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Original Article

Evaluation of frictional resistance between monocrystalline (ICE) brakcets and Stainless Steel, Beta TMA and NiTi arch wires

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Abstract

Introduction: When using sliding mechanics for space closure during orthodontic treatment, friction occurs at the bracket-wire interface. The aim of this study was to evaluate the frictional resistance between monocrystalline (ICE) brackets and Stainless Steel, Beta TMA and NiTi wires.

Methods: In this experimental study, we used 5 different types of orthodontic wires. Brackets and wires were divided in to 5 groups: 1-(monocrystalline+stainless steel 18) 2–(monocrystalline+stainless steel 19×25) 3-(monocrystalline+Beta-TMA) 4–(monocrystalline+Beta TMA 19×25) 5-(monocrystalline+NiTi 18). Instron Universal Testing Machine was used to investigate the static frictional resistance. The angulation between bracket and wire was 0 and the wires were pulled through the slots at a speed of 10 mm/min. Tests were performed 10 times for each group in artificial saliva. The average of 10 forces recorded was considered as static friction. One-way ANOVA and SPSS Version 18 and LSD post hoc test were used to evaluate the results of the study.

Results: The mean static frictional force for each group was: group1: 0.82±0.14, group 2: 1.09±0.30, group 3: 0.87±0.53, group 4: 1.9±1.16, group 5: 1.42±0.30. There was a significant difference when comparing the two groups of similar wires in terms of shape (round or rectangular cross-section) as when comparing Beta TMA 18 and 19×25 arch wires with each other, the obtained p-value was 0.023, while the obtained p-value for the comparison of stainles steel arch wires was 0.034.

Conclusions: The result of this study shows that Stainless Steel 18 wires generate the least amount of friction and round wires produce less friction than the rectangular wires. Beta TMA wires generate the highest amount of friction.

Keywords: Bracket, Wire, Frictional resistance

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بررسی مقایسه‌ای مقاومت اصطکاکی در براکت‌های مونوکریستالین (ICE) با سیمهای Beta TMA, ANiTi, Stainless Steel

چکیده

مقدمه: در هنگام بستن فضا با استفاده از مکانیک sliding اصطکاک بین براکت و سیم به وجود می آید هدف از این مطالعه بررسی مقایسه ای مقاومت اصطکاکی در براکتهای مونوکریستالین (ICE) باسیم های ANITI ، ST. STEEL ، TMA می باشد.

مواد و روش ها: این مطالعه یک مطالعه تجربی آزمایشگاهی بوده که در آن از ۵ نوع سیم ارتودنسی استفاده گردیده است. براکت ها و سیم ها به ۵ گروه تقسیم شدند: گروه ۱: 18 Monocrystalline+Stainless Steel، گروه ۲: 19×25 Monocrystalline+Stainless Steel ،گروه۳: Monocrystalline+Beta TMA، گروه۴: 19 ×25 Monocrystalline+Beta TMA ، گروه ۵: 18 Monocrystalline+NiTi . مجموعه سیم-براکت درون دستگاه اینسترون قرار گرفت. زاویه سیم درون براکت صفر و سرعت جابجایی سیم درون براکت mm/min ۱۰ بود. اندازه نیروی اصطکاک برای هر گروه ۱۰ مرتبه در بزاق مصنوعی انجام شد میانگین میزان مقاومت اصطکاک ایستایی برای هر گروه به دست آمد. آزمون One way ANOVA در نرم افزار SPSS نسخه 18 و آزمون تعقیبی LSD برای تجزیه و تحلیل داده ها استفاده شد.

یافته ها: میانگین نیروی اصطکاک در گروه ۱: ۰/۱۴±۰/۸۲، گروه ۲: ۰/۳۰± ۱/۰۹، گروه ۳: ۰/۵۳±۰/۸۷، گروه ۴: ۱/۱۶±۱/۹، گروه ۵: ۰/۳۰±۱/۴۲، به دست آمد. در مقایسه دو به دو گروه ها از نظر شکل سیم (مقطع گرد یا مقطع مستطیل) در سیم های از یک جنس اختلاف معنی دار مشاهده شد. بطوری که در مقایسه سیم 18 Beta-TMA با سیم 19×25 Beta-TMA، p-value=0.023 بدست آمد و درمقایسه سیم های استیل با یکدیگر p-value=0.034 حاصل شد.

