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The Effect of Different Extrinsic Lubricates on Frictional Resistance Between the Orthodontic Bracket and Archwire: an *in vitro* study

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Abstract

Aim of the study: The purpose of this research was to investigate how the static and kinetic friction between the orthodontic bracket and archwire will be affected by artificial saliva (AS), oil-containing mouthwash (TTO), and olive oil (OO).

Materials and methods: On an Instron universal testing machine with a load cell of 10N and a speed of 2 mm/min. Thirty premolar brackets with 0.019 x 0.025inch stainless steel archwires were assessed. The samples were allocated into three groups randomly. Ten test units were immersed in artificial saliva AS (control group), Tea tree oil mouthwash TTO, and olive oil OO (study groups) for 90 minutes at room temperature. Each test unit is evaluated once only. Statistical analysis used was the ANOVA and Post Hoc LSD tests for parametric tests, the Kruskal-Wallis test, and the Pairwise Comparison test for non-parametric tests.

Results: The samples immersed in olive oil significantly showed increased static and kinetic frictional resistance (p= 0.009 and 0.001, respectively), and the TTO showed the least static and kinetic frictional resistance.

Conclusion: The 90-minute immersion in oil-containing mouthwash reduced static and kinetic frictional resistance between the orthodontic brackets and archwires, while olive oil (OO) significantly increased them. Based on these findings, oil-containing mouthwash can be prescribed as an excellent prophylactic agent for orthodontic patients. However, the OO is not recommended during the sliding mechanics.

Keywords: Static friction, kinetic friction, olive oil, tea tree oil mouthwash.

INTRODUCTION

In orthodontic practice, straight wire appliances rely on the ability of the archwire to slide along the bracket slots and tubes during the second phase of leveling and alignment, closing of spaces, and canine retraction [(1)], but the main problem with this sliding mechanics is friction force generation between the brackets and the archwire [(2)]. Friction is the force that restricts the sliding of one object over another. At the beginning of sliding, the resistance to sliding is known as static friction, while the resistance to sliding during motion is known as kinetic friction [(3)]. Several factors have direct and indirect effects on the frictional resistance, such as the alloy type, amount of clearance between the bracket and archwire, and ligation type directly affecting the friction. In contrast, the type of mouthwash, oral hygiene, diet, and kind of saliva has an indirect effect [4].

Orthodontists prescribe different mouthwashes during the treatment course as the orthodontic 0patients usually have high plaque and gingival bleeding indexes associated with inadequate oral home care; subsequently, the orthodontic appliance is regularly exposed to these mouthwashes [5]. Some lubricants have adverse side effects, such as bracket and archwire corrosion, as in NaF mouthwash [6], which would increase the frictional resistance and cause nickel ions to release in NiTi, which would subsequently increase the risk of nickel allergy[7]. Other mouthwashes like Tea tree oil (TTO) possess antiseptic, fungicidal, and bactericidal properties and can be administered to reduce plaque formation during the active period of orthodontic therapy [8] . In addition, oil pulling is a practical and affordable way to maintain and enhance dental health without the need for strict measures, negative side effects, a persistent aftertaste, or related allergies [9-11]. It has antibacterial activity against C. Albicans and S. Mutans [12]. Also, the oils are known to have an inherited property of friction reduction. During the orthodontic treatment, the frictional resistance must be kept as minimum as possible with regard to sliding mechanics; investigating the effects of these extrinsic lubricants on archwire-bracket friction is quite essential.

MATERIALS AND METHODS

1. Test unit preparation

This investigation was performed on thirty pre-adjusted upper right first premolar stainless-steel Roth brackets with 0.022*0.030-inch slot size, torque (-7), and (0°) angulation (equilibrium ®2, dentaurum, Ispringen, Germany). Stainless steel archwires with dimensions of 0.019x0.025 inch (remanium, ideal arch, dentaurum, Ispringen, Germany) were cut into 4 cm length specimens from the distal end of the archwire and ligated on the bracket with an elastomeric ligature (Unicycle, Masel, Carlsbad, CA, USA) in the conventional O pattern. The test units were randomly divided into three main groups: AS (control group), TTO, and OO (control group). Each group had 10 samples (10 SS archwire-bracket combinations). A 24-hour elastomeric relaxation was allowed before the test units were immersed in the lubricants.

