

# Effect of Mouthwashes on Frictional Properties of Gold-plated and Ordinary Stainless Steel Orthodontic Brackets

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## ABSTRACT

**Background:** This study aimed to evaluate and compare the static frictional forces between the gold-plated and conventional stainless steel brackets following immersion in three types of mouthwashes.

**Materials and methods:** Eighty orthodontic brackets (40 stainless steel and 40 gold-plated) were divided equally into four subgroups and dipped in 15 mL of different mouthwashes for 45 days. The mouthwashes included chlorhexidine, aloe vera, aloe vera with fluoride and distilled water as a control group. The brackets then attached to an experimental model consisted of acrylic block. Frictional resistance was measured on 0.019 × 0.025 inch stainless steel archwires using Tinius Olsen Instron universal testing machine. Independent sample t-test and one way ANOVA were used to analyze the collected data.

**Results:** Gold-plated brackets showed high significant friction in comparison with stainless steel one in all mouthwashes. In both types of brackets, there was a statistically highly significant difference among different mouthwashes. Aloe vera mouthwash showed the highest friction with steel brackets while Chlorhexidine had a maximum effect on the frictional force with gold-plated bracket.

**Conclusion:** During orthodontic treatment and when sliding mechanics with minimum friction is required, the orthodontist should prescribe fluoridated herbal mouth rinse with Gold-plated brackets. Chlorhexidine should be excluded due to exaggerated frictional resistance that may impede or delay the intended tooth movement, from the same point of view, when using stainless steel brackets, chlorhexidine is the best mouth rinse, while herbal mouth rinse without fluoride (aloe vera mouthwash) is contraindicated.

**Clinical significance:** Orthodontists should take care of prescribing mouth rinses to decrease their effects on the friction.

**Keywords:** Chlorhexidine, Friction, Gold-plated brackets, Herbal mouth rinse.

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## INTRODUCTION

Friction during fixed orthodontic treatment is generated by the relative motion between the archwire and bracket. This friction must be overcome before force can be transferred from the orthodontic device to the teeth.<sup>1,2</sup> It is essential for orthodontists to identify the exact frictional forces run into the bracket-wire interface because optimum force had to be applied to provoke the proper biologic response for proficient tooth movement.<sup>2</sup> Frictional forces are of two types: a static frictional force which is the force desired to initiate the relative sliding of two surfaces; it restrains the tooth movement. Friction is diminished and movement began when the elastically deformed wire uprights the tooth. The other type is the kinetic frictional force which occurs when the tooth moves in the direction of the force application<sup>3</sup> and can be defined as the component of friction that has to be overcome to continue the motion or the force that counteracts motion.

Teeth movement along the archwire occurred in a series of incredibly short steps or jumps, i.e., not continuous, so the static friction presented great importance to be overcome each time the tooth moved a little.<sup>4</sup> It had been stated that friction occurred between archwire and bracket may lead to loss of force up to 50%.<sup>3</sup>

A huge number of innovative orthodontic materials and manufacturing techniques have been used as an alternative to the classical stainless steel wires and brackets. Nevertheless, frictional forces must be anticipated for every new combination of archwires and brackets so as to envisage their performance when they are used in clinical applications.<sup>1</sup>

To compare the friction performance for various combinations of bracket/archwire contacts, it is important to consider a number of factors including: the material types of brackets and archwires, relative bracket-wire clearance, size of the archwire, archwire cross-section (round or rectangular), torque at the bracket-archwire interface, surface conditions of the archwires and bracket slot, and type and force of ligation, saliva is a supplementary factor that may affect friction.<sup>5,6</sup>

It is challenging to adequately educate, train and encourage patients to remove plaque solely by mechanical means of plaque control as it requires time, motivation and manual skill<sup>7</sup> which is especially true with fixed

