10.5005/jp-journals-10024-2394

ORIGINAL RESEARCH

Comparison of Frictional Resistance in Conventional Brackets with Different Stainless Steel Wires

[1]Sangeeta Sunda, [2]Anil Miglani, [3]Reena R Kumar, [4]Vikram Panghal, [5]Puja Khanna, [6]Nishtha Arora

ABSTRACT

Aim: The aim of the study was to evaluate and compare static and kinetic friction of round (0.018″) and rectangular (0.019 × 0.025″) stainless steel (SS) wires of different brands with conventional preadjusted edgewise brackets.

Materials and methods: Maxillary canine and two bicuspids of 0.022 × 0.028″ slot sized MBT prescription (*Gemini*, 3M Unitek, Monrovia, California) brackets were chosen. The wires selected were 0.018″ SS (3M Unitek); 0.018″ Australian wire (AJ Wilcock, UK), and 0.019 × 0.025″ SS (3M Unitek). The testing was done on Instron 3382. A total of 30 test combinations with three wires were repeated 10 times. The static and kinetic friction was recorded in Newton. The kinetic friction was also recorded in Newton at 3, 5, 7, and 9 mm of movement. One-way analysis of variance (ANOVA) and descriptive statistics were used for comparing the friction. To test the level of significance, multiple comparisons were used within wire in bracket by using *post hoc* test.

Results: Static friction was found to be greater than kinetic in all wires; 0.018″ SS (3M) wire exhibited minimum static and kinetic friction; while 0.019 × 0.025″ SS (3M) exhibited maximum static friction. Kinetic friction was similar in both 0.018″ AJ Wilcock and 0.019 × 0.025″ SS but greater than 0.018″ SS (3M).

Conclusion: Least static and kinetic friction was exhibited by 0.018″ SS (3M). Kinetic friction was similar in both 0.018″ AJ Wilcock and 0.019 × 0.025″ SS.

Clinical significance: The study concluded that 0.018″ SS (3M) is better for individual canine retraction than the other wires used in the study because it has the least frictional resistance; 0.019 × 0.025″ SS (3M) is a better wire for canine retraction than 0.018″ AJ Wilcock as we can have a three-dimensional control over tooth movement. When torque control is not a prime requisite, then 0.018″ SS (3M) can be used for retraction of incisors instead of 0.018″ AJ Wilcock in severely proclined incisor cases.

Keywords: Bracket, Frictional resistance, Instron, Wires.

How to cite this article: Sunda S, Miglani A, Kumar RR, Panghal V, Khanna P, Arora N. Comparison of Frictional Resistance in Conventional Brackets with Different Stainless Steel Wires. J Contemp Dent Pract 2018;19(9):1135-1139.

Source of support: Nil

Conflict of interest: None

[1,5,6]Department of Orthodontics and Dentofacial Orthopedics Jan Nayak Ch. Devi Lal Dental College, Sirsa, Haryana, India

[2]Department of Orthodontics and Dentofacial Orthopedics, I.T.S Dental College Hospital and Research Centre, Greater Noida Uttar Pradesh, India

[3]Department of Orthodontics and Dentofacial Orthopedics, Divya Jyoti College of Dental Sciences & Research, Modinagar, Uttar Pradesh, India

[4]Civil Hospital, Hisar, Haryana, India

Corresponding Author: Sangeeta Sunda, H. No. 1834, Sec. 16/17, Near DPS Junior Wing School, Hisar-125001, Haryana India, Phone: +918572062957, e-mail: sangeetasunda25@gmail.com

INTRODUCTION

When one body slides or tends to slide over another body, the force that acts to oppose the tendency to move is called the force of friction. This frictional force is always parallel to the surfaces in contact.[1] In orthodontics, when a force is applied to a bracket to slide it along an archwire, the force felt by the tooth will be less than the force applied to the bracket because of frictional resistance.[2] Friction is almost unavoidable and encountered in everyday life on a routine basis. The classical law of friction states that frictional forces are independent of the area of contact between the two sliding bodies and their sliding velocity.[3]

Friction is of two types, namely static and kinetic.[1] Static friction is the initial friction that resists movement while kinetic friction maintains motion once it has been initiated. Values for static friction are greater than that of kinetic friction.[4]

Frictional force is routinely encountered in orthodontics during procedures like archwire engagement in brackets placed on teeth which are out of alignment, ligatures holding the arch wire against the slot base, application of active torque in rectangular wire, and

