Original Article

Evaluation of Friction of Different Ligation Methods In Accordance With and Without Bracket Types

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ABSTRACT

Objective: The aim of this *in vitro* study was to evaluate the frictional values of 3 different ligation methods with different bracket types using a crowded configuration.

Materials and Methods: Three aesthetic conventional brackets (monocrystalline ceramic, polycrystalline ceramic, microfilled copolymer) and 1 metal bracket were evaluated in terms of friction. All brackets were tested in a crowded configuration of bracket alignment with 0.014 nickel titanium archwire in place. All brackets were ligated with metal ligatures, elastomeric ligatures, and nonconventional elastomeric ligatures. For accurate and repeatable placement on metal plates, a special jig was designed. The pulling speed was set to 10 mm/min for 30 seconds for each sample.

Results: When bracket structure was not considered, nonconventional elastomeric ligature produced the lowest friction. For brackets ligated with elastomeric modules, microfilled copolymer bracket showed the lowest friction and monocrystalline ceramic bracket showed the highest friction. When nonconventional ligatures were used, microfilled copolymer bracket showed the least friction.

Conclusion: Nonconventional elastomeric ligatures can be recommended for clinical use because they combine the aesthetics of modules and low friction values. Microfilled copolymer bracket combined with nonconventional elastomeric ligatures had the least friction. (*Turkish J Orthod* 2013;26:72–79)

KEY WORDS: Brackets, Friction, Ligation Methods

INTRODUCTION

Straight wire appliances rely on the ability of orthodontic wires to slide through brackets and tubes during leveling, aligning, and space closing unless friction-free mechanics with looped archwires are used. In sliding mechanics, friction between brackets and archwire affects the amount of force delivered to the teeth.[1]

Friction is the force that retards and resists the relative motion of 2 objects in contact. It is proportional to normal force acting perpendicular to the direction of motion on the contacting surface.[2,3] Frictional force is the product of the friction coefficient and normal force. If frictional forces are high, the efficiency of the system is affected and treatment time may be extended, or the results may be compromised because there is little or no tooth movement and because of loss of anchorage.[4–7] Several variables influence frictional forces, including bracket and wire material, manufacturing process, surface roughness, surface texture and stiffness of wire, dimension, shape of slot and wire, second-order angulations between slot and wire, ligation method, interbracket distance, sliding velocity, saliva, vibration, and corrosion.

With the increasing aesthetic demands of patients, ceramic brackets are being used more commonly, but many problems are associated with their usage, including higher coefficient of friction[8,9] and greater frictional resistance.[10,11] Under scanning electron microscopy, ceramic brackets display a

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To cite this article: Bayri R, Yilmaz HN, Koc E, Kucukkeles N. Evaluation of friction of different ligation methods with different bracket types. *Turkish J Orthod*. 2013;26:72–79 (DOI: http://dx.doi.org/10.13076/j.tjo.2013.26.02_72)

Date Submitted: September 2012. Date Accepted: February 2013.