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orthodontic appliances in whom a high plaque accumulation has been described,<sup>8</sup> therefore, in addition to mechanical plaque control methods, chemical plaque control using mouthwashes is essential to dental patients by orthodontists and other oral health care providers to help maintain oral health throughout treatment when oral hygiene might be compromised.<sup>9</sup>

Clinically, antiseptic mouth rinses are used to reduce the accumulation of plaque during the active phase of orthodontic treatment.<sup>10</sup> However, some of their constituents may lead to corrosion and discoloration of stainless steel and titanium alloys. Corrosion and its end product that rising surface roughness have a prospective effect of increasing the frictional force at the wire-bracket interface. Resistance to corrosion of stainless steel and titanium archwires depends primarily on the development of an inactive oxide layer. When this layer deteriorates, the archwire will be undergoing corrosion.<sup>11</sup>

The effect of mouth rinses on the ions release from various combinations of archwires and brackets had been reported by many researchers.<sup>12-14</sup> The uniqueness of this study is that it has been the first one that tests the frictional forces produced by gold-plated orthodontic brackets under the mouthwash challenge compared to the former classical stainless steel brackets in an attempt to be able to choose the most biocompatible bracket/mouthwash combination in the clinical practice.

## MATERIALS AND METHODS

Eighty maxillary premolar brackets were divided into two groups according to their manufacturing types; 40 stainless steel brackets (Votion™) and 40 gold-plated brackets (Marquis TruGold™). All of these brackets were used in this study in as-received condition, Roth prescription, 0.022-inch slot and from the same company (Orthotechnology, USA).

The brackets were randomly divided into four numerically equal subgroups according to the mouthwash they dipped in. Three types of mouthwash were chosen because of their commercial availability and identical application methods:

- Zordyl® mouthwash (CHX) (Julphar®, United Arab Emirates), containing Chlorhexidine gluconate 0.2% w/v, pH: 7.10
- Aloe Dent® mouthwash (ALO) (Aloe Vera mouthwash, Optima®, Italy) contains natural Aloe Vera ingredient Aqua, Aloe Barbardensis, Sorbitol, Polysorbate 20, Citrus Grandis (grapefruit), Seed extract, Menthapipenta oil, Sodium Lauroyl Sarcosinate, Aroma, Menthol, Melaleuca Altemifolia Oil, Escin (Horse Chestnut), Centtella Asiatica, Xylitol, Sodium Hydroxymethylglycinate, Citric Acid, CI 75810. Limonene, Linalool, Natural constituent of essential oils, pH: 5.17

- Aloe Dent® mouthwash with fluoride (ALOF) (Aloe Vera mouthwash with fluoride, Optima®, Italy), contains the same constituent of Aloe Dent® in addition to Sodium Monofluorophosphate (Fluoride 1500 ppm), pH: 5.46. Distilled water (D.W.), Iraq, pH: 7.04.

Each bracket was individually dipped in 15 mL of mouthwash in 20 mL glass capped container and incubated at a constant temperature of 37°C for 45 days. Several studies have demonstrated that the levels of metal release from fixed orthodontic appliances peak at day 7 and that all release is completed within 4 weeks.<sup>15,16</sup>

To test the effect of mouthwashes on the frictional properties of the Votion and TruGold brackets type, all of the brackets were attached to an experimental model consisted of the acrylic block (3 cm length, 1.2 cm width, and 1.7 cm thickness). A section of 0.0215 × 0.025-inch straight stainless steel archwire was used to align the bracket on the acrylic block,<sup>17</sup> and then the brackets were fixed over acrylic by the light-cured composite.

A total of 80 pieces of archwire measuring 4 cm in length were cut from the straight portion of 0.019 × 0.025-inch stainless steel archwires (Orthotechnology, USA) and randomly divided into eight subgroups (10 per each subgroup).

Each testing archwire was seated in the slot of the bracket after it was degreased with ethanol to remove oil, debris, and dirt because they may affect the frictional resistance,<sup>18,19</sup> and ligated using conventional clear elastomeric modules (Orthotechnology, USA).