Fig. 1: Material used in the study

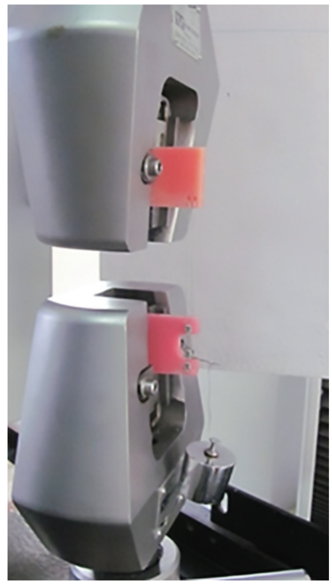

Fig. 2: Force application parallel to the bracket

bodily tooth movement.[5] Bracket size, slot depth, and width also influence the amount of friction registered during sliding mechanics.[6] Archwire bracket material, dimensions, and modulus of the wire are factors known to affect friction.[7] Studies have shown that as much as 12 to 60% of the applied force in fixed mechanotherapy is nullified to friction.[8]

Space closure can be done either with single canine retraction and including it in anchorage unit or *en masse* retraction. Retracting the canines separately in the first step reduces load on the posterior teeth, hence, reducing the tendency of the maxillary molars to move forward. *En masse* retraction of entire anterior segment simultaneously taxes the anchorage unit by mesial movement of molars.[2] Both *en masse*/miniscrew combination and two-step retraction combined with a conventional anchorage are used in maximum anchorage cases.[9]

The study was undertaken to find a round wire of lower friction for individual canine retraction in critical anchorage cases. The objective of taking rectangular wire was to compare the difference in friction among all the three wires.

AIMS AND OBJECTIVES

The aim of this study was to evaluate and compare static and kinetic friction of conventional preadjusted edgewise brackets with 0.018″ SS of two different companies and 0.019 × 0.025″ SS wire. This was done with an objective of finding a wire with lower frictional resistance during sliding mechanics.

MATERIALS AND METHODS

The brackets used in the study were 0.022 × 0.028″ slot sized maxillary left canine and two bicuspid MBT prescription (*Gemini series*, 3M Unitek, Monrovia, California). The wires selected for the experimental set-up were: 0.018″ SS (3M Unitek, Monrovia, California); 0.018″ Australian wire (AJ Wilcock, U.K.) and 0.019 × 0.025″ SS (SS, 3M Unitek, Monrovia, California) (Fig. 1). An acrylic jig was fabricated to conduct the simulated testing. Two premolars preadjusted edgewise brackets were bonded to rigid acrylic baseplate at a distance of 16 mm. The jig was positioned to have/receive wire in a vertical orientation. A canine bracket with a 10 mm power arm was loaded with a 100-gm weight to represent equivalent retraction force acting at the center of resistance of the tooth (Fig. 2). The study was conducted in dry state and experiment was carried out on a universal testing machine (Instron 3382, Fig. 3). The acrylic baseplate with the bonded brackets was clamped on the moving crosshead of the testing machine, while movable canine bracket was connected to the load cell of the machine. This protocol was repeated ten times with each bracket wire combination tested, with

Fig. 3: Instron universal testing machine

a new wire specimen on each occasion to eliminate the influence of wear.

The test procedure had the canine bracket with a 100-gm load cell (on the power arm) drawn along each Wire sample at a crosshead speed of 5 mm per minute. The static friction was recorded in Newton as maximum force needed to move the bracket along the wire. The kinetic friction was also recorded in Newton at 3, 5, 7, and 9 mm of movement.

The test consisted of a total of 30 test combinations with three wire products repeated 10 times. The data were tabulated and the mean values were obtained. For statistical analysis, one-way ANOVA and descriptive statistics were used for assessing and comparing static and kinetic frictional forces in bracket with variable modulus and dimension wires. To test the level of significance of static and kinetic frictional force, multiple comparisons were used within wire in bracket by using *post hoc* test. Reliability test or test–retest reliability was analyzed to ascertain the variation in measurements taken by a single person or instrument on the same item and under the same conditions. It also included intrarater reliability.