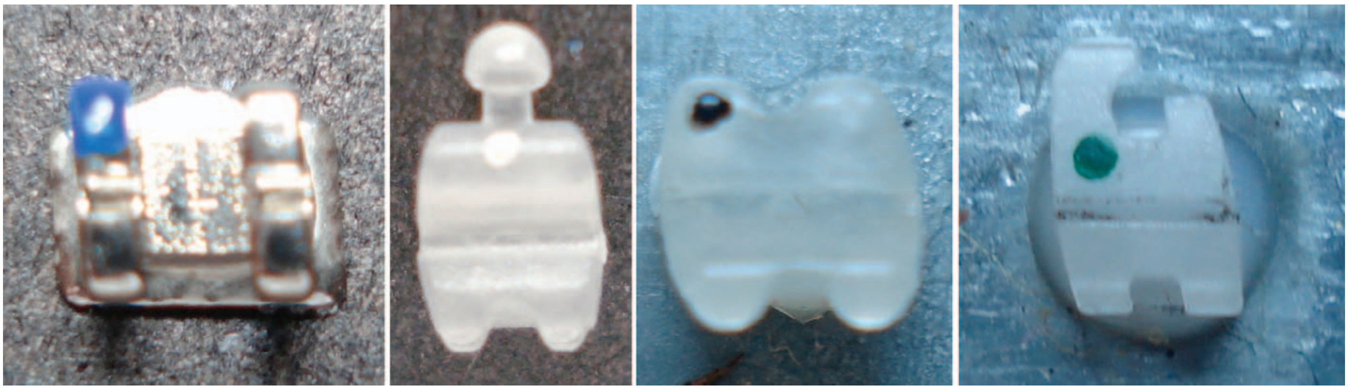

Figure 1. Brackets tested in the study.

crystalline structure containing many pores, whereas stainless steel brackets are smoother and have fewer irregularities. Even though low-friction ligatures are becoming popular, there is not enough research to evaluate the frictional forces attributed to various orthodontic elements. Thus, the purpose of our study was to compare the frictional resistance of different types of conventional aesthetic and metal brackets ligated with different methods.

MATERIALS AND METHODS

In this study, three aesthetic brackets and one metal conventional bracket were evaluated in terms of friction. The aesthetic brackets were made of monocrystalline ceramic, polycrystalline ceramic, and microfilled copolymer. They were all Roth prescription and had 0.018″ main slots (Figure 1).

Three different ligation methods—metal ligatures, elastomeric ligatures, and nonconventional elastomeric ligatures—have been used to ligate 0.014″ preformed (standard) nickel titanium (NiTi) archwires. Metal ligatures were 0.010″ stainless steel (SS) (Figure 2).

Stainless steel plates 90 mm long, 70 mm wide, and 2 mm thick were prepared to perform the tests. Transbond XT (3M Unitek, Monrovia, CA, USA) light cure bracket adhesive and bonding materials were used to fix the brackets on the metal plates. For the correct and repeatable bracket placement on metal plates, a special jig was prepared (0.017″ × 0.025″ SS) to ensure that the brackets were bonded without any angulations and torque (Figure 3). A crowded bracket configuration was designed to mimic the initial phase of treatment, so the canine brackets were positioned 2 mm superiorly and 2 mm buccally in relation to other brackets. Interbracket distances were 8.5 mm between each bracket (Figure 4).

Tests were performed for the following;

1. Three different conventional aesthetic brackets and 1 metal bracket ligated with metal ligatures
2. Three different conventional aesthetic brackets and 1 metal bracket ligated with elastomeric ligatures.
3. Three different conventional aesthetic brackets and 1 metal bracket ligated with nonconventional elastomeric ligatures.

Figure 2. Ligatures used in the study.

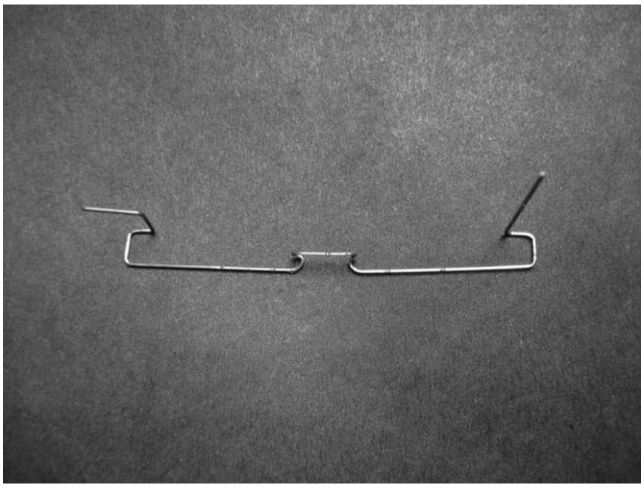

Figure 3. Jig for crowded configuration.

While ligating elastomeric ligatures, a ligature gun was used to standardize the placement. While ligating with metal ligatures, 7 turns were performed and squeezed from the sides.