Frictional properties were measured with a universal testing machine (Instron H50KT Tinius Olsen testing machine, England with 10N load cell). A computer connected to the testing machine displayed a graph showing ultimate force variation and recorded the tensile force produced on every 0.01 mm distance. The tensile force needed to slide 12 mm of the archwire over the test specimen bracket for two minutes at a speed of six mm per minute, was measured (Fig. 1). Graphs from each sample

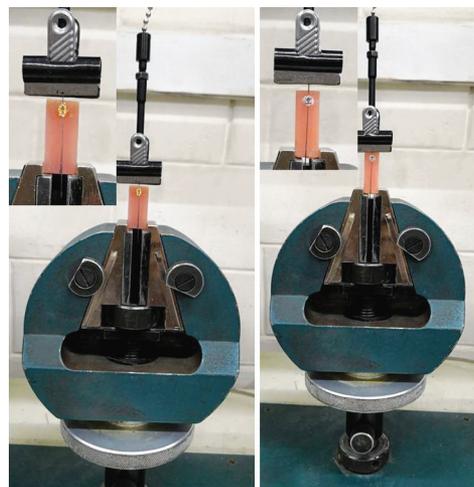


Fig. 1: Frictional resistance test for gold-plated bracket (left side), and for stainless steel brackets (right side)

were analyzed to determine the primary tensile strength peak of the tested archwire in Newton for every traction test that was converted into grams then after. This represented the maximum frictional resistance force required to initiate movement of the archwire through the bracket (static friction).<sup>20,21</sup>

Each bracket/mouthwash combination was submitted once to the tensile test and the test was performed 10 times by a single operator for each subgroup, thus totalizing 40 mechanical testing for each group of brackets and eighty for both brackets groups.

**Statistical Analysis**

The collected data were managed statistically using SPSS (statistical package of social sciences) software version 24. The following types of statistics were used in this study:

- Descriptive statistics: including means, standard deviations, minimum and maximum values.
- Inferential statistics: including:
  - Independent sample t-test: For comparison the friction between the two types of brackets in each medium.

- One-way ANOVA test: For comparison friction among different media.
- Tukey's honestly significant difference (HSD) test: To test any statistically significant difference between every two types of media.

In the statistical evaluation, the following levels of significance are used:

- $p > 0.05$  Nonsignificant
- $p$  between  $\geq 0.05$  and  $p > 0.01$  Significant
- $p \leq 0.01$  Highly significant

**RESULTS**

Table 1 demonstrated the descriptive statistics of the static friction of different types of brackets in each brand of mouthwashes. In general, gold-plated brackets showed high significant friction in comparison with steel one in all mouthwashes.

Studying the effect of different mouthwashes on the static friction of stainless steel and gold-plated brackets was demonstrated in Tables 2 and 3. In both types of brackets, there was a statistically highly significant dif-

**Table 1:** Effect of brackets types on the static frictional force in different mouthwashes

Media	Bracket types	Descriptive statistics				Comparison	
		Mean	SD	Min.	Max.	t-test	p value
D.W.	Gold	73.837	3.404	69.806	78.776	-9.728	0.000
	Votion	55.733	2.393	52.857	59.327		
CHX	Gold	209.749	1.966	207.041	211.939	-92.585	0.000
	Votion	62.659	2.959	58.776	66.633		
ALOF	Gold	105.424	2.780	102.245	109.918	-10.660	0.000
	Votion	84.347	3.437	80.561	89.816		
ALO	Gold	195.825	3.965	190.204	199.592	-49.180	0.000
	Votion	96.374	2.174	94.184	99.898		