2. Artificial saliva preparation

The artificial saliva used in this study was a modified Carter's solution. It was prepared by mixing (0.7g sodium chloride NaCl, 1.2g potassium chloride KCl, 0.26g sodium phosphate Na2 HPO4, 0.2g Potassium phosphate K2 HPO4, 1.5g sodium hydrogen carbonate NaHCO3, 0.33g potassium thiocyanate KSCN, and 0.13g urea). The mixture dissolved in 1000ml of deionized water. Then 5µm pore filter paper was used to remove any impurities and make the solution as clear as possible. The PH was modified using sodium chloride and lactic acid to reach 6.75 [7,13,14].

3. Assessment of frictional resistance

Three glass containers each contained 300 ml of AS, 1.5% TTO mouthwash (TEBODENT ®, Wild, Muttenz, Switzerland), and OO (Extra version olive oil, Basso Fedele, Avellino, Italy), in which the test units were immersed at room temperature for 90 minutes. The 1.5-hour immersion period was selected to represent the accumulation of daily mouthwash teaching over three months (30 sec * twice daily * one month). The specimens were removed and placed on the Instron (Figure 1) (H50KT Tinius Olsen testing machine, UK). For archwire withdrawal, a crosshead speed of 2 mm/min over a 10 mm archwire length with a load cell of 10 N was employed. Once all the setting data were entered, the test stats and the wire were pulled in a vertical direction by the upper crosshead of the machine (the Instron's load cell) until the mm span of the wire was entirely pulled out of the bracket slot. Cotton was placed at the lower part of the Instron machine to prevent the lubricants from wetting the machine .

The frictional force was displayed on the computer connected to the testing device using the QMat 4.53 T series software as a force-distance graph. The static friction was represented by the force's first peak, and the kinetic friction was calculated by averaging the frictional forces that were registered at intervals of 0.75 mm from the graph. All these forces were produced in Newton, and using the following equation, they were converted to grams:

Friction (gm)= [Friction in (N) ÷ 9.8] x 1000

In Each of the three groups, 10 new test units (bracket/wire/ligature combinations) were tested to avoid bracket and archwire wearing.

4. Statistical analysis

Using SPSS software, the obtained data were statistically analyzed, and their normality was checked using the Shapiro-Wilk test (version 22). The mean, median, standard deviation, and lowest and maximum values within groups were used to summarize the data. The significance of friction resistance was examined using a one-way ANOVA test, followed by a post hoc LSD test for parametric tests and the Kruskal-Wallis test and pairwise test for non-parametric tests. A P value of 0.05 or less was regarded as statistically significant.

RESULTS

Static friction

Figures 2,3, and 4 show the friction-distance plots for the archwire-bracket test unit in the three lubrications. Again, the static friction in the AS and OO is less than the kinetic friction, while the static friction of TTO group was higher than kinetic friction.

The descriptive statistics showed that the mean of the static friction in the presence of TTO was the least, followed by artificial saliva. While the OO showed the highest static resistance, as shown in (Table 1). This difference was significant (p 0.001). The post hoc analysis reveals that there was a significant difference in the static friction mean between TTO and OO (p = 0.009). The other differences were not significant, as shown in (Table 2).

Kinetic

The mean of the kinetic friction was significantly different (P 0.001) between the three study groups (Table 3). The highest mean was of the OO group (206.7 gm), then the SA (174.9 gm), while the lowest mean was that of the TTO group (110.8 gm).

The TTO significantly reduces the frictional resistance (P 0.002) when compared to AS. While the OO double increases the frictional resistance than the TTO (P 0.001). However, there is a nonsignificant increase in kinetic frictional resistance between OO and AS (Table 4).

DISCUSSION

This study focused on the friction between stainless steel orthodontic brackets and archwires since the stainless-steel brackets are superior to the ceramic, plastic and titanium brackets from friction perspective [14]. The brackets used were made from SS with a 0.022 slot since it is preferable to use a large slot size during sliding mechanics to decrease frictional resistance [4,15].