A Z250 testing machine (Zwick-Roell Group, Ulm, Baden Wuerttemberg, Germany), which has two jaws, upper and lower, was used to perform the friction tests. The lower jaw was steady but the upper jaw was mobile. First, metal plates with brackets and the wires were fixed to the transferring part of the testing machine with a screw and a clamp and then fixed to the lower jaw of the machine. Next, the upper end of the test wire was fixed to upper jaw of the machine and 200 g weight was attached to the lower end of the wire to standardize the tension (Figure 5).

The pulling speed was 10 mm/min, and the test lasted 30 seconds for each sample. The static frictional values and the kinetic frictional values at 5, 10, and 15 seconds were recorded by Test-Expert Software program (Siemens, Plano, TX, USA). All bracket-ligation combinations were tested 10 times for each sample. Before each test, the wire was removed, the testing machine was recalibrated. and a new wire was inserted for the new test.

We used NCSS 2007 (Number Cruncher Statistical System) PASS 2008 (Power Analysis and Sample Size) Statistical Software (NCSS LLC, East Kaysville, Utah, USA) program for the statistical analysis. One-way ANOVA was used to compare quantitative data and to make intergroup comparisons, followed by Tukey honestly significant difference as a post hoc test. The Student *t* test was used in double group comparisons. The results were evaluated at a significance level of $p < 0.05$ with a confidence interval of 95%.

RESULTS

Descriptive statistics for the frictional values of brackets according to ligation method are given in Table 1, and evaluation of frictional values of bracket types with different ligation methods in couple comparison is given in Table 2. The mean frictional values of monocrystalline ceramic brackets ligated with elastomeric ligatures were significantly higher than all other samples ($p<0.01$) and microfilled copolymer brackets showed significantly lower frictional values than all other samples ($p<0.01$). Microfilled copolymer brackets ligated with nonconventional elastomeric ligature presented significantly lower values than all other brackets ligated with nonconventional elastomeric ligatures ($p<0.01$). When the brackets were ligated with metal ligatures, monocrystalline ceramic brackets showed the highest frictional values.

Descriptive statistics for the frictional values of 3 ligation methods without consideration of bracket type showed that the mean frictional values of nonconventional elastomeric ligature were significantly lower than those for the elastomeric modules

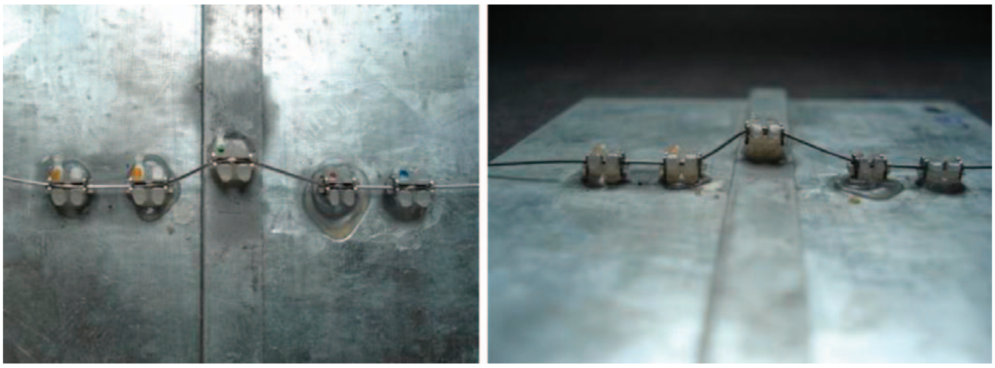

Figure 4. Brackets placement on the plates.