RESULTS

The static and kinetic frictions of conventional bracket obtained with 0.018″ SS (3M), 0.018″ AJ Wilcock and 0.019 × 0.025″ SS (3M) at a crosshead speed of 5 mm/min of the Instron machine (recorded in Newtons) are tabulated in Table 1. Mean static frictional resistance exhibited by 0.018″ SS (3M) was 2.2671 N ± 0.06499; that of 0.018″ AJ Wilcock was 3.3286 N ± 0.04845; and that of 0.019 × 0.025″ SS (3M) was 3.9129 N ± 0.04030. Mean kinetic frictional resistance exhibited by 0.018″ SS (3M) was 1.8254 N ± 0.10710; that of 0.018″ AJ Wilcock was 2.9157 N ± 0.11027; and that of 0.019 × 0.025″ SS (3M) was 2.9986 N ± 0.09667. Comparison of static and kinetic friction among wires in conventional bracket is shown in Tables 2 and 3. The results showed that static friction was greater than kinetic friction with all wire dimensions. The 0.018″ SS (3M) wire exhibited minimum static and kinetic friction, while 0.019 × 0.025″ SS (3M) exhibited maximum static friction. Kinetic friction was similar in both 0.018″ SS AJ Wilcock and 0.019 × 0.025″ SS (3M), but greater than 0.018″ SS (3M); 0.018″ AJ Wilcock and 0.019 × 0.025″ SS (3M) exhibited almost equal kinetic friction.

Intraclass correlation coefficients obtained are shown in Table 4. The results were highly significant with reliability coefficient alpha between 0.98 and 0.99 with significance of $p < 0.01$ (Table 4).

Table 1: Mean static and kinetic frictional resistance of conventional bracket with variable dimension and cross-section wires

Load	*Static*		*Kinetic*	
Wire	*Mean in N*	*SD*	*Mean in N*	*SD*
0.018″ SS (3M)	2.2671	0.06499	1.8254	0.10710
0.018″ AJ Wilcock	3.3286	0.04845	2.9157	0.11027
0.019 × 0.025″ SS (3M)	3.9129	0.04030	2.9986	0.09667

N: Newton; SD: Standard deviation

Table 2: Comparison of static friction among wires in conventional bracket

Wire	*Wires*	*Mean difference*	*Significance*
0.018″ SS	0.018″ AJ Wilcock	1.0614	0.000*
	0.019 × 0.025″ SS	1.6457	0.000*
0.018″ AJ Wilcock	0.018″ SS	1.0614	0.000*
	0.019 × 0.025″ SS	0.5843	0.000*
0.019 × 0.025″ SS	0.018″ SS	1.6457	0.000*
	0.018″ AJ Wilcock	0.5843	0.000*

Sig.: Significant; *Statistically significant results with $p < 0.001$. Static friction increases from round to rectangular cross-section. Wires when compared among each other were highly significant with $p < 0.001$

Table 3: Comparison of kinetic friction among wires in conventional bracket

Wire	*Wires*	*Mean difference*	*Significance*
0.018″ SS	0.018″ AJ Wilcock	1.0904	0.000*
	0.019 × 0.025″ SS	1.1732	0.000*
0.018″ AJ Wilcock	0.018″ SS	1.0904	0.000*
	0.019 × 0.025″ SS	0.0829	0.100
0.019 × 0.025″ SS	0.018″ SS	1.1732	0.000*
	0.018″ AJ Wilcock	0.0829	0.100

*Exhibit statistically significant results with $p < 0.001$. Kinetic friction increases from round to rectangular cross-section. Kinetic friction between 0.018″ AJ Wilcock and 0.019 × 0.025″ SS was not significant with $p > 0.05$

Table 4: Intraclass correlation coefficients

Bracket	*Wires*	*Reliability coefficients, p ≤ 0.000*
Conventional bracket	0.018″ SS	0.9978
	0.018″ AJ Wilcock	0.9975
	0.019 × 0.025″ SS	0.9985

DISCUSSION

In orthodontics, friction between archwire and bracket is multifactorial in nature and can essentially be classified into physical or biological factors.[10] The widespread adoption of preadjusted bracket systems and sliding mechanics has lead to considerably increased frictional resistance to deal with in clinical orthodontics. Finite element analysis has proved that 60 to 80% of the applied orthodontic force is utilized to overcome frictional resistance during canine retraction along a rectangular archwire.[8] Hence, the frictional force between the bracket and archwire must be overcome before the intended tooth-moving force can be effective during sliding mechanics.[2] Hence, the study was conducted on conventional brackets with a statistically adequate sample size of 30 wires and each test experiment was repeated ten times. Elastomeric modules were used in the current study in order to eliminate variation in ligation force associated with SS ligatures.[11] The wire dimensions were chosen with an objective to include both round and rectangular wires. Round wires of small size are recommended during the aligning/leveling and canine retraction during orthodontic treatment, while rectangular wires are recommended for *en masse* retraction and final phase of treatment when a remarkable torque control is necessary. Force of 100-gm weight was suspended from the power arm of the canine bracket. This 100 gm was chosen to represent equivalent retraction force acting at the center of resistance of the tooth. Ireland et al[12] studied the effect of sliding velocity on frictional resistance at a crosshead speed of 0.5, 1, and 5 mm per minute, and found no significant difference between velocities. Hence, in the current study, static and kinetic frictions were recorded at a crosshead speed of 5 mm/min on an Instron universal testing machine.

