Global Journal of Medical Research: J
Dentistry & Otolaryngology
Volume 17 Issue 2 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

In Vitro Comparison of Friction Generated by Various Models of Self-Ligating and Conventional Brackets While Performing Retraction with Sliding Mechanics

By Mario Cappellette Jr., Luciano Nogueira de Almeida Campos, Andre Besen,
Lucia Hatsue Yamamoto Nagai, Carolina Marins Ferreira da Costa
& Paulo de Tarso Almeida Carvalho
Universidade Federal de São Paulo

Abstract- Introduction: In vitro studies suggest that certain variables such as friction coefficient, archwire size and force decay affect the effectiveness of sliding mechanics. To maximize the efficiency of sliding mechanics one should seek to control these variables.

Objective: This *in vitro* study aimed to compare frictional forces in several models of self-ligating brackets, conventional systems, as well as different ways to tie the wire to the brackets during a simulation of sliding mechanics using 0.019"X0.025" stainless steel wire.

Material and Methods: The study evaluated the levels of dynamic and static friction in sixdifferent types of brackets andthree different ligation systems were used with conventional brackets: elastomeric modules, unconventional elastomeric ligature low friction system, and 0.20mm stainless steel-ligature.

Keywords: *friction; in vitro; orthodontic brackets; self-ligating brackets, sliding mechanics.*

GJMR-J Classification: *NLMC Code: WU1*

INVITROCOMPARISONOFFRICTIONGENERATEDBYVARIOUSMODELSOFSELFLIGATINGANDCONVENTIONALBRACKETSWHILEPERFORMINGRETRACTIONWITHSLIDINGMECHANICS

Strictly as per the compliance and regulations of:

In Vitro Comparison of Friction Generated by Various Models of Self-Ligating and Conventional Brackets While Performing Retraction with Sliding Mechanics

Mario Cappellette Jr. [α], Luciano Nogueira de Almeida Campos [σ], Andre Besen [ρ],
Lucia Hatsue Yamamoto Nagai [ω], Carolina Marins Ferreira da Costa [¥]
& Paulo de Tarso Almeida Carvalho [§]

Abstract- Introduction: In vitro studies suggest that certain variables such as friction coefficient, archwire size and force decay affect the effectiveness of sliding mechanics. To maximize the efficiency of sliding mechanics one should seek to control these variables.

Objective: This *in vitro* study aimed to compare frictional forces in several models of self-ligating brackets, conventional systems, as well as different ways to tie the wire to the brackets during a simulation of sliding mechanics using 0.019"X0.025" stainless steel wire.

Material and Methods: The study evaluated the levels of dynamic and static friction in sixdifferent types of brackets andthree different ligation systems were used with conventional brackets: elastomeric modules, unconventional elastomeric ligature low friction system, and 0.20mm stainless steel-ligature.

Results: The results showed that for both static and dynamic friction all other ligating systems exhibited statistically less friction than Gemini brackets with conventional elastomeric. Systems with lower levels of friction were as follows: SmartClip (E0.08N; D0.00N), Gemini brackets with Leone ligature (E0.08N; D0.04N), and Vision LP (E0.04N; D0.00N).

Conclusion: During sliding mechanics frictional forces generated by the conventional ligation system were significantly higher than the forces generated by self-ligating brackets and other ligation systems.

Keywords: friction; in vitro; orthodontic brackets; self-ligating brackets. sliding mechanics.

I. BACKGROUND

Premolar extraction is a common treatment option in orthodontics. Space closure can then be achieved with sliding mechanics, which consists in pulling or pushing a tooth along a straight archwire using an appropriate system of forces to produce a sustained movement. Elastomeric materials or springs are often employed to produce this force. *In vitro* studies[1] suggest that certain variables such as friction coefficient, archwire size and force decay impair the effectiveness of sliding mechanics. Other factors that affect friction include saliva, material and wire size, and angulation between bracket, wire and ligation system[2]. To maximize the efficiency of sliding mechanics one should seek to control these variables[1]. In orthodontic movement, friction (static or dynamic) results from the interaction of an archwire with the walls of the bracket slots or the ligatures[3]. Moreover, the forces generated at the bracket/wire interface may hinder the achievement of optimal force levels in the supporting tissues. Therefore, a decrease in this response is likely to benefit the response of hard and soft tissues. Frictional force is classified into static and kinetic. Static friction is the smallest force needed to start a movement between solid objects at rest and the kinetic friction force resists the sliding motion of a solid object against another at a constant speed[3]. It has been reported that 50% of the force applied to slide a tooth is used just to eliminate friction.

With the increase in the use of self-ligating brackets[4], many studies have been conducted using self-ligating brackets and reported advantages including increased patient comfort, improved oral hygiene, less chair time, anchorage conservation, and reduction of the friction[5-7]. Although reports of reduced friction are one of the advantages of self-ligating brackets when compared with conventional brackets[8,9], this issue is still controversial. The term self-ligation in orthodontics implies that the bracket has the ability to engage itself to the archwire by a mechanical device (clip) built into the bracket to close off the slot[10] and the clip could be active when the ligation clip exerts a pressure on the arch wire or passive when the clip transforms the slot to a tube.

