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The Evaluation of the Static Friction within Molar Buccal Tubes

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ABSTRACT

Objective: *Buccal tubes are orthodontic attachments used on the posterior teeth instead of bands, so it is important to focus on the effect of their properties on orthodontic treatment. The aim of this in vitro study was to evaluate and compare the static frictional forces of the upper first molar tube from 6 brands.* ***Materials and methods:*** *The samples consisted of single bondable, non-convertible first molar buccal tubes from 6 brands (Dentaurum, Forestadent, Ormco, 3M, American Orthodontic, A-Star). For each brand 12 steel blocks were prepared by using CNC machine. A hole was drilled in the center of each block and a steel rod was made by an electric metal turning lathe to fit loosely in the hole which allows it to rotate. On each block 3 buccal tubes adhered in one line, the center one being on the rotating rod. A straight 0.019" × 0.025" stainless steel wire was passed through the 3 tubes and static friction was measured by a Universal Testing Machine (Instron) at a crosshead speed of 5 mm per minute. The test was repeated with a 100 gm weight attached to the middle buccal tube's hook to rotate the steel rod and the middle buccal tube with its increasing friction. The data was then statistically analyzed using ANOVA and LSD tests.* ***Results:*** *Higher frictional resistance force was noted with Ormco, 3M and American Orthodontics tubes, while the least values were observed with Forestadent tubes.* ***Conclusion:*** *The frictional forces of molar tubes vary among 6 brands tested in this study.*

Keywords: Static frictional force, Molar tubes, Buccal tubes

INTRODUCTION

Friction is the resistance to the movement of two or more contacting bodies [1]. Several factors influence the friction and it is very difficult to isolate individual factors [2]. Or friction, defined as the force that resists movement, in which 2 surfaces slide over each other, and has a multifactorial nature [3]. Friction resistance is a frequently used term that refers to the force resisting the sliding movement of the teeth. The resistance to sliding is a more proper term, as it can be classified into 3 phenomena: classic friction, binding, and notching. In orthodontics, friction competes with tooth movement whenever sliding mechanics are involved. During sliding mechanics, the wire contacts the bracket and ligation and a frictional force occurs in the opposite direction and against the orthodontic force thus decreasing its magnitude [4].

The frictional force is classified into static and kinetic. Static friction is the smallest force needed to start a movement between solid objects at rest. Moreover, kinetic friction force resists the sliding motion of a solid object against another at a constant speed. Kinetic frictions are always smaller than static friction since it is more difficult to draw a body from a resting position than to perpetuate its movement [5]. It was found that the static frictional force was more appropriate than the kinetic frictional force as orthodontic sliding tooth movement is not continuous. For this reason, only the maximum static frictional force was measured in the present study [6].

Among the numerous attempts to reduce friction, the introduction of buccal tubes can be considered as one of the friction reducing methods. The buccal tube is a metal tube fixed to the facial (buccal) surface of an orthodontic molar band or directly to the surface of the tooth which allows the archwire to pass through while applying either a torquing force or allowing the wire to slide as tooth movement occurs [7]. This is the basic molar attachment of the edgewise appliance. The original tube was a piece of 0.022-inch by 0.028-inch gold or nickel silver tubing that was fused to the molar band [8]. The reason that the edgewise mechanism uses the buccal tube in the molar tooth, is that it is used for treatment and stabilization of the archwire. Consequently, it is a totally enclosed attachment used in the remaining teeth of the arches instead of the regular edgewise bracket [9].

This study aimed to assess the static friction force delivered in buccal tubes when using stainless steel rectangular (0.019 × 0.025) inch archwires in orthodontic.

MATERIALS AND METHODS

This *in vitro* study focused on the upper first molar buccal tube made by 6 different international companies in which samples were tested to measure friction within the slot. Total 84 single bondable, non-convertible first molar buccal tubes from 6 companies, 14 from each company were used in this study. All the tubes had an MBT 0.022 prescription from the following companies:

- Dentaurum (Dentaurum, Ispringen, Germany)
- Forestadent (Forestadent, Pforzheim, Germany)
- Ormco (Ormco, California, USA)
- 3M (3M Unitek, Monrovia, California, USA)
- AO (American Orthodontics, Washington Avenue, Sheboygan, USA)
- A-Star (A-star Orthodontics Inc., Shanghai, China)

A CNC machine (CNC Freza, Japan) which is a computer controlled machine was used to make 12 steel blocks (6 cm × 1.2 cm × 1.2 cm in dimension) for friction test. A hole was drilled in the center of each block, is 8 mm wide from the front and 5 mm wide from the back (Figure 1). Total 48 steel rods were made by an electric metal turning lathe to fit loosely in the hole. The difference in rod and hole widths between the front and back creates a relative resistance and ensure the stability of the small movable steel rod in the hole.