0.019x0.025 SS archwires, usually utilized during sliding and space closure, were employed in this study. When compared to other orthodontic archwire materials, SS archwires are commonly utilized and recognized for their low friction qualities, high strength, rigidity, and smooth surface

[16,17]. Remember that rectangular wires cause more friction than rounded wires, and friction rises as the diameter increase [18].

The friction test was conducted on a universal testing machine at 2 mm/min. Wright (2009) stated that there is no significant change in friction at a speed range between 0.5 and 5 mm/min [19].

The type of ligation can either increase or decrease the amount of friction. For the SS ligatures, even for skilled orthodontists, it is difficult to achieve a constant ligation force [20]. We utilized the “O pattern” elastomeric ligation method, the most common type of ligation utilized in everyday orthodontic practice. Regarding the effect of elastomeric ligatures on frictional resistance, old research stated that they produce higher friction than SS ligatures [20–22]. Other studies found no difference between the two types of ligations [23], but more recent research found that O-pattern elastomeric ligatures produce less friction than SS ligatures [1,23,24].

Static friction

The in-vitro studies should be performed in a condition approximating the oral cavity; it has been reported that there was no difference when frictional tests were performed in the presence of artificial and natural human saliva [25,26]. Furthermore, since the use of natural saliva is associated with difficulties in collecting and storing natural saliva, the risk of cross-contamination, and the demand for a saliva donor, artificial saliva was chosen as a control group.

TTO produces non-significant friction than AS group (Figure 5); this goes with Choudhary et al. [27] findings. TTO has a higher viscosity than artificial saliva. Lubricants having higher viscosity, produce a thicker lubricating film that can separate the surface asperities and prevent them from contacting one another. Subsequently, reduce the friction. Also, the amount of kinetic friction was less than the static friction.

However, TTO significantly reduces the static friction compared to the OO group (Figure 5). At the same time, OO had more friction than the artificial saliva, even though this difference was non-significant. This increase in friction may be related to the fact that the OO has a much higher viscosity than TTO and AS. The internal frictional force between fluid layers in relative motion is defined as viscosity. When a liquid has a high viscosity, it has high internal friction [28], and because the space between the slot and the archwire was so small, OO did not act as a lubricant as expected but rather as an adhesive.

To our knowledge, only one study investigated the effect of OO on frictional resistance in conventional and self-ligating brackets. They reported that OO was more effective in friction reduction in the self-ligating bracket than in the conventional bracket. This may be related to more clearance between the bracket and archwire. However, they also used an archwire gauge of 0.018’’ x 0.025’’ smaller than the one we used in our study [29].

Kinetic friction

According to Amontons-Coulomb principles, the constancy of the kinetic frictional coefficient is dependent on maintaining a steady sliding velocity controlled by the computerized Instron machine [30].

Regarding kinetic friction, TTO produces significantly less frictional force than AS (Figure 6). Moreover, we found that within the same tested sample, the kinetic friction in the presence of artificial saliva is higher than static friction. This is justified because the kinetic friction lies under the boundary lubricant friction, in which the kinetic friction results from adhesion between two surface asperities and shearing friction of the lubricant film [31].

The TTO is considered a good alternative to chlorhexidine in maintaining oral health and gingivitis treatment [27]. Its appropriate viscosity makes TTO able to enter between the slot and the archwire and makes TTO a better lubricant than AS. The increased liquid viscosity will reduce wettability[32], which means less adherence of the lubricant to the solid surface, producing less friction than wetting lubricant [33]. At the same time, it will produce a film thickness that is thick enough to separate the surfaces. According to our knowledge, no previous study investigated the effect of TTO on kinetic frictional resistances to compare our findings to it, so further investigations are required.