This *in vitro* study aimed to compare static and dynamic friction frictional forces in self-ligating brackets, conventional systems with different methods to tie the

---

*Author α: D.D.S., Ph.D., Department of Otolaryngology–Head and Neck Surgery, Discipline of Pediatric Otolaryngology, Universidade Federal de São Paulo–UNIFESP/EPM, São Paulo, Brazil.
e-mail: mjrcappellette@terra.com.br
Author σ ρ Ѡ: Dr. Orthodontist, Universidade Federal de São Paulo, São Paulo, Brazil. e-mails: dr.lucianocampos@gmail.com, andrebesen@gmail.com, lhyamamoto@gmail.com
Author ¥ §: MDS, Universidade Federal de São Paulo, São Paulo, Brazil.
e-mails: carolinamfc@gmail.com, paulodetarsoac@gmail.com*

wire to the brackets during a simulation of sliding mechanics devised by Bennett & McLaughlin[11] using 0.019"X0.025" stainless steel (NiCr) wire.

II. METHODS

Six different types of brackets - 0.022 x 0.027 -in slots, were selected both self-ligating and conventional appliances: Gemini (3M Unitek® Monrovia, California, USA), SmartClip (3M Unitek® Monrovia, California, USA), Empower (American Orthodontics®), Quick (Forestadent®), In-Ovation (GAC®), Vision LP. (Table 1)

Three different ligation systems were used with conventional brackets, i.e., conventional elastomeric modules (EMs) manufactured by Morelli® unconventional elastomeric modules (Slide by Leone® Italy) and 0.10-in ligatingstainless-steel ligature also manufactured and marketed by Morelli®.

The tests were conducted using 0.019"x0.025" (Morelli®) steel wire on all brackets or ligation systems. Five observations were carried out for each brackets-ligation system combination. To eliminate the influence of wear, a wire sample was drawn only once through a brackets-ligation system combination and news brackets, ligation and wire were used in each test run.This generated a trial with 200 brackets and 40 tests readings were taken for the study. Altogether, there were eight separate groups of brackets and ligation systems (Table 2).

a) *Friction assessment device*

To evaluate the friction levels a device[12] was created specifically designed for this purpose. It was adapted to an EMIC DL2000 machine to simulate retraction movements commonly used in orthodontic sliding mechanics at a constant speed of 10 mm/min (Fig 1). The device consisted of a stainless-steel base fixed with screws, and cylindrical rods each with a cavity where each bracket was bonded. This set of grouped rods simulates a group of teeth.

The brackets were attached to a bonding guide with 0.10-in steel ligatures (Morelli). This guide consisted of a stainless-steel plate with a thickness of 0.019-in where the brackets were placed. Once positioned at the same distance, height and with the same buccolingual relationship, which neutralized any expression of torque or tip preadjusted in the brackets, the latter were bonded to the cylinders with Transbond XT (3M Unitek®) adhesive and light-cured for 20 seconds. The brackets were all aligned and leveled so as to avert any factors that might generate friction and thereby impair the accuracy of the data[12] and the effect of different forms of ligation could be isolated with greater precision[13,14]. (Fig. 2 a, b, c)

b) *Statistical analysis*

Statistical analysis of all data collected in this research was initially performed descriptively by calculating some summary measures such as mean, median, minimum, maximum and standard deviation values. Additionally, one-dimensional scatter diagram charts were built[15].

The Kruskal-Wallis test was employed as inferential analysis in order to compare static and dynamic friction between the eight types of brackets[16].

A significance level of $\alpha = 5\%$ was applied to all conclusions reached through inferential analyses.

The data were entered spreadsheets in Excel 2010 for Windows software for proper information storage. The statistical analyses were performed with R software version 2.15.2.

III. RESULTS

The sample in this study consisted of 40 specimens, 5 each of 8 different types of brackets (Gemini/EMs, Gemini/Ligature, Gemini Leone, Empower, Vision, Quick, GAC and SmartClip).

Static and dynamic friction was measured for each of the specimens (see details in Table 1 and Graphs 1 and 2).

Gemini/EMs brackets showed a mean static friction of 5.86N, ranging from 5.31 to 6.70N, with a standard deviation of 0.59N. Mean dynamic friction was 5.12N, ranging from 4.80 to 5.50N, with a standard deviation of 0.29N.

Gemini/Ligature brackets showed a mean static friction of 3.27N, ranging from 2.58 to 4.38N, with a standard deviation of 0.73N. Mean dynamic friction was 2.76N, ranging from 2.20 to 3.80N, with a standard deviation of 0.67N.

Gemini/Leone brackets displayed a mean static friction of 0.08N, ranging from 0.06 to 0.08N, and a standard deviation of 0.01N. Mean dynamic friction was 0.04N, ranging from 0.00 to 0.10N, with a standard deviation of 0.05N.

Gemini/Ligature brackets showed a mean static friction of 3.27N, ranging from 2.58 to 4.38N, with a standard deviation of 0.73N. Mean dynamic friction was 5.12N, ranging from 4.80 to 5.50N, with a standard deviation of 0.29N.

Vision LP brackets showed a mean static friction of 0.04N, ranging from 0.03 to 0.06N, and a standard deviation of 0.01N. All five specimens of this type of bracket showed no dynamic friction.