نتیجه گیری: یافته های حاصل از این مطالعه بیان می کنند که سیم 18 Stainless Steel کمترین میزان اصطکاک را داشته و سیم های round هم نسبت به سیم های با سطح مقطع مستطیلی نیروی اصطکاک کمتری را ایجاد می کنند. سیم Beta-TMA بیشترین میزان اصطکاک را دارا می باشند.

واژگان کلیدی: براکت، سیم، مقاومت اصطکاکی

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Introduction

Over the years, there have been several theories regarding the relation between orthodontic forces and tooth movement. Schwartz proposed that orthodontic forces should not exceed capillary blood pressure in the periodontal ligament (1).

Storey and Smith developed the concept of optimal force as the minimum value of force that results in the maximum rate of tooth movement within the limits of biologic response (2). However, the realization of the optimal force value for movement of individual teeth has been elusive. Quinn and Yoshikawa conducted a critical review of the theories relating orthodontic force and tooth movement and concluded that the increased forces do not result in an appreciable increase in tooth movement. They stated that there is an optimal range of forces within which the maximum tooth movement is achieved. When sliding mechanics are used, friction occurs at the bracket-wire interface. Some of the applied force is therefore dissipated as friction, and the remainder is transferred to supporting structures of the tooth to mediate tooth movement.

Therefore, maximum biological tissue response occurs only when the applied force is of sufficient magnitude to adequately overcome friction and lies within the optimum range of forces necessary for movement of the tooth (3). Friction depends on factors such as vertical force and relative condition of contact surfaces including roughness and their types of material. Studies have shown that about 50% of the applied force necessary to initiate tooth movement is required to overcome friction (4).

Variables affecting frictional resistance are listed as follows: Saliva, physical properties, arch wire material, angulations of arch wires to bracket and methods of ligation of arch wire to bracket. Depending on the types of arch wire–bracket combination, saliva can have lubricous as well as adhesive behavior (5). The stainless steel wires show an adhesive behavior with saliva and a resultant increase in the coefficient of friction in the wet state, on the other hand, the coefficient of friction in the beta titanium arch wires in the wet state was 50% of the values in the dry state. It is therefore hypothesized that saliva probably acts in preventing solid-to-solid contact.

The role of wire alloy in the frictional characteristics of sliding mechanics has been extensively studied. Studies show that stainless steel wires are associated with the least amount of friction and beta titanium with the most (6).

Although more than 70 years have passed since the introduction of stainless steel brackets, they continue to be the most used in orthodontic practice owing to their superior working qualities. Their only disadvantage perhaps is their lack of aesthetic appearance. Nevertheless, ceramic brackets currently represent an esthetic alternative, although their use is limited. They abrade the enamel, and fracture more easily, and they have a higher coefficient of friction, increasing resistance to sliding.

Despite manufacturers' efforts to improve their qualities by incorporating metal slots, dulling the slot edges, and glazing their surfaces, the physical properties of ceramic brackets are still inferior (7). Up to 60% of the force applied for dental movement can be lost as a result of ceramic bracket resistance to sliding, leading to a longer treatment period. Since ICE bracket is newly introduced and much less studies have been conducted on it, therefore the aim of this study was to evaluate the frictional resistance between monocrystalline (ICE) brackets, Stainless Steel, Beta TMA and NiTi wires.

Methods

In this experimental study, we used 5 different types of orthodontic wires. The brackets and wires were divided in to 5 groups:

1-(monocrystalline+stainlesssteel 18)
2-(monocrystalline+stainlesssteel 19×25)
3-(monocrystalline+Beta-TMA)
4-(monocrystalline+Beta TMA 19×25)
5-(monocrystalline+NiTi 18)

Instron universal testing machine was used to investigate the static frictional resistance. (STM-250-SANTAM).