Andreasen and Quevedo[13] found no difference in friction force levels between trials with saliva and those without saliva. Kusy et al[14] found higher friction in wet state testing due to increased surface tension. Read-Ward et al[15] found inconsistent effect of saliva with frictional resistance. It is often difficult to simulate the oral environment due to variations in diet, bite force, and masticatory forces.[16] Hence, the current study was carried out in dry state *in vitro*.

The results showed that static friction was higher than kinetic friction, which was in consonance with the study by Taylor and Ison,[17] Kim et al,[18] and Gandini et al.[19] However, no significant difference between static and kinetic friction was reported by Kusy et al,[14] which is in contrast with the present study. This difference could be attributed to the dissimilar experimental set-up.

The wires' dimensions considered in the study were with the purpose of evaluating appropriate wire for individual canine retraction. The study by Rizk et al[9] stated that both *en masse* and two-step retraction methods are effective during the space closure phase with regard to anchorage preservation and amount of retraction.

Comparison of friction between 0.018″ SS (3M) and 0.018″ AJ Wilcock wires showed significant difference between the two. AJ Wilcock wires showed higher frictional resistance (both static and kinetic) when compared with 3M wire of the same dimension (0.018″). This is in contrast with the study by Acharya and Jayade,[20] where they had a greater value of friction with wires from Ortho Organizers and T.P. Orthodontics than with AJ Wilcock Australian wires. The difference in the study could be attributed to the different brand used in the two studies to compare AJ Wilcock wires.

The maximum frictional resistance was exhibited by 0.019 × 0.025″ SS (3M) followed by 0.018″ AJ Wilcock and 0.018″ SS (3M). Round wires exhibited the lower frictional resistance than rectangular wires. The result of the current study was in consonance with Garner et al.[1] They concluded that frictional resistance increases with increased wire dimension and also from round to rectangular wires.

The kinetic friction showed no significant difference between 0.018″ AJ Wilcock wires and 0.019 × 0.025″ SS (3M) cross-section wires. This was unexpected because one is round and the other is rectangular in cross-section. It could be attributed to the properties and surface characteristics as rest of other conditions were the same, i.e., bracket, method of ligation, dry state test procedure, retraction force being parallel to bracket, and were equal with both the wires. The study by Gómez et al[21] is in contrast with the present study as 0.018″ SS archwires exhibited lesser friction than 0.019 × 0.025″ SS archwires. The difference can be attributed to the different brands of bracket and wire (Ormco) used in the study. The present study is also in contrast with study by Tecco et al[22] between 0.018″ SS wire and 0.019 × 0.025″ SS archwires; it is because of dissimilar experimental set-up and brand of wires used.

After evaluating unexpected results between 0.018″ AJ Wilcock and 0.019 × 0.025″ SS (3M), we are considering a scanning electron microscopic study to check the surface characteristics of wires. We will also be evaluating if there is any correlation between frictional resistance and surface roughness.

CONCLUSION

Conventional brackets with 0.022 × 0.028″ slot were tested with 0.018″ SS (3M), 0.018″ AJ Wilcock, and 0.019 × 0.025″ SS at a crosshead speed of 5 mm/min. Using Universal testing machine in dry state, it was found that:

- Static friction was greater than kinetic friction with all wire dimensions.
- 0.018″ SS (3M) exhibited lesser friction when compared with 0.018″ AJ Wilcock and 0.019 × 0.025″ SS (3M).
- 0.018″ AJ Wilcock and 0.019 × 0.025″ SS showed no difference in kinetic friction.

CLINICAL SIGNIFICANCE

The study concluded that 0.018″ SS (3M) is better for individual canine retraction than the other wires used in the study; 0.019 × 0.025″ SS (3M) is a better wire for canine retraction than 0.018″ AJ Wilcock, as we can have a three-dimensional control over tooth movement. When torque control is not a prime requisite, then 0.018″ SS (3M) can be used for retraction of incisors instead of 0.018″ AJ Wilcock in severely proclined incisor cases.