BioQuick brackets showed a mean static friction of 2.78N, ranging from 2.62 to 3.11N, with a standard deviation of 0.19N. Mean dynamic friction was 2.56N, ranging from 2.50 to 2.80N, with a standard deviation of 0.13N.

In-Ovation brackets exhibited a mean static friction of 1.83N, ranging from 1.61 to 2.06N, and a standard deviation of 0.16N. Mean dynamic friction was 5.12N, ranging from 4.80 to 5.50N, with a standard deviation of 0.29N.

SmartClip brackets displayed a mean static friction of 0.08N, ranging from 0.07 to 0.08N, with a standard deviation of 0.01N. All five specimens of this type of bracket showed no dynamic friction.

Inferential results showed that the static ($p<0.001$) and dynamic ($p<0.001$) friction levels are not statistically identical across the different types of brackets (Graphs 1 and 2).

- Gemini/EMs brackets have higher static friction than Gemini/Ligature ($p<0.001$), Gemini Leone ($p<0.001$), Empower ($p<0.001$), Vision LP ($p<0.001$), BioQuick ($p<0.001$), In-Ovation ($p<0.001$) and SmartClip ($p<0.001$) brackets.
- Gemini/EMs brackets have higher dynamic friction than Gemini/Ligature ($p<0.001$), Gemini Leone ($p<0.001$), Empower ($p<0.001$), Vision LP ($p<0.001$), BioQuick ($p<0.001$), In-Ovation ($p<0.001$) and SmartClip ($p<0.001$) brackets.

IV. Discussion

In preparing the patient for sliding mechanics, one should insert rectangular steel archwires as of one to two months prior to applying the mechanics itself. This preparation allows all brackets to express their torques and angulations more efficiently. The goal is to make the archwire as passive as possible to avoid interfering with the archwire as it slides along the bracket slot. Thus, the brackets were placed passively, applying sliding mechanics as much as possible in its clinical form as well.

During *in vivo* sliding mechanics, the steel wire slides along the molar and premolar brackets performing incisor and canine retraction while simultaneously closing spaces. This study used incisor, canine and premolar brackets to minimize bonding errors since it would be quite a challenge to place the appliance passively with tubes bonded to the molars. This may have slightly altered the absolute results, but given that the intention was to compare ligation systems, any changes would apply to all systems.

In a critical review of the literature in 2009 Burrow[3] defined friction as a minor component in the set of forces that cause resistance to tooth movement. Possibly, sliding mechanics is an exception to this rule, given (a) the way in which the wire slides along the premolar and molar brackets with no forces being applied directly to the tooth, but rather to a hook welded to the wire, and (b) preparation involves the use of rectangular steel wires. These factors help to reduce the binding effect, which occurs when force is applied directly to the tooth being moved, rendering this type of mechanics highly dependent on the friction between wire and bracket. Some forms of sliding mechanics described in the literature[1] apply force to the tooth being moved, such as canines. This would completely change the force components of the system, making binding its major component.

Other limitations stem from not considering the moment caused by the elastomeric modules during movement. As described in the study by Budd et al[17] in 2008, a typodont with brackets bonded to it, and dipped in a fluid would undergo variations in the movements that occur during the mechanics. Pliska et al[18] in 2014 concluded that friction induced by ligation has little influence on the overall resistance to slinding when moment forces are combined. It should be underscored that the main objective of this investigation was to compare ligation systems. If rotation were to be incorporated during movement the variables would be far too numerous making it impossible to compare the systems themselves. Thus, not all clinical conditions were simulated in their entirety, and the number of variables was deliberately reduced to facilitate the study. For example, Leal et al[19] in 2014, clarified the significant role of lubricant, like artificial saliva in friction forces between self-ligating brackets and wires. Nevertheless, the main results agreed with those reported by Budd et al[17] in 2008, which included momentum in their laboratory model.

Furthermore, there is no denying that there are limitations in this study given that the laboratory environment does not provide clinical factors such as: The action of saliva, possible occlusal forces, muscle interference, interferences with oral functions such as mastication and swallowing, different degrees of malocclusion, thickness and compressibility of the periodontal ligament, rotated teeth, torque at the wire/bracket interface, angulations and temperature.

Many studies[2,17,20] used various wire sizes for comparison. The goal here was to simulate sliding mechanics, which is always performed with 0.019"x0.025" steel wire. Most studies also test the friction in a single bonded bracket and not in a set of brackets, as was done here. Future research should consider other rectangular steel wire sizes, such as 0.018"x0.025".

The static friction is the force that opposes the beginning of movement at the moment when activation is performed. The results showed a statistically significant difference ($p<0.001$) between the Gemini/EMs group and the other groups. These results demonstrate that during sliding mechanics other ligation systems are better suited than elastomeric modules given the substantial difference in the friction force generated. It should be remembered that the lower the friction force, the less force is required to initiate movement, and the more optimized and physiological this movement will be.

