	66.52 (26.48) [B]	**0.001647***

*Statistically significant for p<0.05.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table V. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests, to evaluate the behavior of the brackets using_**Aesthetic Nickel Titanium** wire (N=10).

Variable	Clarity	Mystique	Inspire Ice	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	403.73 (25.46) [A]	392.90 (6.46) [A]	434.05 (27.23) [B]	**0.000739***
2mm	279.29 (19.52) [A]	287.67 (15.39) [A]	256.09 (16.68) [B]	**0.001042***
1mm	128.95 (48.39) [A]	195.05 (19.13) [B]	159.52 (31.83) [A,B]	**0.001125***
0.5mm	41.83 (33.54) [A]	82.99 (27.76) [B]	27.14 (32.50) [A]	**0.001356***

*Statistically significant for p<0.05.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table VI. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests, when necessary, to evaluate the behavior of the brackets using **Spectra** wire (N=10).

Variable	Clarity	Mystique	Inspire Ice	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	297.45 (16.03) [A,B]	292.07 (19.28) [A]	321.19 (30.29) [B]	**0.018297***
2mm	131.72 (13.12)	125.11 (5.67)	122.27 (9.55)	0.110971
1mm	122.60 (18.59)	128.67 (14.37)	126.00 (9.64)	0.654518
0.5mm	32.55 (17.58)	29.04 (27.58)	34.96 (24.44)	0.853368

*Statistically significant for $p<0.05$.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table VII. Mean (in cN) and standard deviation (SD) of the results esults one-way ANOVA and Tukey tests, when necessary, to evaluate the behavior of the brackets using **Optis** wire (N=10).

Variable	Clarity	Mystique	Inspire Ice	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	214.24 (32.77) A,B	194.96 (21.66) A	240.87 (31.98) B	**0.048559***
2mm	29.90 (15.63) A	28.30 (18.15) A	31.80 (7.36) A	0.916206
1mm	14.21 (8.08) A	12.98 (13.67) A	7.84 (9.54) A	0.562287
0.5mm	0.16 (0.88) A	1.36 (6.71) A	0.53 (4.17) A	0.772254

*Statistically significant for $p<0.05$.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table VIII. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests to evaluate the behavior of the wires using **Clarity** bracket (N=50).

Variable	Reflex Nickel Titanium	Flexy NiTi	Aesthetic Nickel Titanium	Spectra	Optis	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	405.69 (5.66) A	428.49 (23.89) A	403.73 (25.46) A	297.45 (16.03) C	214.24 (32.77) B	**0.000000***
2mm	268.38 (5.93) A	308.59 (34.47) D	279.29 (19.52) A	131.72 (13.12) C	29.90 (15.63) B	**0.000000***
1mm	176.29 (19.38) B	187.16 (13.70) B	128.95 (48.39) A	122.60 (18.59) A	14.21 (8.08) C	**0.000000***
0.5mm	52.75 (30.05) A	24.42 (15.40) A, B	41.83 (33.54) A	32.55 (17.58) A, B	0.16 (0.88) B	**0.001637***

*Statistically significant for p<0.05.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table IX. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests to evaluate the behavior of the wires using **Mystique** bracket (N=50).

Variable	Reflex Nickel Titanium	Flexy NiTi	Aesthetic Nickel Titanium	Spectra	Optis	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	390.33 (18.67) A	408.60 (37.42) A	392.90 (6.46) A	292.07 (19.28) C	194.96 (21.66) B	**0.000000 ***
2mm	280.20 (9.80) A	303.04 (39.63) A	287.67 (15.39) A	125.11 (5.67) C	28.30 (18.15) B	**0.000000 ***
1mm	174.99 (20.22) A,B	173.20 (15.54) A	195.05 (19.13) B	128.67 (14.37) D	12.98 (13.67) C	**0.000000 ***
0.5mm	56.55 (25.37) A,B	52.91 (27.38) A,B	82.99 (27.76) B	29.04 (27.58) A,C	1.36 (6.71) C	**0.000002 ***

*Statistically significant for $p<0.05$.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

Table X. Mean (in cN) and standard deviation (SD) of the results one-way ANOVA and Tukey tests to evaluate the behavior of the wires using **Inspire Ice** bracket (N=50).