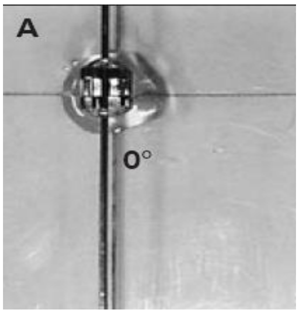

Figure 1. The angle of bracket to metal interface

The arch wires were then placed in the slots and fixed in place by means of Oring (Dentarum) according to their groups. The angulations between bracket and wire was 0 and the wires were pulled through the slots at a speed of 10 mm/min. Tests were performed 10 times for each group in artificial saliva (Aquoral–Sinclair-UK). Since we want to measure the static frictional force rather than the kinetic frictional force, therefore, the applied force was measured upon the initiation of movement. To calculate the frictional resistance, lower central incisors brackets ICE -022 (because of their lower torque) were used. The brackets were assessed in 5 groups:

Group1: ICE brackets and stainless steel arch wire 18
Group2: ICE brackets and stainless steel arch wire 19×25
Group3: ICE brackets and TMA arch wire 18
Group4: ICE brackets and TMA arch wire 19×25
Group5: ICE bracket and NiTi arch wire 18

The ICE brackets we used were produced by Ormco-USA and the arch wires we used were for Dentarum-Germany.To mimic the oral environment, we used artificial saliva (Aquoral–Sinclair-UK).

Statical analysis: Descriptive statistical information, including mean and standard deviation, was calculated for each bracket/arch wire combination. To determine any significant difference in data, KSS test (Kolmogorov-Smirnov Test) was used. The results were compared with one-way analysis of variance (ANOVA) testing ($p \leq 0.05$), T test that was completed with the use of statistical software (Statistical Package for the Social Sciences [SPSS] for Windows vista version 12.0; SPSS Inc. Chicago, Ill).

Results

Stainless Steel arch wires exhibit the least amount of recorded frictional force while rectangular Beta TMA 19×25 archwires exhibit the most amount of recorded frictional force (table1). There was a significant difference when comparing the groups in terms of shape (round vs rectangular) in similar arch wires as when comparing Beta TMA 18 and 19×25 arch wires with each other, the obtained p-value was 0.023 while the obtained p-value for the comparison of stainles steel arch wires was 0.034 (table2).

Table 1. Mean friction in each group

Gruop	Friction (Mean±SD)	Minimum (N)	Maximum (N)
Group1 Stainless Steel 18	0.82(±0.14)	0.61	1.04
Group2 Stainless Steel 19×25	1.09(±0.30)	0.66	1.66
Group3 Beta-TMA 18	0.87(±0.53)	0.364	1.44
Group4 Beta-TMA 19×25	1.9(±1.16)	0.42	3.32
Group5 NiTi 18	1.42(±0.30)	0.99	1.97

Table 2. Comparison of the groups with mann-whitney test

Group	Group	P value
Beta-TMA 19×25	Stainless Steel 18	0.01*
Beta-TMA 18	Beta-TMA 19×25	0.023*
NiTi 18	Beta-TMA 19×25	0.82
Stainless Steel 19×25	Beta-TMA 19×25	0.104
Beta-TMA 18	Stainless Steel 18	0.791
NiTi 18	Stainless Steel 18	0.00*
Beta-TMA 18	NiTi 18	0.003*
Beta-TMA 18	Stainless Steel 19×25	0.174
Stainless Steel 18	Stainless Steel 19×25	0.034*S
Stainless Steel 19×25	NiTi 18	0.031*