**Table 2:** Effect of various mouthwashes on the static frictional force in each bracket type

Bracket types	Media	Descriptive statistics				Comparison	
		Mean	SD	Min.	Max.	F-test	p value
Gold	D.W.	73.837	3.404	69.806	78.776	2296.253	0.000
	CHX	209.749	1.966	207.041	211.939		
	ALOF	105.424	2.780	102.245	109.918		
	ALO	195.825	3.965	190.204	199.592		
Votion	D.W.	55.733	2.393	52.857	59.327	229.397	0.000
	CHX	62.659	2.959	58.776	66.633		
	ALOF	84.347	3.437	80.561	89.816		
	ALO	96.374	2.174	94.184	99.898		

**Table 3:** Tukey's HSD test after ANOVA test

Media	Media	Gold		Votion	
		Mean difference	p-value	Mean difference	p value
D.W.	CHX	-135.912	0.000	-6.927	0.006
	ALOF	-31.588	0.000	-28.614	0.000
	ALO	-121.988	0.000	-40.641	0.000
CHX	ALOF	104.325	0.000	-21.688	0.000
	ALO	13.924	0.000	-33.714	0.000
ALOF	ALO	-90.400	0.000	-12.027	0.000

ference among different mouthwashes. ALO showed the highest friction with steel brackets while Chlorhexidine had a maximum effect on the frictional force with gold-plated bracket.

Tukey's HSD test revealed a highly significant difference between every two types of mouthwashes in both bracket types.

## DISCUSSION

The final results of orthodontic treatment depend to a large extent on how will the forces and the consequential reactions be controlled and whether sliding movements between brackets and archwires are required in orthodontics. Friction is created between the sliding surfaces and has a major impact on the force ultimately delivered to the teeth, therefore friction is considered as an important determining factor of the final outcome in orthodontics.<sup>22</sup>

According to Eliades and Brantley,<sup>23</sup> there are two methods used to determine the frictional properties of orthodontic archwires: first by measuring the roughness of the tested bracket's slot in addition to study morphology of the archwires surface prior and after the sliding on the brackets slot and, second by real simulation of sliding at a given distance using a mechanical testing machine (Instron) with custom-made assemblies under different bracket-wire engagement modes.

This study measured the frictional forces of two types of orthodontic brackets when exposed to various types of mouthwashes as plaque control measures using an Instron universal testing machine with the custom-made assembly in dry condition.

Although stainless steel brackets were widely tested regarding frictional forces, yet up to date, there was no former study determined which mouth rinse is the best when using gold-plated brackets during orthodontic treatment stages concerning these forces. In this study, two types of brackets were used: gold-plated brackets (stainless steel brackets plated with 24K gold of one piece) and Votion brackets (two pieces stainless steel). The brackets were immersed in mouthwash for 45 days, as this period represented approximately the period of contact between the brackets and mouthwash during two years of fixed orthodontic treatment.<sup>24</sup> The mouthwashes used were: chlorhexidine, aloe vera mouthwash with fluoride, aloe vera mouthwash without fluoride, and distilled water.

Static friction is the friction force component that must be overcome to initiate motion, it also can be defined as while kinetic friction is the component of friction that has to be overcome to maintain motion, or in other words, it is the force that resists motion during orthodontic tooth movement.<sup>4</sup> The determination of static and kinetic fric-

tion can be difficult and misleading because they are dynamically interrelated, especially at very low sliding velocity.<sup>25</sup>

From a clinical point of view, static friction is always greater than kinetic friction and is considered to be more important<sup>26</sup> as it is harder to change a body from its initial situation than to maintain it moving as a force is applied to an object; and since the merit of tooth movement along an archwire is a step-like series, static friction is considered to be more valuable than kinetic friction in orthodontics,<sup>22</sup> hence the static friction generated between the brackets and archwires during sliding movement was chosen to be measured in this study.

Concerning brackets types, gold-plated brackets showed higher frictional forces than stainless steel brackets in all immersed and control groups. In spite of the presence of the exterior protective gold layer which is plated originally on one piece casted steel bracket to enhance resistant to wear, chipping and peeling,<sup>27</sup> results elucidating that this layer was not stable under the mouth rinses being used in the present study.