Variable	Reflex Nickel Titanium	Flexy NiTi	Aesthetic Nickel Titanium	Spectra	Optis	p
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	
3mm	460.48 (27.92) A	465.88 (23.59) A	434.05 (27.23) A	321.19 (30.29) C	240.87 (31.98) B	**0.000000** *
2mm	259.80 (14.97) A,B	277.31 (23.89) B	256.09 (16.68) A	122.27 (9.55) D	31.80 (7.36) C	**0.000000** *
1mm	195.09 (19.88) A	198.86 (12.74) A	159.52 (31.83) D	126.00 (9.64) C	7.84 (9.54) B	**0.000000** *
0.5mm	61.98 (32.02) B	66.52 (26.48) B	27.14 (32.50) A	34.96 (24.44) A,B	0.53 (4.17) A	**0.000080** *

*Statistically significant for $p<0.05$.
Different letters indicate presence of a statistically significant difference among the groups, indicated by Tukey test.

3 Discussion

3 DISCUSSION

Three clinical simulation devices were used in this study. Each of them received a different type of conventional esthetic bracket, varying according to the composition. All brackets had 0.022-in slot size and were ligated by elastomeric ligature with outer diameter of 3.23mm in conventional way ("O" shaped). In these devices, four different NiTi wires (with and without esthetic coating) and one translucent wire, with superelastic and mechanical properties similar to NiTi wire, manufactured with a reinforced polymeric composite of plastic resin and fiberglass were used.

All archwires evaluated had same format (Standard or Medium). The specimens were divided in 15 groups using 10 wires per group, totaling 150 tests.

By presenting fewer variables than clinical tests, *in vitro* comparison between different brackets and wires was performed in this research, ensuring lower discrepancy of individual responses and reliable results(KAPILA; SACHDEVA, 1989; TONNER; WATERS, 1994).

All evaluated wires were 0.016-in. This was based on the fact that, during alignment and leveling, low size round wires are the most employed. Thus, during deflection test, it becomes possible to simulate a crowding condition by requiring a larger wire deflection(ANDREASEN; MORROW, 1978; KUSY; GREENBERG, 1981; RUBIN, 1999).

The elastic deflection test has been chosen because it is the clinically closest to the interest of the orthodontist, because that is what he will do when adapting a wire to the teeth of the patient(BURSTONE; GOLDBERG, 1983; ASGHARNIA; BRANTLEY, 1986; BURSTONE; FARZIN-NIA, 1995; KRISHNAN; KUMAR, 2004). Although engineers work with parameters like elastic modulus and yield value, the orthodontist is more concerned with knowing the force released in relation to the amount of deflection(BURSTONE; GOLDBERG, 1983).

Although the deflection test in three-point bend test is widely used in the literature(ELAYYAN; SILIKAS; BEARN, 2008, 2010; IIJIMA *et al.*, 2011; BALLARD *et* *al.*, 2012; DA SILVA *et al.*, 2013), by simulating the pressure of the wire to the teeth during orthodontic treatment and offering reproducibility, thus facilitating comparisons between studies, this research employed a clinical simulation device, as reported by other authors(SANTORO; NICOLAY; CANGIALOSI, 2001; ELAYYAN; SILIKAS; BEARN, 2010; BURSTONE; LIEBLER; GOLDBERG, 2011; KAPHOOR; SUNDARESWARAN, 2012; DA SILVA *et al.*, 2013) who sought to enhance or modify the three-point bend test, including to these variables as types of brackets and elastomeric rings in order to best reproduce the clinical setting, where situations such as the friction between these components may influence the magnitude of the force, because frictional force between wire and bracket increases the loading force, but decreases the unloading force(SEGNER; IBE, 1995; ALAVI; HOSSEINI, 2012).

To quantify the clinical relevance of the data achieved, the clinical simulation device should be closer to possible in a clinical condition. Different force levels have been presented by esthetic wires depending on the different designs of devices used.

There is a wide variability in laboratory methodology in which deflection tests are performed, which makes it more difficult comparison of results from different studies. Differences as bracket type employed (conventional or self-ligating), type of ligation bracket/wire or environment in which the tests were performed (dry or underwater) are variables quite common to be found.

The use of a NiTi wire without esthetic coating, as the Reflex Nickel Titanium evaluated in this research, was necessary for representing, theoretically, a parameter to be followed by the other wires (control), since, with exception of Optis wire, all the other NiTi wires were coated with some type of esthetic material.

When tested with Inspire Ice bracket, in 3 mm deflection, 460.48g force was produced, the second largest force of all tests realized, differing from the results obtained with the other brackets, which produced lower forces (Table III).