On the other hand, OO has non-significant higher kinetic friction than AS, and a significant friction increase compared to TTO. The higher viscosity and little space available between the bracket and archwire due to the high *wire gauge used during the test are responsible for this increase in kinetic friction. And even if it enters between them, the resistance to sliding will be the friction force between the solid surfaces and the internal friction of the fluid layers. To our knowledge, no previous study has discussed the effect of the OO on kinetic friction bit we found that the kinetic friction was higher than the static friction; this increase may be related to the fact that the total friction result from internal fluid friction added to the bracket archwire friction.

The present study has some limitations, such as the fact that the test was performed at room temperature, which is different from the temperature in the oral cavity. Also, studying the effect of these lubricants on the frictional resistance between the ceramic and plastic brackets and the aesthetic archwire is recommended as a further study.

Conclusion

Within the limitations of this study, 1.5% tea tree oil mouthwash was found to reduce static and kinetic frictional resistance between stainless steel brackets and archwires, but olive oil increased it. Oil-containing mouthwash can be administered as an orthodontic prophylaxis. Olive oil isn't recommended during sliding mechanics.

Conflicts of Interest

The authors reported that they have no conflicts of interest.

References

1. Yousif AA, Abdel Karim UM. Assessment of friction resistance of four orthodontic arch wires using three ligation methods in dry and wet conditions. EOS. 2016:85–102.

2. Mascarelo AC, Godoi AP, Furletti V, Custódio W, Valdrighi HC. Evaluation of friction in metal, ceramic and self-ligating brackets submitted to sliding mechanics. Revista de Odontologia da UNESP. 2018, 47(4):244–8.

3. Burrow SJ. Friction and resistance to sliding in orthodontics: a critical review. American Journal of Orthodontics and Dentofacial Orthopedics. 2009;135(4):442–7.

4. Proffit WR, Fields HW, Msd DM, Larson B, Sarver DM. Contemporary Orthodontics, 6th ed: South Asia Edition-E-Book. Elsevier India; 2019.

5. Mahindra RK, Suryawanshi GR, Doshi UH. Effects of fixed orthodontic treatment on gingival health: an observational study. Int. J. Appl. Dent. Sci. 2017;3(3):156–61.

6. Kassab EJ, Gomes JP. Assessment of nickel titanium and beta titanium corrosion resistance behavior in fluoride and chloride environments. Angle Orthod. 2013;83(5):864–9.

7. Obaid DA. Assessment of friction and surface roughness of nickel free orthodontic brackets and archwires in wet condition (An in vitro comparative study) [Master's thesis]. Iraq: Baghdad university; 2020.

8. Rahman B, Alkawas S, Al Zubaidi EA, Adel OI, Hawas N. Comparative antiplaque and antigingivitis effectiveness of tea tree oil mouthwash and a cetylpyridinium chloride mouthwash: A randomized controlled crossover study. Contemp Clin Dent. 2014, 5(4):466–70.

9. Lakshmi T, Rajendran R, Krishnan V. Perspectives of oil pulling therapy in dental practice. Dent. Hypotheses. 2013;4(4):131.

10. Coleman M. Oil Pulling Revolution: The Natural Approach to Dental Care, Whole-Body Detoxification and Disease Prevention. Ulysses Press; 2015.

11. Tomar P, Hongal S, Jain M, Rana K, Saxena V. Oil pulling and oral health: A review. IJSS case reports rev. 2014;1(3):33–7.

12. Anand TD, Pothiraj C, Gopinath RM, Kayalvizhi B. Effect of oil-pulling on dental caries causing bacteria. Afr J Microbiol Res. 2008;2(3):63–6.

13. Duffó GS, Castillo EQ. Development of an Artificial Saliva Solution for Studying the C-orrosion Behavior of Dental Alloys. Corros. 2004; 60(6):594–602.

14. Mohammed SA, Mahmood AB, Nahidh M. Measurement the Chemical Composition and Topography of Copper Nickel Titanium Arch Wires at Dry and Wet conditions (An In-Vitro Study). Indian J. Forensic Med. Toxicol . 2020;14(4):1493.

15. Ogata RH, Nanda RS, Duncanson Jr MG, Sinha PK, Currier GF. Frictional resistances in stainless steel bracket-wire combinations with effects of vertical defections. Am. J. Orthod. Dentofac. Orthop. 1996;109(5):535–42.