Ehsani et al[2] in a review of the literature written in 2009 report that five studies were conducted and found no significant differences between self-ligating and conventional brackets in terms of friction force when rectangular wires of greater caliber are utilized. Moreover, in seven other studies, self-ligating brackets produced lower friction than conventional brackets. All seven agree with the results of this study, if one considers conventional brackets tied with elastomeric modules. Regarding metal ligatures and Slide ligatures, the results agree with the first group. A 2007 study[20] compared the use of metal ligatures with SmartClip self-ligating brackets and found no statistically significant difference during en masse sliding mechanics. The literature review's conclusions disagree with the results of this investigation by admitting that there was not enough evidence to prove that self-ligating brackets produce lower friction forces than conventional brackets with rectangular archwires. This divergence may have occurred due to the fact that the authors could not specify comparisons amidst such an overwhelming number of articles. In this study, for example, if one were to compare the ligature system with the Empower or BioQuick brackets, no differences would be found. Holtmann et al[12] in 2014 demonstrated that self-ligating and steel-ligated brackets are more effective to correct misalignment and exertion of lower forces at the same time, than brackets with elastic ligatures. However, since the comparison was made with elastomeric modules the difference was statistically significant. Perhaps because literature reviews are so comprehensive one may miss some important details that might clarify certain issues.

As shown in Table 3, the mean static friction forces of the Gemini Leone (0.08N), Vision LP (0.04N) and SmartClip (0.08N) ligation systems are clearly lower than the forces found in the other groups. This may be related to the fact that in these three ligation systems the wire is tied to the brackets passively. Slide ligatures (Leone®,Italy) cover the open part of the slot leaving the wire completely passive within it. Vision LP brackets feature an opening with the same passive cover design to keep the wire into the slot. Moreover, SmartClip brackets also have clips that appear not to compress the archwire inside the slot. Studies comparing active and passive self-ligating brackets concluded that passive brackets produce statistically lower friction forces[21].

With the Gemini/Ligature ligation system (3.27N), Empower brackets (3.24N) and BioQuick brackets (2.78N) have also been shown to generate similar mean values of static friction forces during sliding mechanics. These forces are obviously higher than in the groups discussed above, but still lower than in the Gemini/EMs group.

Metal ligatures push the wire against the base of the slot but because they are made from stainless steel they produce less friction. The Empower bracket is equipped with a chromium cobalt clip which with thicker wires acts by pressing the wire against the bracket base. The BioQuick bracket, in turn, has a steel clip that also exerts a continuous force on the wire.

The In-Ovation bracket has a mean static friction of 1.83N. This bracket also features a chromium cobalt spring that compresses the wire inside the bracket slot when thicker wires are inserted. This spring, however, can exert forces that are lighter than the springs. These data agree with Budd et al[17], who in 2008, after analyzing several variables, concluded that the binding mechanism is the main variable affecting frictional forces in the different ligation systems.

Dynamic friction is here defined as the force that opposes the force that allows the movement to continue. It is known that in sliding mechanics the force intensity applied in the initial activation usually weakens with each passing hour, and will probably be extinguished before the next activation. Thus, the lower the dynamic friction, the longer it takes this force to subside completely. Additionally, it is more effective, which optimizes the mechanics.

The results found in this study were very similar to the results found for static friction. Elastomeric ligatures (5.12N) showed a dynamic friction force statistically higher ($p=0.001$) than all other ligation systems. These other systems are therefore not indicated for use with sliding mechanics.

With the Gemini/Leone group (0.04N), SmartClip (0.00N) and Vision LP (0.00N) brackets exhibited the lowest mean dynamic friction. This is probably since these are passive systems.

On the other hand, the Gemini/Ligature group (2.76N), as well as the Empower (2.66N) and BioQuick (2,56N) brackets also showed values that are similar to dynamic frictional forces.

The In-Ovation bracket group showed a mean friction force of 1.44N, which was remained unchanged between the lowest and the intermediate values.

It is the authors' view that due to similarities between the results for static vs. dynamic friction, the arguments expressed in the literature probably apply to both types of friction. A study conducted in 2010 by Stefanos et al[21] also found significant similarities between the results of both types of friction. A 2009 literature review by Burrow[3] argued that for practical purposes dynamic friction is irrelevant in orthodontic tooth movement. The author goes on to explain that the continuous movement of a tooth along an archwire is a rare phenomenon and that in sliding mechanics one is dealing with a quasi-static thermodynamic process. This means that the process occurs slowly and leads to a sequence of quasi-equilibrium states. Force and resistance to sliding change as the tooth moves along the archwire. It then inclines and responds by producing a biological response, i.e., bone remodeling, then inclines once again[3]. This process is seen by Burrow[3] as quasi-static, although for many other researchers it could be considered as an ongoing process. The results showed a striking similarity between the two types of friction, which led the authors to believe that regardless of its relevance or irrelevance dynamic friction can be considered as complementary to static friction. It can be present on rare occasions during orthodontic movement but should never be ignored, irrespective of relevance.

Certain types of materials used in this study could influence friction. The first such material is steel, sliding underneath elastomeric modules present in the Gemini/EMs and Gemini Leone groups, since the steel archwire slides along a metal slot covered with an elastomeric module. The second type is steel with steel, as in the Gemini/Ligature and Quick groups. The third type is steel and chromium cobalt alloy in the Empower and In-Ovation groups, since the covers are made of cobalt chromium. The fourth and last type is steel with nickel-titanium, as in the Vision and SmartClip groups.