Thus, it is suggested that this magnitude of force is directly related to the low friction caused by the contact of the wire with sapphire bracket, considering that in all other tested wires, greater forces were produced by this bracket, in 3 mm deflection.

On the other hand, in 2 mm deflection, again with Ice Inspire bracket, this wire presented a totally opposite behavior from the above, showing a significantly lower force values.

The result of the tests performed with the esthetic NiTi wire plated with Rhodium shows that it presented the highest average force of all tested wires, especially when employed with Inspire Ice bracket (Table IV).

Thus, two hypotheses were suggested: the first related to the bracket composition, a monocrystalline porcelain (sapphire), which is produced by casting of aluminum oxide particles at very high temperature, followed by a controlled cooling, in order to avoid failures in the crystallization. Due to high resistance and a more polished surface, it becomes possible to produce less friction on its groove, when in contact to the orthodontic wire, releasing larger forces during the unloading. The second refers to the NiTi wire itself covered with Rhodium, a noble metal and ductile and silver white coloring. Accurate data about the manufacturing process and conditions of this wire investigated here were not available by the manufacturer. It is suggested that its esthetic cover layer with low friction characteristics, should contribute, likewise, to release higher forces during unloading. However, in a recent work(KATIC *et al.*, 2014) the authors found that the NiTi wire Rhodium plated (High Esthetic, by Dentsply GAC) showed the highest surface roughness, greater elasticity and force during activation, but not on unloading. In addition, it has also showed the highest corrosion rate between the tested wires.

Given the above, it is important to highlight that although some brands present wires covered with Rhodium, the literature is still scarce regarding this coverage, doubt remains about the effects of Rhodium coating on NiTi wires.

Analogous to what has happened with the NiTi wire without esthetic covering, the Aesthetic Nickel Titanium also showed statistically higher values of force only in 3mm deflection, when also associated with sapphire bracket. On the other hand, a 2mm deflection, with the same bracket, recorded the lowest force average (Table V). Kaphoor(KAPHOOR; SUNDARESWARAN, 2012) found no statistically significant difference in force values of this epoxy resin coated wire, showing a better behavior than found in this study.

By analyzing their performance in small deflections (0.5 mm and 1 mm) it was also observed their different load values when associated with other brackets, evidencing a marked variability and inconsistency in the results presented in this wire.

These findings show a rather atypical behavior of this wire, especially in larger deflections, possibly caused by the surface of the esthetic coating, influencing on the resistance to sliding while measuring the forces at unloading.

It was observed that during the tests employing the esthetic wire coated with epoxy resin (Spectra) there was not a significant decrease in force values between the deflections from 2 mm to 1mm, unlike what happened with the other wires (Table VI). This fact may be related to the coating composition of the wire, since such factors as the material thickness, hardness and heat treatment affect their rigidity, and therefore may also alter the surface roughness of the wire.

The lower force values recorded by Spectra wire may be related to increased friction arising from its coating material, since the greater the friction interface at the wire / bracket interface, the lower the force generated during unloading, because friction consumes part of the accumulated initial force during the wire activation, and only from the moment that it exceeds the static friction, the wire will actually express its stored energy.

This result emphasizes the findings by Elayyan (ELAYYAN; SILIKAS; BEARN, 2010), Alavi (ALAVI; HOSSEINI, 2012) and Kaphoor (KAPHOOR; SUNDARESWARAN, 2012) that found lower force generated by the epoxy resin coated wire.

Although recent studies(KAPHOOR; SUNDARESWARAN, 2012) have shown that coated wires may now be able to generate forces similar to the uncoated wire, particularly when only the labial surface of the wire is coated, this fact has not occurred in the present study, in which the spectra wire presented one of the lowest deflection force values.

In the present research, purely esthetic wire presented the lowest force values for all deflections. In 3 mm unloading, statistically high force was found, when used with Inspire Ice bracket. From 3 mm, the wire produced permanent deformation (crack), producing an extremely low force, near zero, meaning that the wire stopped exerting force (Table VII).

Cracking is defined as a region of ultrafine cracks in the resin phase leading to the appearance of a white band(PEBLY, 1987). It is noticed by a significant drop in force values. Even with the cracking, the wires still exert some force, but they are much less than without cracking(CHANG *et al.*, 2013).