16. Krishnan V, Kumar KJ. Mechanical properties and surface characteristics of three archwire alloys. Angle Orthod. 2004;74(6):825–31.

17. 17.Yu JH, Wu LC, Hsu JT, Chang YY, Huang HH, Huang HL. Surface roughness and topography of four commonly used types of orthodontic archwire. J Med Biol Eng. 2011;31(5):367–70.

18. Drescher D, Bourauel C, Schumacher HA. Frictional forces between bracket and arch wire. Am. J. Orthod. Dentofac. Orthop. 1989;96(5):397–404.

19. Wright NS. Orthodontic Applications of Biomaterials: A Clinical Guide. Eur J Orthod. 2018.

20. Iwasaki LR, Beatty MW, Randall CJ, Nickel JC. Clinical ligation forces and intraoral friction during sliding on a stainless steel archwire. Am. J. Orthod. Dentofac. Orthop. 2003;123(4):408–15.

21. Hain M, Dhopatkar A, Rock P. The effect of ligation method on friction in sliding mechanics. Am. J. Orthod. Dentofac. Orthop. 2003;123(4):416–22.

22. Thorstenson GA, Kusy RP. Effects of ligation type and method on the resistance to sliding of novel orthodontic brackets with second-order angulation in the dry and wet

states. Angle Orthod. 2003;73(4):418–30.

23. Mendes K, Rossouw PE. Friction: validation of manufacturer's claim. In: Seminars in orthodontics. Elsevier; 2003. p. 236–50.
24. Natt AS, Sekhon AK, Munjal S, Duggal R, Holla A, Gupta P, et al. A Comparative Evaluation of Static Frictional Resistance Using Various Methods of Ligation at Different Time Intervals: An In Vitro Study. Int. J. Dent. 2015: e407361.
25. Leal RC, Amaral FL, França FM, Basting RT, Turssi CP. Role of lubricants on friction between self-ligating brackets and archwires. Angle Orthod. 2014;84(6):1049–53.
26. Almeida FAC, Almeida APCPSC, Amaral FLB, Basting RT, França FMG, Turssi CP. Lubricating conditions: effects on friction between orthodontic brackets and archwires with different cross-sections.DOAJ. 2019; 24:66–72.
27. Choudhary J, Shashikumar B, Patil AK. Evaluation and Comparison of Two Different Mouthwashes on Frictional Resistance Between Orthodontic Bracket and Archwire: An in Vitro Study. J Indian Orthod Soc [Internet]. 2019;53(2):117–25.
28. Symon KR. Mechanics. Addison. Vesley Publishing Co., Reading, Mass; 1971.
29. Dridi A, Bensalah W, Mezlini S, Tobji S, Zidi M. Influence of bio-lubricants on the orthodontic friction. J Mech Behav Biomed Mater. 2016; 60:1–7.
30. Gao J, Luedtke WD, Gourdon D, Ruths M, Israelachvili JN, Landman U. Frictional Forces and Amontons' Law: From the Molecular to the Macroscopic Scale. J Phys Chem B. 2004;108(11):3410–25.
31. Williams J, editor. Boundary lubrication and friction. In: Engineering Tribology. Cambridge: Cambridge University Press; 2005. p. 348–80.
32. Rossouw PE, Kamelchuk LS, Kusy RP. A fundamental review of variables associated with low velocity frictional dynamics. In: Seminars in Orthodontics. Elsevier; 2003. p. 223–35.
33. Ortiz-Young D, Chiu HC, Kim S, Voïtchovsky K, Riedo E. The interplay between apparent viscosity and wettability in nanoconfined water. Nat Commun. 2013; 4(1):2482.

Table 1. Means of static friction of the study groups.

		Static friction (gm)			95% C.I.				
	N	Mean	(SD)	SE	Lower	Upper	Min.	Max.	P*
AS	10	170.0	24.2	7.7	152.7	187.4	134.7	205.1	
TTO	10	125.9	44.6	14.1	94.1	157.8	76.6	206.1	<0.001
OO	10	186.6	30.5	9.7	164.8	208.4	145.2	261.2	

Kruskal Wallis test. C.I.: Confidence interval. SD: Standard deviation. SE: Standard error. gm: gram. The mean difference is significant at the 0.05 level.