***p-value≤0.05 was considered significant**

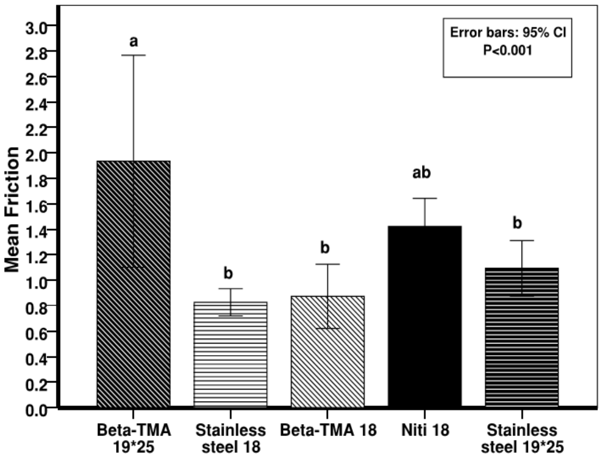

Figure 2. Comparison of the frictional forces in different wires

Discussion

Beta–titanium arch wire is typically associated with higher levels of friction when compared with Stainless steel arch wire (8-9), the reason behind this according to the authors lies in two microscopic examination of the wires before and after sliding indicated several surface differences between the wire materials.

Stainless steel appeared initially to have a polished surface, but after sliding, it exhibited wear tracks. Beta–titanium wire had a considerably evident grain structure which was polished and worn by sliding. The second explanation which was recently applied by other researchers (8-10).

Consider the surface roughness to be a minor contributor to the increase in friction of Beta–titanium wire compared to Stainless steel wire, the main reason, as they concluded, is attributed to the adherence of the wire material to the surface of the bracket slot during sliding, although both Stainless steel and Beta–titanium arch wires tend to demonstrate adhesive wear, Beta–titanium wires exhibited more severe adhesion.

The result of this study showed that the circular stainless steel archwire exhibit the least amount of friction while resctangular Beta TMA archwire exhibit the highest amount of friction which is in accordance to the study of Dilip, et al. They conducted a study to evaluate the difference in magnitude between the friction generated by stainless steel, Nickel titanium, TMA, timolium and CNA archwires with stainless steel brackets under dry condition. They concluded that TMA wires exhibited highest frictional resistance while stainless steel exhibited the least resistance with stainless steel brackets (11). Obaidi, et al. compared the frictional coefficients between the stainless steel and Beta–titaniumarch wire ligated to the stainless steel bracket via different ligatures. They showed that the stainless steel arch wire tied to the bracket via stainless steel ligature achieved significant lower frictional coefficient value when compared with other wire subgroups. Our findings in this study demonstrate similar results (12).

Yu, et al. used a surface profilometer and a hardness tester to evaluate the surface roughness and hardness of four commonly used types of orthodontic arch wire: (1) stainless steel (SS) wire, (2) conventional nickel-titanium (NiTi) alloy wire, (3) improved superelastic NiTi-alloy wire (also called low-hysteresis (LH) wire), and (4) titanium molybdenum alloy (TMA) wire. The results of their study showed that SS wire has the smoothest surface (roughness of 0.051±0.023 µm, mean±SD), followed by TMA wire (0.206±0.007 µm), NiTi wire (0.627±0.072 µm), and LH wire (0.724±0.117 µm).

In addition, SS wire has the hardest surface (hardness of 405.4±9.9 kg/mm2), followed by TMA wire (303.3±13.2 kg/mm2), LH wire (215.1±48.5 kg/mm2), and NiTi wire (195.4±17.2 kg/mm2). This characteristic of stainless steel wire results in the least amount of frictional resistance among the other types of orthodontic wires (13). A similar study was conducted by Guerrero et al. on static frictional force and surface roughness of various wire and bracket combinations. The result of their study was similar to the results of Yu (14).

The present study shows results similar to the above mentioned findings. With respect to shape of wires, the results of this study are in agreement with other studies. Tecco, et al. conducted a study on friction between arch wires of different sizes, cross-section and alloy and brackets ligated with low-friction or conventional ligatures. They concluded that the circular type of arch wires demonstrate the least friction while the rectangular arch wires exhibit the highest friction (10).

Conclusion

Round stainless steel arch wires exhibit the least amount of frictional force and rectangular Beta-TMA arch wires have the highest amount of frictional force.

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Conflict of interest: There was no conflict of interest.

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