ACKNOWLEDGMENTS

The authors would like to extend their thanks to Mr. Mann Singh for technical assistance and the Central Institute of Plastic Engineering, Lucknow, for the cooperation rendered by them during the study.

REFERENCES

1. Garner LD, Allai WW, Moore BK. A comparison of frictional forces during simulated canine retraction of a continuous edgewise arch wire. Am J Orthod Dentofacial Orthop 1986 Sep;90(3):199-203.
2. Proffit, WR.; Fields, HW.; Sarver, DM. Contemporary orthodontics. 4th ed. Chapter 10. St. Louis (MO): Mosby-Year Book Inc.; 2007. p. 375.
3. Budd S, Daskalogiannakis J, Tompson BD. A study of the frictional characteristics of four commercially available self-ligating bracket systems. Eur J Orthod 2008 Dec;30(6): 645-653.
4. Burrow SJ III. Critical appraisal of *in vitro* steady-state frictional resistance studies. Semin Orthod 2010 Dec;16(4):244-248.
5. Tidy DC. Frictional forces in fixed appliances. Am J Orthod Dentofacial Orthop 1989 Sep;96(3):249-254.
6. Pacheco MR, Jansen WC, Oliveira DD. The role of friction in orthodontics. Dent Press J Orthod 2012 Mar-Apr;17(2): 170-177.
7. 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 Dentofacial Orthop 2009 Nov;136(5):675-682.
8. Hain M, Dhopatkar A, Rock P. A comparison of different ligation methods on friction. Am J Orthod Dentofacial Orthop 2006 Nov;130(5):666-670.
9. Rizk MZ, Mohammed H, Ismael O, Bearn DR. Effectiveness of en masse versus two-step retraction: a systematic review and meta-analysis. Prog Orthod 2018 Jan;18(1):41.
10. Emile RP. Friction: an overview. Semin Orthod 2003 Dec;9(4): 218-222.
11. Reicheneder CA, Gedrange T, Berrisch S, Proff P, Baumert U, Faltermeier A, Muessig D. Conventionally ligated versus self-ligating metal brackets—a comparative study. Eur J Orthod 2008 Dec;30(6):654-660.
12. Ireland AJ, Sherriff M, McDonald F. Effect of bracket and wire composition on frictional forces. Eur J Orthod 1991 Aug;13(4):322-328.
13. Andreasen GF, Quevedo FR. Evaluation of friction forces in the 0.022 × 0.028 edgewise bracket *in vitro*. J Biomech 1970 Mar;3(2):151-160.
14. Kusy RP, Whitley JQ, Prewitt MJ. Comparison of the frictional coefficients for selected archwire-bracket slot combinations in the dry and wet states. Angle Orthod 1991 Winter;61(4):293-302.
15. Read-Ward GE, Jones SP, Davies EH. A comparison of self-ligating and conventional orthodontic bracket systems. Br J Orthod 1997 Nov;24(4):309-317.
16. Fourie Z, Ozcan M, Sandham A. Effect of dental arch convexity and type of archwire on frictional forces. Am J Orthod Dentofacial Orthop 2009 Jul;136(1):14.e1-14.e7.
17. Taylor NG, Ison K. Frictional resistance between orthodontic brackets and archwires in the buccal segments. Angle Orthod 1996 Feb;66(3):215-222.
18. Kim TK, Kim KD, Baek SH. Comparison of frictional forces during the initial leveling stage in various combinations of self-ligating brackets and archwires with a custom-designed typodont system. Am J Orthod Dentofacial Orthop 2008 Feb;133(2):187.e15-187.e24.
19. Gandini P, Orsi L, Bertoncini C, Massironi S, Franchi L. *In-vitro* frictional forces generated by three different ligation methods. Angle Orthod 2008 Sep;78(5):917-921.
20. Acharya KA, Jayade VP. Metallurgic properties of stainless steel orthodontic archwires: a comparative study. Trends Biomater Artif Organs 2005 Jan;18(2):125-136.
21. Gómez SL, Montoya Y, Garcia NL, Virgen AL, Botero JE. Comparison of frictional resistance among conventional, active and passive self-ligating brackets with different combinations of arch wires: a finite elements study. Acta Odontol Latinoam 2016 Sep;29(2):130-136.
22. Tecco S, Tete S, Festa F. Friction between archwires of different sizes, cross-section and alloy and brackets ligated with low-friction or conventional ligatures. Angle Orthod 2009 Jan;79(1):111-116.