Table 2. Pairwise Post hoc test of the static friction.

Group 1	Group 2	Mean difference (Group 1- Group 2)	P value	Sig
AS	TTO	44.1	0.07	NS
	OO	-16.5	0.416	NS
TTO	OO	-60.6	0.009	HS

*The numbers inside the table represent the p values obtained by pairwise test. NS: non-significant. HS: highly significant.

Table 3. Means of kinetic friction of the study groups.

		Kinetic friction (gm)			95% C.I.				
	N	Mean	(SD)	SE	Lower	Upper	Min.	Max.	P*
AS	10	174.9	(33.9)	10.7	150.7	199.2	109.5	227.2	
TTO	10	110.8	(40.6)	12.8	81.7	139.8	35.5	174.7	0.001
OO	10	206.7	(49.5)	15.7	171.3	242.2	150.8	300.3	

*By One way ANOVA. C.I.: Confidence interval. SD: Standard deviation. SE: Standard error. gm: gram. Highly significant: $P \leq 0.01$.

Table 4. Post hoc test results (LSD) comparing each two groups*.

Group 1	Group 2	Mean difference (Group 1- Group 2)	P value	Sig
AS	TTO	64.1	0.002	HS
	OO	-31.8	0.113	NS
TTO	OO	-95.9	<0.001	HS

*The numbers inside the table represent the p values obtained by LSD test. The mean difference is significant at the 0.05 level. HS: highly significant. NS: non-significant.

Figure 1: bracket- archwire test unit on Instron machine.

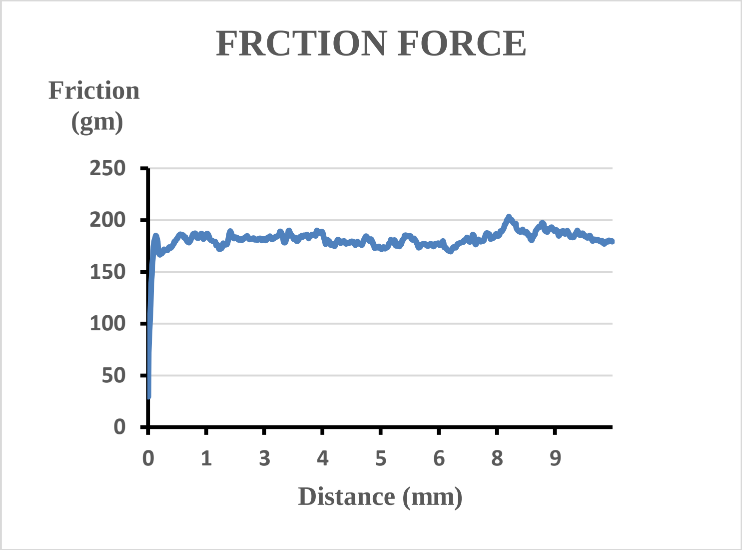

Figure 2: Friction force plots of the Stainless-Steel bracket- archwire combination in artificial saliva.

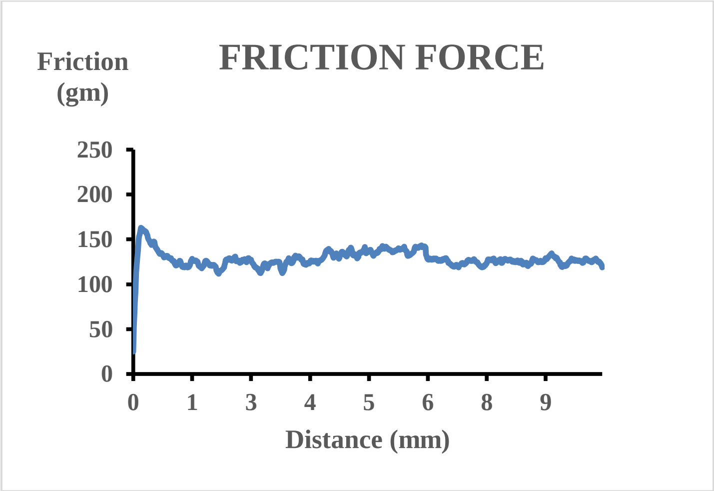

Figure 3: Friction force plots of the Stainless-Steel bracket- archwire combination in Tea tree oil.