In one recent study<sup>27</sup> that examined the ions release from stainless steel and gold-plated brackets after immersion in different herbal mouthwashes, no subtle pattern between bracket types and concentration of cations released could be seen, and consequently this could not be clear-cut cause and effect relationship, instead results might be due to the effect of cold working (bending, shearing, punching, etc.). A non-uniform deformation could be happened during the manufacturing process of gold-plated brackets, moreover; unequal cooling from high temperature lead to internal structure rearrangements involving volume change causing internal stress that may produce cracks of the outer protective layer, accelerating corrosion<sup>28</sup> and consequently increase the surface roughness which is a critical variable in determining friction since the smoothest surface is expected to yield the lowest friction and vice versa.<sup>1</sup>

In addition, strong adherence of the gold film to steel would produce shearing that naturally leads to a higher friction coefficient and shorter wear life,<sup>29</sup> furthermore; the presence of irregularities in the floor surface of the bracket's slot will increase the pressure applied by the arch wire onto the few small peaks (asperities) leading to abrasion throughout tooth sliding movements, so it is recommended that the materials of the brackets should have ample stiffness and hardness to defy the morphologic deformation associated with frictional forces through tooth sliding movements.<sup>30</sup>

Among gold-plated brackets subgroups, gold-plated brackets immersed in aloe vera with fluoride showed the lowest frictional forces making aloe vera with fluoride mouthwash to be the most recommended mouth rinse

with this bracket type. This was interesting since fluoride showed higher corrosive ability in previous studies<sup>24,27</sup> while the highest static friction was recorded in gold-plated brackets immersed in chlorhexidine group, this could be consistent with other researches describing the corrosive ability of chlorhexidine.<sup>24,31</sup>

Considering Votion brackets subgroups, the highest static friction was measured in aloe-vera mouthwash group. This is consistent with another study compared ion release among mouthwashes.<sup>27</sup> Aloe-Vera herb showed the highest manganese and copper ions which are considered as main components of stainless steel alloy, detecting surface corrosion of the metal and consequently increase surface roughness and friction. These results disagreed with Singh<sup>32</sup> who claimed that herbal mouth rinses showed inhibition efficiency of corrosion lied between 22% and 73% at different concentrations.

Contrary to other researchers<sup>33-35</sup> who claimed that fluoride-containing agents have fluoride ions and pH between 3.5 and 7 which may damage the oxidized layer formed on the steel surfaces and causes corrosion and roughness, the results of the current study revealed that adding Fluoride to Aloe Vera herbal mouth rinse (aloe vera with fluoride) significantly decreased the static frictional resistance, which might be due to the copious herbal ingredients of this mouth rinse. It consisted of 75 nutrients including vitamins, sugar, enzymes, lignin phenolic compounds, sterols, saponins, amino acids, salicylic acid and minerals such as Ca, Mn, Na, K, Cu, Mg, Z, Cr and Fe.<sup>36</sup> These variant substances may suppress the corrosive ability of fluoride anion by chemical combination of positively charged ions (cations) with negatively charged fluoride ion, so adding fluoride to herbal mouth rinse would have a positive impact on the final results of orthodontic treatment whether the brackets used are stainless steel or gold-plated.

The major limitation of the present study was being an in-vitro study and the laboratory data might not reflect the clinical situations regarding the effect of saliva, food, and beverages, etc., and yet, these data aimed to interpret comparatively the effect of different mouthwashes on the frictional properties of two types of orthodontic brackets.

## CONCLUSION

Based on the results of this study and considering frictional resistance during clinical practice, whenever sliding mechanics is needed using gold-plated brackets, the orthodontist should consider the use of fluoridated herbal mouth rinse. Chlorhexidine should be excluded because it exaggerated the frictional resistance that may impede or delay the required tooth movement. On the other hand, Chlorhexidine is the best mouth rinse if the brackets used

are votion stainless steel type, while herbal mouth rinse without fluoride (aloe vera mouthwash) is contraindicated.

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