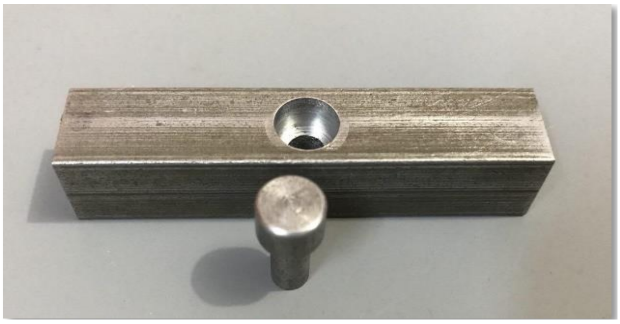

Figure 1 The steel block

The mesiodistal widths of the upper right second premolar bracket, the upper right first and second molar tubes were measured using a digital vernier caliper (Yato, Poland). The width of each buccal tube is displayed in Table 1.

Table 1 Measured width of buccal tubes for each company by digital vernier caliper

Company	Width of buccal tube
3M	4.47 mm
A-Star	4.11 mm
American Orthodontics	4.31 mm
Forestadent	4.51 mm
Dentaurum	3.30 mm
Ormco	4.61 mm

The mean mesiodistal widths of the upper buccal teeth were 7 mm for second premolars, 10 mm for first molars and 9 mm for second molars [10]. Accordingly, the inter-bracket span was calculated as 5 mm between the second premolar bracket and first molar buccal tube and 6 mm between the first and second molar buccal tubes (Figure 2).

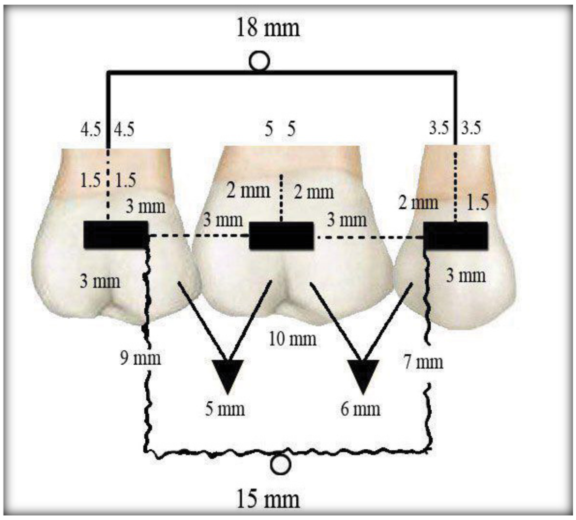

Figure 2 Measuring the inter-bracket span

The 3 buccal tubes were adhered by cyanoacrylate adhesive (Rexon, Turkey) with steel epoxy (Trust Mart, China) on each steel block in one line. The middle buccal tube was fixed on the rotating steel rod and the other 2 tubes were fixed on either side on the steel block at 5 mm and 6 mm intervals. A section of 0.0215″ × 0.025″ (Dentaurum, Ispringen, Germany) straight stainless steel archwire was used to align the tubes on the steel block [11,12] (Figure 3). This eliminated tip and torque as factors affects the frictional resistance [13].

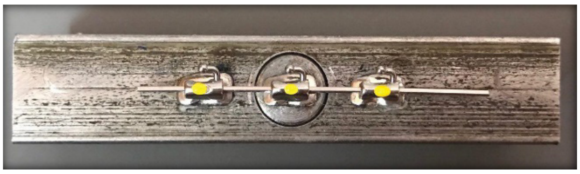

Figure 3 Alignment of buccal tubes

A straight 0.019''× 0.025''(Forestadent, Pforzheim, Germany) stainless steel wire (8 cm long) was passed through the 3 buccal tubes and static friction was measured by a Universal Testing Machine (Instron). The block was grasped by the lower jaw of the machine and the wire by the upper jaw. Then 5 mm of the wire was pulled slowly at a crosshead speed of 5 mm per minute to measure initial friction (Figure 4).

Figure 4 Instron H50KT Tinius Olsen testing machine with a testing model in place

Then a 100 gm weight was attached to the middle buccal tube's hook to rotate the steel rod and the middle buccal tube with its increasing friction. This force simulates the traction force intraorally during orthodontic treatment [14]. The wire is pulled again at another 5 mm at a crosshead speed of 5 mm per minute and the friction was registered.

RESULTS

The data obtained from the present experimental study were managed statistically to compare and explain the frictional differences between 6 different brands of upper first molar tubes. These statistics included mean, standard deviation, standard error, minimum, and maximum values. All the data of this experiment was normally distributed because the p-values of the Shapiro-Wilk test are greater than 0.05 meaning non-significant (Table 2).

Table 2 The p-values of the Shapiro-Wilk test for normality of distribution for the data

Brands	Friction	
	Active	Passive
3M	0.383	0.059
A-Star	0.448	0.054
AO	0.057	0.128
Dentaurum	0.088	0.095
Forestadent	0.698	0.052
Ormco	0.060	0.339

The mean value of static friction in passive (without application of weight) and active (with 100 gm weight on the middle tube) for all buccal tubes from the 6 brands ranged from 3.2 gm to 54.5 gm in a passive state (Table 3 and Figure 5). A-Star, Dentaurum, and Forestadent showed values of 5 gm or less, while the highest value was for Ormco. On the other hand, active friction ranged from 27.4 gm to 85.7 gm in which Forestadent and Dentaurum had the lowest frictional values and Ormco showed the highest frictional value.