It became unequivocally clear that in types 1 and 3 substantial differences were found in the results, which rules out the possibility that the materials affected the tests in any way. These findings contrast with some studies[17] that consider the material from which the cover was made as a factor capable of influencing the amount of friction that occurs in each bracket type. This may have occurred since this study involved at least two different ligation systems for each type of material, which was not the case in the study by Budd in 2008, which examined a more limited range of brackets[17].

V. Conclusions

Friction was influenced by the type of bracket and by the ligating systems. During sliding mechanics, frictional forces generated by the conventional ligation system (Gemini brackets + elastomeric modules) were statistically higher than the forces generated by self-ligating brackets and other ligating systems. Specifically, SmartClip and Vision LP brackets as well as Leone's Slide ligating system generated the lowest frictional forces during sliding mechanics.

Table 1: Brackets used in the study and their key features

Group	Brackets	Torque	Angulation (tip)	In/out
Gemini/EMs, Gemini/Ligatures and Gemini Leone	Maxillary right central incisor	17	4	0.82
Gemini/EMs, Gemini/Gemini Leone and Ligatures	Maxillary right lateral incisor	10	8	1.06
Gemini/EMs, Gemini/Gemini Leone and Ligatures	Maxillary right canine	-7 or 0	8	0.8
Gemini/EMs, Gemini/Gemini Leone and Ligatures	Maxillary first right premolar	-7	0	0.83
Gemini/EMs, Gemini/Gemini Leone and Ligatures	Second right pre-molar	-7	0	1.06
Empower	Maxillary right central incisor	17	4	-
Empower	Maxillary right lateral incisor	10	8	-
Empower	Maxillary right canine	0 or -7	8	-
Empower	Maxillary right first premolar	-7	0	-
Empower	Maxillary right second premolar	-7	0	-

Vision LP	Maxillary right central incisor	17	4	-
Vision LP	Maxillary right lateral incisor	10	8	-
Vision LP	Maxillary right canine	0	8	-
Vision LP	Maxillary right first premolar	-7	2	-
Vision LP	Maxillary right second premolar	-7	2	-
Quick	Maxillary right central incisor	17	4	1.1
Quick	Maxillary right lateral incisor	10	8	1.5
Quick	Maxillary right canine	-2	11	0.75
Quick	Maxillary right first premolar	0	0	0.75
Quick	Maxillary right second premolar	0	0	0.75
In-Ovation	Maxillary right central incisor	12	5	-
In-Ovation	Maxillary right lateral incisor	8	9	-
In-Ovation	Maxillary right canine	-2	13	-
In-Ovation	Maxillary right first premolar	-7	0	-
In-Ovation	Maxillary right second premolar	-7	0	-
SmartClip	Maxillary right central incisor	17	4	-
SmartClip	Maxillary right lateral incisor	10	8	-
SmartClip	Maxillary right canine	-7	8	-
SmartClip	Maxillary right first premolar	-7	0	-
SmartClip	Maxillary right second premolar	-7	0	-

Table 2: Groups used in the study divided by ligation system

Group	System	Material	Slot	Ligation System
Gemini/EMs	Gemini^{TM} (® 3M Unitek, Monrovia, California, USA) with conventional elastomeric module ligation	Elastomeric	0.022"	Conventional elastomeric ligature modules Morelli ®
Gemini/Ligature	Gemini^{TM} (3M Unitek ® Monrovia, California, USA) with steel ligatures	Steel	0.022"	0.020" steel ligatures Morelli ®
Gemini Leone	Gemini^{TM} (3M Unitek,® Monrovia, California, USA) with Slide® elastomeric module ligatures (Leone, Italy)	Elastomeric	0.022"	Slide® elastomeric ligatures (Leone, Italy)
Empower	Empower (American Orthodontics,®, Wisconsin, USA)	Chromium cobalt clip	0.022"	Active Clip
Vision	Vision LP (American Orthodontics,® Wisconsin, USA)	NiTi clip	0.022"	Passive design
Quick	BioQuick (Forestadent, ® Germany)	Steel clip	0,022"	Active Clip
In-Ovation	In-Ovation (GAC,® New York, USA)	Chromium cobalt spring	0.022"	Active spring
SmartClip	SmartClip (3M Unitek,® Monrovia, California, USA)	NiTi clip	0.022"	Passive clip