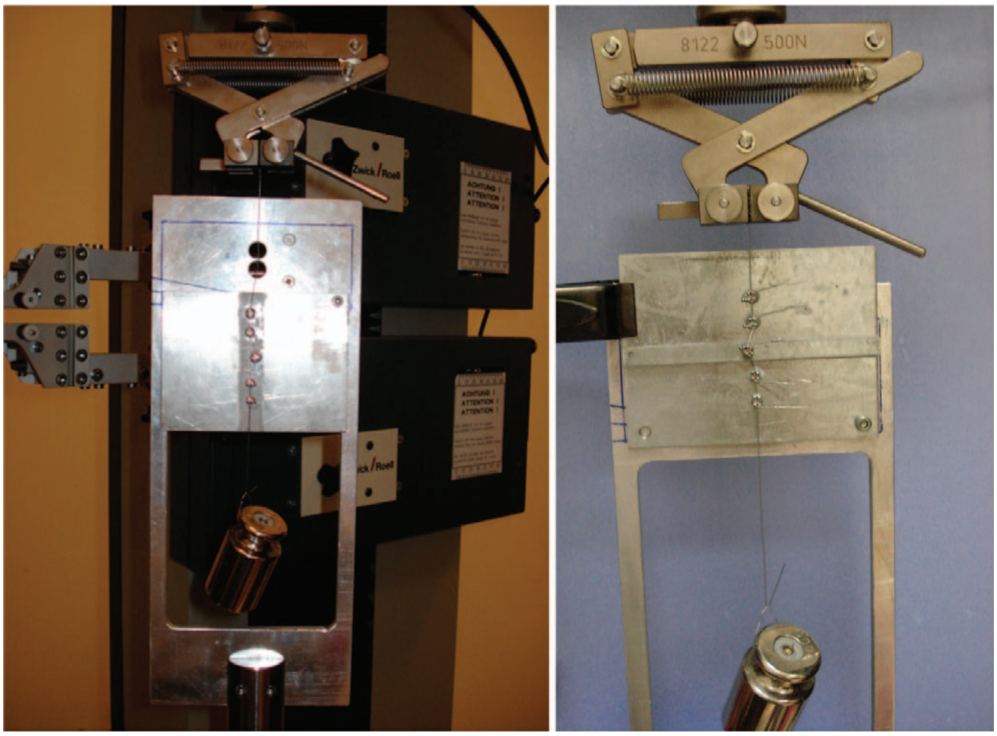

Figure 5. Zwick-Roell Z250 testing machine.

and metal ligating method ($p<0.01$; Tables 3 and 4). Evaluation of mean frictional values of ligation methods by bracket type is given in Table 5. Nonconventional elastomeric ligature had the lowest frictional values ($p<0.01$) among all bracket types.

DISCUSSION

In modern society, the aesthetic aspect of orthodontic therapy is important because of the increasing number of adult patients. Ceramic brackets were developed to improve aesthetics during orthodontic treatment. However, they tend to have high frictional resistance with sliding mechanics compared with stainless steel brackets. Frictional forces can be reduced by means of passive self-ligating brackets or low-friction ligatures. The purpose of our study was to compare the frictional resistance of different brands of conventional aesthetic and metal brackets ligated with different methods.

Conventional aesthetic brackets were selected because of their different structures (monocrystal-

Table 1. Evaluation of frictional forces of bracket types according to ligation method

Ligation Method	Bracket Types	Force (Newton) Mean ± SD	p	ANOVA[a]
Elastomeric ligature	Microfilled copolymer	7.42 ± 0.13	0.001**	527.325
	Monocrystalline	15.12 ± 0.29		
	Metal	12.15 ± 0.63		
	Polycrystalline	13.07 ± 0.55		
Nonconventional elastomeric ligature	Microfilled copolymer	4.33 ± 0.07	0.001**	502.925
	Monocrystalline	8.23 ± 0.28		
	Metal	6.54 ± 0.22		
	Polycrystalline	6.26 ± 0.25		
Metal ligature	Microfilled copolymer	7.37 ± 0.19	0.001**	836.345
	Monocrystalline	15.37 ± 0.48		
	Metal	12.59 ± 0.48		
	Polycrystalline	14.62 ± 0.35		

[a] One-way ANOVA.
** $p < 0.01$.