It is suggested that 0.016-in FRP wire evaluated in this research has an internal fiber configuration unable to withstanding 3 mm elastic deflection and keep their original shape without losing the stiffness and elasticity. These wires can fail during utilization, due to stress fractures in detachment of fibers, fractures close to polymer-fiber bonding, compression fractures from bends in fibers and fractures close to the intralaminar surface.

A similar result that found in this study was obtained by Spendlove (SPENDLOVE *et al.*, 2014) who found fracture of the wires and decrease of force released in 2 mm unloading, when evaluated after 30 days of successive tests.

The research of Elayyan(ELAYYAN; SILIKAS; BEARN, 2010) evaluated the unloading force of two wires of the same commercial brand (G&H Wire), 0.016-in and 0.018x0,025-in, comparing them to the nitinol wire in the same dimensions, using three-point bend test with conventional and self-ligating brackets, adapted to it in deflections 2; 1.5; 1 and 0.5 mm, at room temperature. Deflection forces ranged from 255g to 18g. Esthetic wires produced statistically lower forces when compared to the control wire. In this study, despite some differences in methodology, such as degree of deflection and temperature, the forces encountered ranged from 240g to 0.16g, which are close to the results found by Elayyan et al., in 2010.

The clinical applicability of these fiber-reinforced composite archwires may be limited as they are unable to sustain deflections of 2 mm without experiencing crazing and loss of force delivery. Clinical efficacy of the esthetic, fibre-reinforced composite orthodontic wires remains to be observed(SPENDLOVE *et al.*, 2014).

Three types of conventional esthetic brackets employed exerted influence on the results of the different wires, assessed in all deflections studied. This fact suggests that the interpretation of the load-deflection values, presented by the various specimens of wires, should not be done isolated and quantitatively, because a determined part of this generated force, reflects a greater or lesser contribution of the bracket, depending on the friction generated by its insert, result from different materials composition.

Important aspect to be considered is the difficulty in extrapolating to the clinical environment the findings obtained in the laboratory associated to the frictional forces due to many different factors such as occlusal forces, which by tightening or loosening the wire in brackets during treatment, may have different force values, with significant clinical relevance (KUSY; WHITLEY, 1999).

Due to the stated above, the results of this study do not allow a thorough comparison with the others, therefore, aspects such as wire size, deflection values, brackets and elastomeric rings and temperature are variables in this type of research which need to be taken into consideration (IMAI *et al.*, 1998; IMAI *et al.*, 1999; ELAYYAN; SILIKAS; BEARN, 2010; IIJIMA *et al.*, 2011; KAPHOOR; SUNDARESWARAN, 2012; DA SILVA *et al.*, 2013).

The optimal deflection occurs at clinically useful displacements between 1 and 2.5 mm. These are the movements that predominate during leveling and aligning with the low gauge wires. This unloading region is the force value most likely to be applied in the clinical situation as soon as some movement of the teeth has occurred within the periodontal ligament(HEMINGWAY *et al.*, 2001). Thus, it is suggested that a deflection above this range may be clinically excessive and not show a reliable behavior of 0.016-in NiTi coated wire, as observed in this search, where all wires tested in 3 mm deflection showed statistically significant values, regardless wire/bracket interaction.

It was observed that esthetic wires employed in this work presented mostly deflection forces compatible to those obtained by uncoated NiTi wires (Reflex Nickel Titanium). Special attention should be given to Optis wire, which despite being highly esthetic presented a permanent crack in 3 mm deflection. This means that when the glass fiber wire is employed in moderate to severe crowding, may undergo a permanent bending interrupting tooth movement. Although light forces during deactivation are desirable, cannot be effective if they are below the range of optimal orthodontic force for tooth movement.

4 Conclusions

4 CONCLUSIONS

Based on the results shown by five different types of esthetic wires and the three types of esthetic brackets, when used together, we conclude that the lowest forces were generated by Spectra wire in combination with Clarity and Mystique brackets, for all deflections studied; and highest mean forces were generated by Flexy NiTi wire in combination with Inspire Ice bracket. During 2; 1 and 0.5 mm unloading, Optis wire experienced cracking and produced an extremely low force, resulting into extremely low forces, non-compatible to the mean forces generated by the other wires.

Regarding evaluated brackets can be noted that Inspire Ice bracket presented the highest mean forces in unloading, regardless the wire employed.

Ultimately, when used together, esthetic brackets and wires, can exhibit very different patterns of forces due to bracket composition and type of wire coating.

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