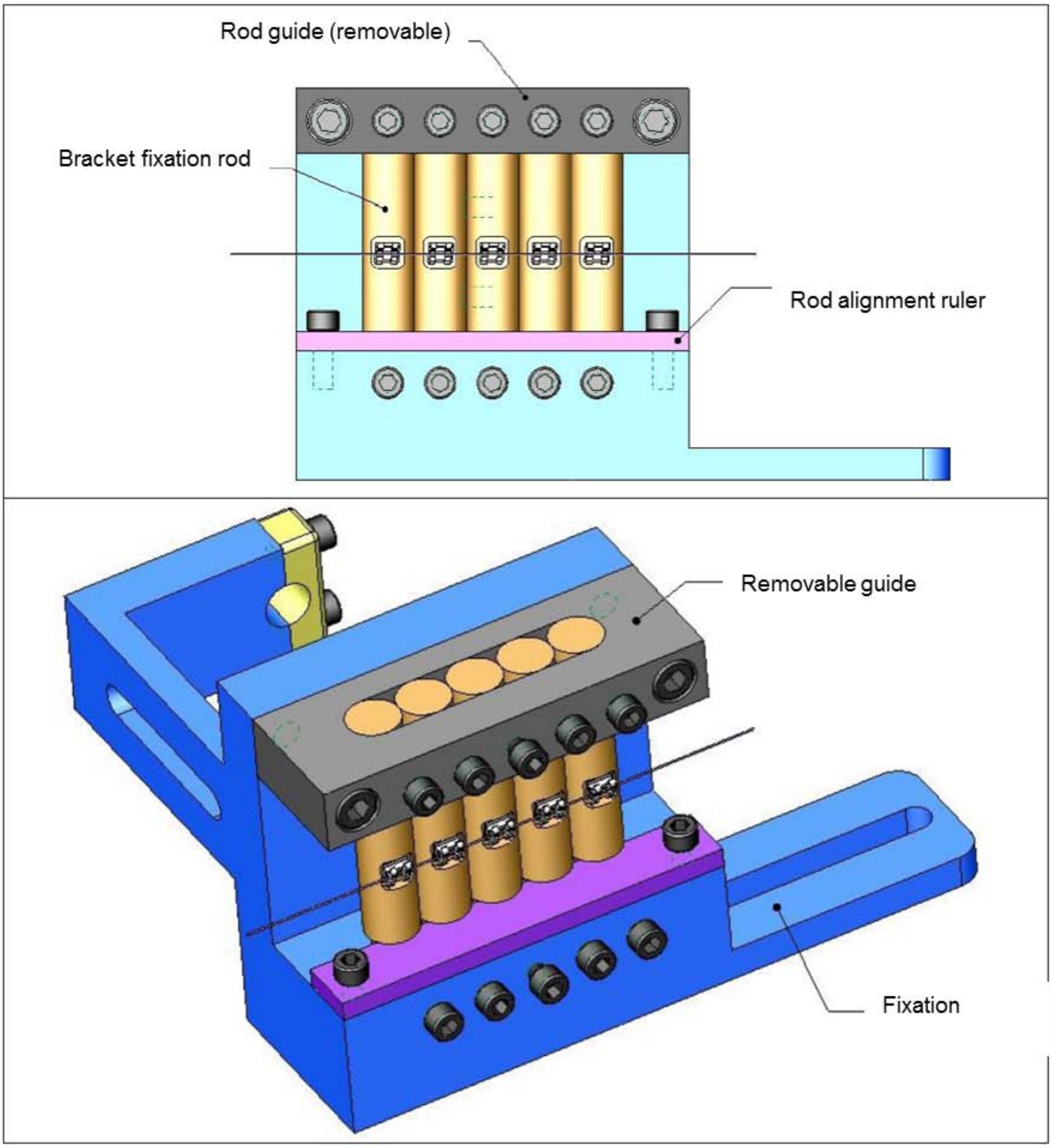
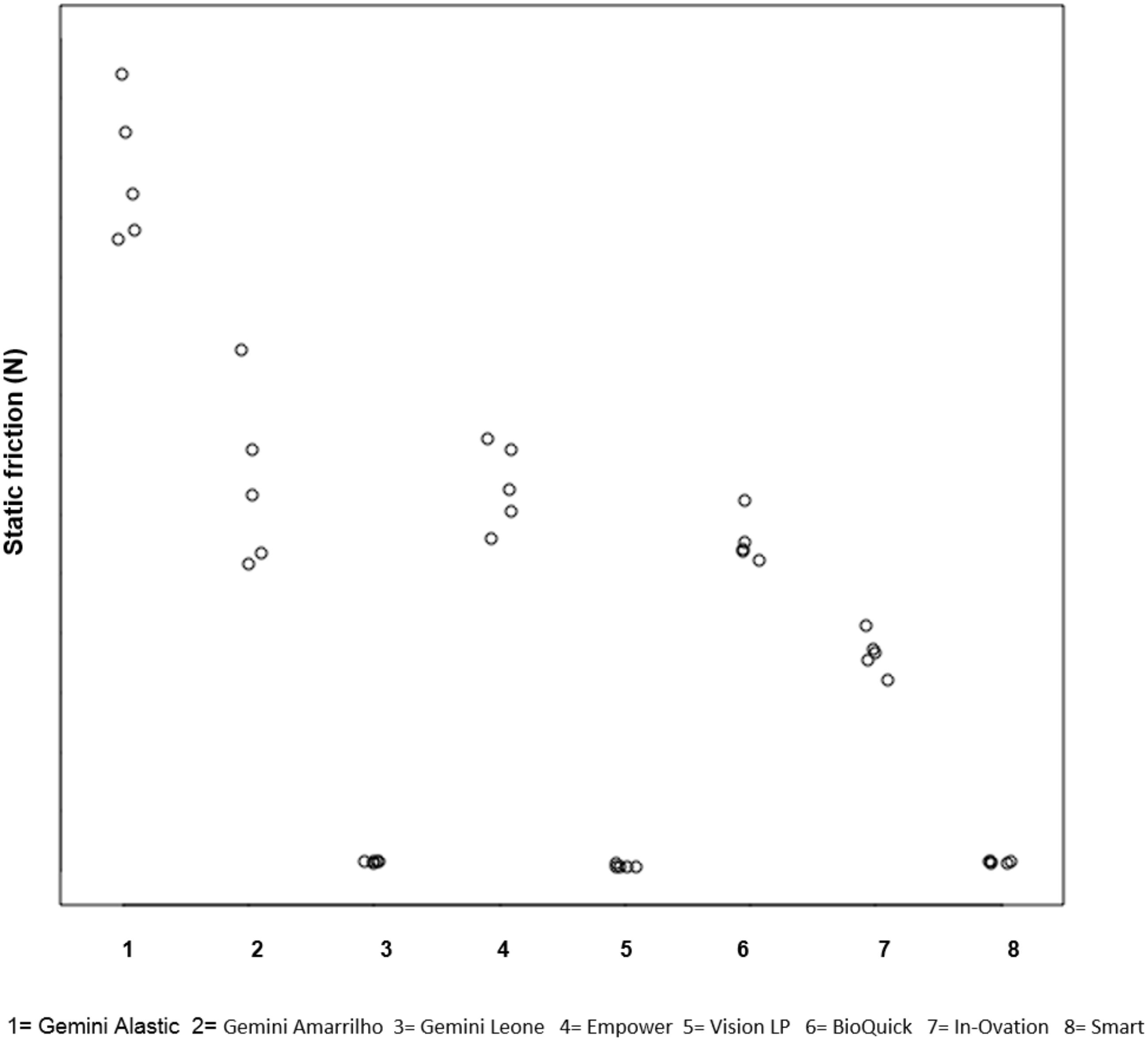