Table 2. Evaluation of frictional forces of bracket types with different ligation methods in couple comparison using Tukey test

Bracket Type	Elastomeric Ligatures	Non-conventional Elastomeric Ligatures	Metal Ligature
Microfilled copolymer Monocrystalline	0.001**	0.001**	0.001**
Microfilled copolymer Metal	0.001**	0.001**	0.001**
Microfilled copolymer Polycrystalline	0.001**	0.001**	0.001**
Monocrystalline Metal	0.001**	0.001**	0.001**
Monocrystalline Polycrystalline	0.001**	0.001**	0.001**
Metal Polycrystalline	0.001**	0.048*	0.001**

* $p < 0.05$; ** $p < 0.01$, Tukey test.

line, polycrystalline, and microfilled copolymer). As a control group, a conventional metal bracket was selected because it is a well-known and widely used bracket type. In addition, 0.014" NiTi archwires were used in the crowded configuration of the bracket alignment because they are commonly used in the leveling phase of orthodontic treatments. They are very flexible and have a large working range.

In our study all tests were performed in dry conditions and at room temperature. Different studies have drawn conflicting conclusions about the presence of saliva. Some researchers found that the presence of the saliva decreases the friction,[12,13] likely because of the lubricating effect of the saliva. In contrast, Pratten *et al.*[14] and Stannard *et al.*[15] found that saliva increased friction. They claimed that adhesion occurs between the archwire and the bracket slot, which increases frictional resistance. Kusy and Schafer[13] found that saliva decreased friction in ceramic brackets but increased friction in metal brackets. Since the results related to the presence of the saliva are contradictory, the tests in our study were performed in dry conditions.

Table 3. Evaluation of mean frictional forces of 3 different ligation methods

Ligation Method	Force (Newton) Mean ± SD	*p*	ANOVA[a]
Elastomeric ligature	11.94 ± 2.89	0.001**	67.702
Nonconventional elastomeric ligature	6.34 ± 1.41		
Metal ligature	12.49 ± 3.18		

[a] One-way ANOVA.
** $p < 0.01$.

When we compared the frictional values of different ligation methods without consideration of bracket types, nonconventional elastomeric ligatures produced the lowest frictional values compared with the other ligation methods. In the *in vitro* study of Baccetti and Franchi,[16] conventional and nonconventional elastomeric ligations were compared in dry conditions with 22 slot brackets, 0.014 NiTi and 19 × 25 SS wires. Similar to our findings, they found that the nonconventional elastomeric ligatures showed lower frictional resistance. Fortini *et al.*,[17] found that nonconventional elastomeric ligatures showed significantly lower friction than other elastomeric ligation methods. This can be explained by the nonconventional elastomeric ligatures converting the bracket into a tube, which results in decreased pressure on archwires.

In our study, elastomeric ligatures showed lower frictional resistance compared with metal ligatures ($p > 0.05$), probably because elastomeric ligatures cause less binding on the archwire as they are

Table 4. Evaluation of frictional forces of ligation methods in couple comparison

Ligation Method	Tukey Test
Elastomeric ligature Nonconventional elastomeric ligature	0.001**
Elastomeric ligature Metal ligature	0.616
Nonconventional elastomeric ligature Metal ligature	0.001**

** $p < 0.01$, Tukey test.

Table 5. Evaluation of mean frictional values of ligation methods according to bracket type

Bracket Type	Ligation Method	Force (Newton) Mean ± SD	p	ANOVA[a]
Microfilled copolymer	Elastomeric ligature	7.42 ± 0.13	0.001**	1602.027
	Nonconventional elastomeric ligature	4.33 ± 0.07		
	Metal ligature	7.37 ± 0.19		
Monocrystalline	Elastomeric ligature	15.12 ± 0.29	0.001**	1234.617
	Nonconventional elastomeric ligature	8.23 ± 0.28		
	Metal ligature	15.37 ± 0.48		
Metal	Elastomeric ligature	12.15 ± 0.63	0.001**	501.543
	Nonconventional elastomeric ligature	6.54 ± 0.22		
	Metal ligature	12.59 ± 0.48		
Polycrystalline	Elastomeric ligature	13.07 ± 0.55	0.001**	1206.135
	Nonconventional elastomeric ligature	6.26 ± 0.25		
	Metal ligature	14.62 ± 0.35		