Table 3 Descriptive data of the passive and active friction of the molar tubes

Brands	Passive		Active	
	Mean	S.D.	Mean	S.D.
3M	37.702	10.656	73.64	12.317
AS	3.278	1.664	38.237	6.379
AO	20.811	7.963	47.859	9.748
De	5.119	2.552	34.822	8.53
Fr	4.186	0.83	27.41	4.845
Or	54.506	13.292	84.711	15.476
* All measurements are in grams				

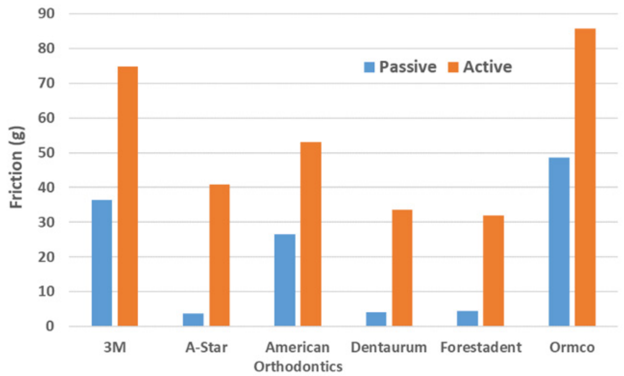

Figure 5 Mean passive and active friction of the molar tubes

Statistical Difference for Friction Test

ANOVA test for all molar tubes showed a very highly significant difference between the 6 brands (Table 4).

Table 4 Statistical difference between the six brands for the passive and active friction of the molar tubes by ANOVA test

Friction	F	Sig.
Passive	16.753	0.000***
Active	19.39	0.000***
***p<0.001		

LSD test was performed for comparison between 2 brands for the passive and active friction of the molar tubes and the results are displayed in Table 5.

Table 5 Statistical difference between each two brands for passive and active friction of the molar tubes by LSD test

Brands		Friction	
		Passive	Active
3M	AS	0.000***	0.000***
	AO	0.119	0.007**
	De	0.000***	0.000***
	Fr	0.000***	0.000***
	Or	0.055	0.162
AS	AO	0.001**	0.119
	De	0.936	0.360
	Fr	0.887	0.252
	Or	0.000***	0.000***
AO	De	0.001**	0.015*
	Fr	0.001**	0.008**
	Or	0.001**	0.000***
De	Fr	0.950	0.814
	Or	0.000***	0.000***
Fr	Or	0.000***	0.000***
* p<0.05, ** p<0.01, *** p<0.001			

Friction between the brands was generally statistically significant except between:

- 3M and Ormco tubes for both passive and active friction
- A-Star, Dentaurum and Forestadent tubes for both passive and active friction

DISCUSSION

In this study, for passive and active situations Ormco tubes showed higher friction value while A-Star, Dentaurum, American Orthodontics, and Forestadent tubes showed less frictional values about 5 gm. These results can be explained by the smaller tube opening dimension of Ormco's tubes and slightly larger dimensions of the previously mentioned companies.

In general, there is no significant difference in the friction values founded among the tested tubes from the 6 brands, these finding agreed with previous studies on passive self-ligating brackets done by Yeh, et al., in which Damon SL II and Smart Clip (Passive SLB) with Ni-Ti archwires in various cross-sections, with first-order rotation, second-order intrusion, and third-order labial crown inclinations, showed that there were no significant bracket differences in terms of friction once binding occurred in the second-order distances [15].

There is higher friction in active situation than in passive one which can be explained by the effect of application of the weight on middle tube's hook that produce a movement similar to tipping in upper first molar tube so it stimulates friction within the tube and the low friction related to tubes in passive situation which reflected the lack of normal force as the wire is undersized in relation to the tube dimension and no friction could be anticipated in this experiment without angulation these results can be supported by previous studies done on self-ligating brackets [16].

In the current study, the frictional forces of buccal tubes were small which come inconsistently with the previous study performed on passive self-ligating bracket [15,17-19]. In all straight-wire techniques, the alignment of one part of the dental arch depends on the amount of frictional force in the adjacent segment of the arch, since the alignment phase implies the slide of the wire in the nearby segment of the arch.

The easier the wire slides, the faster the teeth are aligned. When the wire slides through passive self-ligating brackets, the presence of lighter frictional forces in one part of the arch (e.g. canine and the two premolars) increases the alignment of the adjacent arch (e.g. anterior teeth). This could partly explain the clinical findings of who demonstrated that orthodontic treatment is significantly faster with passive self-ligating brackets [20].

CONCLUSION

The frictional forces of molar tubes vary among 6 brands tested in this study with the lowest value for Forestadent and highest value for Ormco tubes.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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