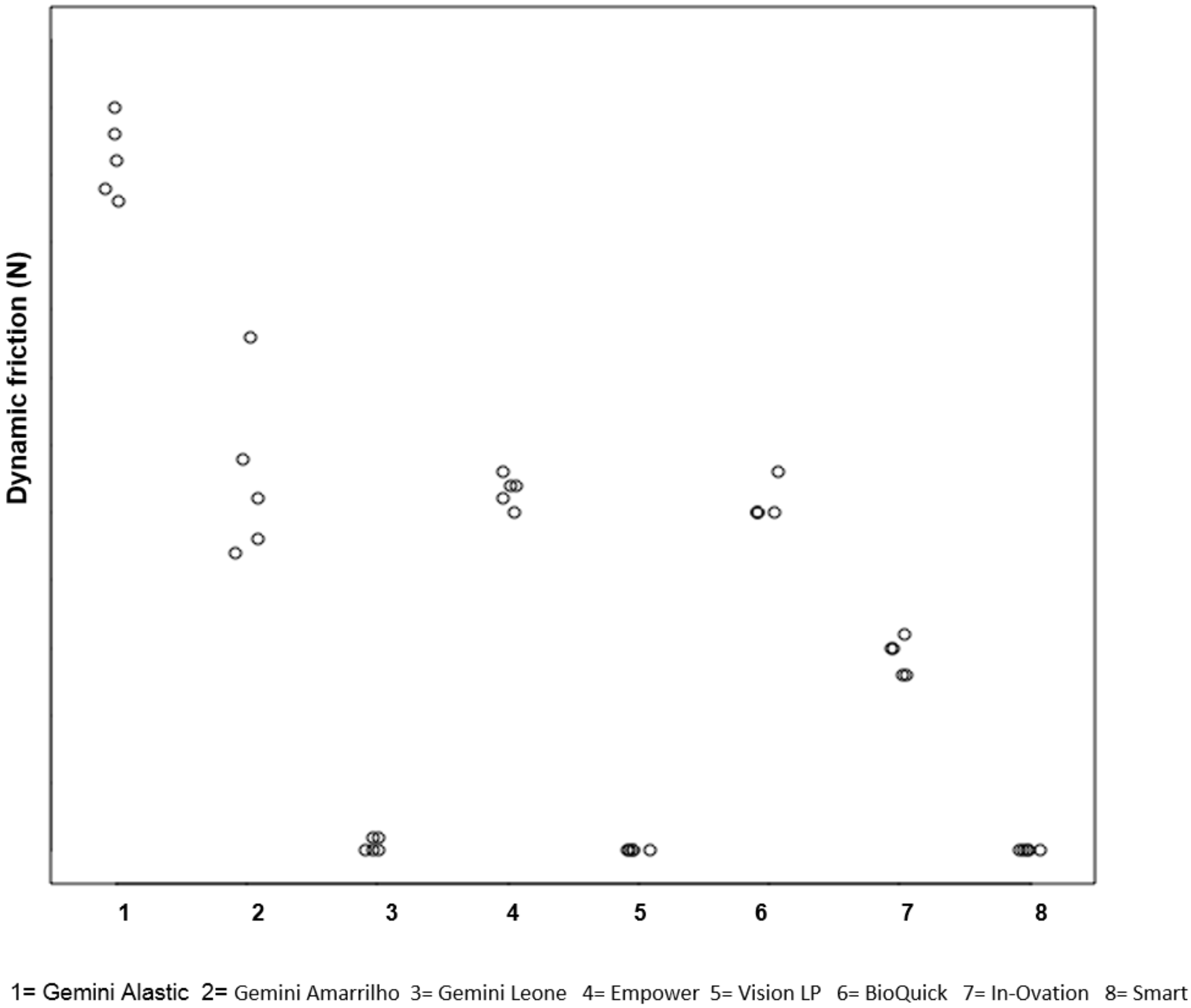
Figure 1: Illustration of the device structuredesigned by Martins (2008) and its parts.