[a] One-way ANOVA.
** $p < 0.01$.

more flexible. In contrast to our findings, in 1990, Berger[18] compared the frictional resistance of metal ligatures and elastomeric ligatures with metal and ceramic brackets and found that metal ligatures cause less friction than elastomeric ones, as in the studies of Bednar *et al.*,[19] Braun *et al.*,[20] Voudoris,[21] and Khambay *et al.*[22] Bazakidou *et al.*[10] compared metal and elastomeric ligatures in their *in vitro* study and stated that it is not possible to conclude that one method has more friction than the other; they added, however, that the frictional resistance of metal ligation can increase up to 3 times more than elastomeric ligatures. In 1993, Sims *et al.*[23] found no difference between metal and elastomeric ligatures related with the frictional resistance when elastomeric ligatures were tied conventionally whereas metal ligature tightened with 7 turns.

The evaluation of bracket brands with different ligation methods revealed that, when ligated with elastomeric modules micro-filled copolymer bracket showed the least friction, which was followed, by metal, polycrystalline ceramic and monocrystalline ceramic brackets. De Franco *et al.*[24] found that single crystal alumina brackets tended to be lower in friction than polycrystalline brackets. In 1994 Saunders and Kusy[25] showed by scanning electron microscopy (SEM) that mono crystalline alumina brackets were smoother than polycrystalline ones, but found no difference in frictional characteristics. On the other hand, Omana *et al.*[26] stated that polycrystalline injection molded ceramic brackets were smoother which means less friction values. Our results resemble with the study of Omana *et al.*[26] since we measured the highest friction in mono crystalline alumina type. Tselepsis *et al.*[27] and Bazakidou *et al.*[10] reported that newer composite brackets have lower friction than ceramic and stainless steel brackets. We also found lower frictional values with the composite type.

Significant differences were found between the friction values of brackets ligated with metal ligatures. The maximum frictional values were found in the monocrystalline type, followed by polycrystalline ceramic, metal, and microfilled copolymer brackets. The values of monocrystalline and polycrystalline ceramic brackets were nearly twice those of microfilled copolymer brackets. The results were identical with those of other studies, but we should keep in mind that it is simply not possible to standardize the ligating method with metal ligatures. That is probably why Bazakidou *et al.*[10] found that there was up to 3 times greater variability in friction with SS ligation than elastomeric ligation. Similarly, in 1997, Nanda and Ghosh[28] reported that the force of ligation with SS ligatures can range from 50 to 300 g. Metal brackets had lower frictional values than polycrystalline ceramic bracket, which is consistent with the results in the literature. In 2005 Griffiths *et al.*[29] compared a monocrystalline bracket to a metal one and found the same results as we did. Microfilled copolymer brackets ligated with metal ligatures showed the lowest frictional resistance, which was consistent with the findings of Bazakidou *et al.*[10] and Tselepsis *et al.*[27]

Significant differences were found between brackets ligated with nonconventional elastomeric ligature. Maximum frictional values were found in the monocrystalline bracket, followed by the metal, polycrystalline, and microfilled copolymer brackets.

Although De Franco *et al.*[24] claims that monocrystalline brackets show lower frictional values, Omana *et al.*[26] claims the opposite. Similarly, we found that monocrystalline brackets had the highest friction, even with nonconventional elastomeric ligatures.

CONCLUSION

1. This study revealed that bracket material and ligation type affect frictional resistance.
2. Monocrystalline ceramic brackets showed the highest frictional resistance.
3. Polycrystalline ceramic brackets showed higher frictional resistance than metal brackets except when ligated with nonconventional elastomeric ligatures.
4. Microfilled copolymer brackets presented significantly lower frictional values compared with other conventional brackets with all ligation methods.
5. Nonconventional elastomeric ligation showed the lowest friction values followed by elastomeric modules and metal ligatures.

The method in this study could not completely duplicate the oral environment, so the frictional values do not reflect real conditions; however, they can give us an idea about the frictional behaviors of the tested samples.

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