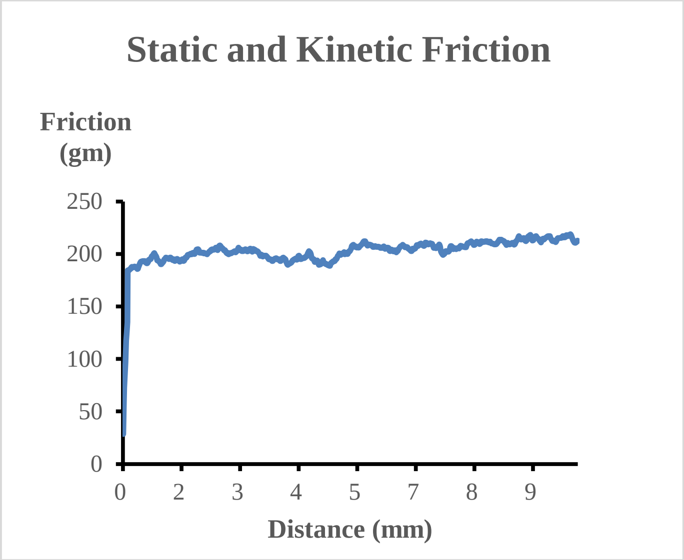

Figure 4: Friction force plots of the Stainless-Steel bracket- archwire combination in Olive oil.

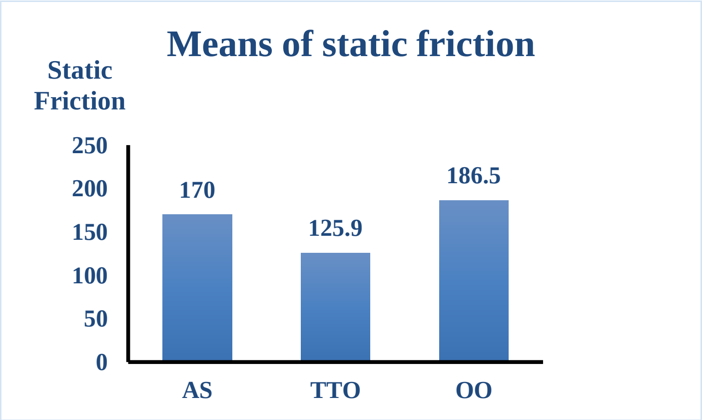

Figure 5: Mean of static friction in artificial saliva, tea tree oil and olive oil.

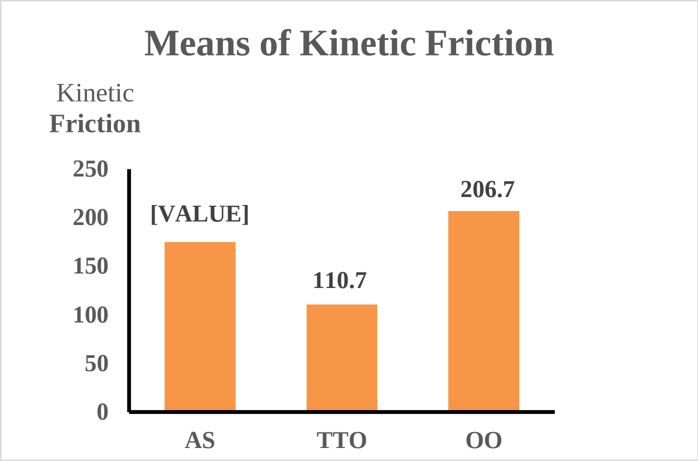

Figure 6: Mean of kinetic friction in artificial saliva, tea tree oil and olive oil.