EMIC

Figure 2: Device structure adapted to a machine EMIC DL2000.



Graph 1: Scatter diagram of one-dimensional static friction of the specimens according to bracket type.



Graph 2: One-dimensional scatter diagram of dynamic friction of specimens according bracket type.

Referências Bibliográficas

1. Barlow M; Kula K. Factors influencing efficiency of sliding mechanics to close extraction space: a systematic review. Orthod Craniofac Res 2008; 11: 65-73.
2. Ehsani S; Mandich M; El-Bialy T H etal. Frictional resistence in self-ligating orthodontic brackets and conventionally ligated brackets. A sistematic review. Angle Orthod 2009; 79(3): 592-601.
3. Burrow S J. Friction and resistence to sliding in orthodontics: A critical review. Am J Orthod Dentofac Orthop 2009; 135(4): 442-447.
4. Franchi L, Baccetti T, Camporesi M, Barbato E. Forces released during sliding mechanics with passive self-ligating brackets or nonconventional elastomeric ligatures. Am J Orthod Dentofacial Orthop 2008; 133(1): 87-90.
5. Turnbull NR, Birnie DJ. Treatment efficiency of conventional vs self-ligating brackets: effects of archwire size and material. Am J Orthod Dentofacial Orthop 2007; 131: 395-399.
6. Chen SS, Greenlee GM, Kim JE, Smith CL, Huang GJ. Systematic review of self-ligating brackets. Am J Orthod Dentofacial Orthop 2010; 137: 726.e1-726.e18.
7. Monteiro MR, Silva LE, Elias CN, Vilella Ode V. Frictional resistance of self-ligating versus conventional brackets in different bracketarchwire-angle combinations. J Appl Oral Sci 2014; 22: 228-234.
8. Krishnan M, Kalathil S, Abraham KM. Comparative evaluation of frictional forces in active and passive self-ligating brackets with various archwire alloys. Am J Orthod Dentofac Orthop 2009; 136(5): 675-682.

9. Dholakia KK, Bhat SR. Clinical efficiency of nonconventional elastomeric ligatures in the canine retraction phase of preadjusted edgewise appliance therapy: an in-vivo study. Am J Orthod Dentofacial Orthop 2012; 141(6): 715-722.
10. Al-Thomali Y, Mohamed RN, Basha S. Torque expression in self-ligating orthodontic brackets and conventionally ligated brackets: A systematic review J Clin Exp Dent 2017; 9(1): e123-128.
11. Bennet J C, McLaughlin R P. Controlled space closure with a preajusted appliance system. J Clin Orthod 24: 251-260.
12. Martins MF. Proposição de dispositivos para testes de atrito e força para sistemas de arcos [Dissertação]. Campinas: Centro de Pesquisas Odontológicas São Leopoldo Mandic; 2008.
13. Hain M, Dhopatkar A, Rock P. The effect of ligation method on friction in sliding mechanics. Am J Orthod Dentofacial Orthop 2003; 123(4): 416-422.
14. Hain M, Dhopatkar A, Rock P. A comparison of different ligation methods on friction. Am J Orthod Dentofacial Orthop 2006; 130(5): 666-670.
15. Bussab, W.O.; Morettin, P.A. Estatística Básica. 5ed. São Paulo: Saraiva, 2006, 526p.
16. Siegel, S. Estatística não-paramétrica para ciências do comportamento. 2. ed. Porto Alegre: Artmed, 2006, 448p.
17. Budd S; Daskalogiannakis J; Tompson B D. A study of the frictional characteristics of four commercially available self-ligating brackets systems. Eur J Orthod 2008; 30: 645-653.
18. Pliska BT, Rick W. Fuchs RW, John P. Beyer JP, Brent E. Larson BE. Effect of applied moment on resistance to sliding among esthetic self-ligating brackets. Angle Orthodontist 2014, 84(1):134-139.
19. Leal RC, Amaral FLB, França FMG, Basting RT, Turssi CP. Role of lubricants on friction between self-ligating brackets and archwires. Angle Orthod 2014;84(6):1049-1053.
20. Miles P G. Self-ligating vs conventional twin brackets during en-masse space closure with sliding mechanics. Am J Orthod Dentofac Orthop 2007; 132(2): 223-25.
21. Stefanos S; Secchi A G; Coby G et al. Friction between various self-ligating brackets and archwire couples during sliding mechanics. Am J Orthod Dentofac Orthop 2010; 138: 463-467.

This page is intentionally left blank