***ISSN:* 1812–1217**

The Frictional Coefficient Comparison Between Stainless Steel And Beta– Titanium Arch wires Ligatured to the Stainless Steel Bracket Via Different Ligatures

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ABSTRACT

Aims: To compare the frictional coefficients between the stainless steel and B–titanium arch wire ligatured to the stainless steel bracket via different ligatures. **Materials and Methods:** The sample of the study included the stainless steel and *β*–Titanium arch wire groups, the wire group comprised of three subgroups, each wire subgroup ligatured to stainless steel brackets via different ligatures. The measurement of the frictional coefficient was performed using the simulated side arch fixed appliance attached to the tensile machine. The data were analyzed by using the descriptive and variance statistical tests at $p \leq 0.05$ significance level. **Results**: The results demonstrated that the stainless steel arch wire tied to the bracket via stainless steel ligature achieved significant lower frictional coefficient value when compared with other wire subgroups.
Conclusions: The combination of the stainless steel; arch wire, bracket and ligature is more practical choice in sliding orthodontic treatments.
Key Words: Frictional coefficient, stainless Steel, *β*–Titanium, elastic ligatures.

Obaidi HA, Al-Mukhatr AM. The Frictional Coefficient Comparison Between Stainless Steel And Beta– Titanium Arch wires Ligatured to the Stainless Steel Bracket Via Different Ligatures. *Al–Rafidain Dent J*. 2008; 8(1): 79–82.
Received: 26/3/2007 ***Sent to Referees***: 27/3/2007 ***Accepted for Publication:*** 6/6/2007

INTRODUCTION

Most fixed appliance techniques involve some degree of sliding between bracket and arch wire, whenever sliding occurs frictional resistance is encountered [(1)]. The frictional resistance is recognized by most clinicians to be very harmful to tooth movement [(2)].

Frictional resistance must be kept to the minimum during sliding movement so that orthodontic tooth movement can be generated through light optimum force [(3)]. If frictional forces are high, the efficiency of the system may be affected and the treatment time may be extended or the outcome may be compromised because of little tooth movement and/or loss of anchorage [(4)].

Straight–line traction with nonbinding sliding as shown in zero tip and torque brackets has demonstrated that frictional resistance generally increases respectively with arch wire selections of stainless steel, cobalt–chromium, nickel–titanium, and beta–titanium [(1,5,6)]. Interestingly, arch wire alloys of stainless steel, cobalt chromium, nickel–titanium, and beta – titanium have an increasing surface roughness characteristics in ascending order, which is believed to create higher frictional resistance [(7)].

Stainless steel brackets have lower frictional forces than ceramic brackets. It appears that metal brackets have smoother surfaces as compared with ceramic brackets [(8,9)].

Riley *et al*.,[(10)] showed that stainless steel ligatures produce greater friction than elastomers. In contrast, Frank and Nikolai [(11)] compared frictional resistances between elastomeric and stainless steel ligations and found no differences. other researchers [(12)] showed that elastomers induce greater friction than steel ligatures.

The reason behind these conflicting results may be attributed to the fact that the force produced by ligature wires is sensitive to the method used to apply the ligatures and may vary from zero to extremely high levels [1,13].

The aim of this study was to evaluate and compare the values of the frictional coefficient of the Stainless Steel and *β*–titanium ligatured to Stainless Steel brackets via stainless steel, elastomeric and Teflon coated.

MATERIALS AND METHODS

The sample comprised three groups of ligature material, each group has 20 ligatures, the first ,second and third groups were stainless steel, teflon coated and elastomeric ligatures respectively. 10 ligatures of each type were used in tying the stainless steel wire to the brackets, and the other 10 ligatures were used in tying *β*–titanium arch wire to the brackets. The arch wires used were rectangular wires (0.017" X 0.025"), while the brackets used were stainless steel brackets (upper right canines) with 0.022" X 0.030" slot dimension. All the experimental items are products of Dentaurum company, Isprengen, Germany.

The method used in this study is quoted from a previous work on the friction measurement carried out by other researchers [1,9,12,14]. The forces acting on the surface of the tooth root were simulated by single equivalent force acting at the center of resistance of the root [15].

The measurements of friction between bracket and arch wire were performed with the attached apparatus to the tensile testing machine (ZWEGLE F 140, Germany).

All tests were conducted under dry conditions at 29C° using a tensile testing machine with the crosshead moving downward at a speed of 0.5 mm/sec. An equation used by Tidy [1] was applied to calculate the coefficient of friction which is: $\mu = p\ w / 2\ f\ h$, were μ=coefficient of friction, p = friction (load cell readings minus the load suspended from the power arm), w = width of the bracket, f= load suspended from the power arm, and h = length of the power arm (distance from the center of the bracket to the center of resistance of a normal canine tooth root).

The statistics of the results included; the descriptive (mean, standard deviation, minimum and maximum values), the analysis of variance (ANOVA) and Duncan's Multiple Range Test at $P \leq 0.05$ significance level.

RESULTS

The descriptive statistics and the results of Duncan's Multiple Range Test for the static and kinetic frictional coefficients of the Stainless steel and *β* –titanium arch wires engaged in stainless steel brackets via the different ligature materials are demonstrated in Tables (1, 2, 3 and 4). The combination of the Stainless steel; arch wire, bracket and ligature wire disclosed significantly lower values as compared to the other combinations. Whereas; the combination of the *β*–titanium arch wire, stainless steel bracket and elastic ligature displayed significantly greater values of static and kinetic frictional coefficient when compared with other combinations.

Table (1):Descriptive statistics of the static frictional coefficient of the arch wires

Bracket material	Arch wire material	Ligature material	No	Mean	SD	Min	Max
Stainless Steel	Stainless Steel	Stainless Steel	10	0.117	0.009	0.105	0.135
		TEFLON coated	10	0.139	0.023	0.097	0.18
		Elastic ligature	10	0.188	0.014	0.172	0.219
	β–titanium	Stainless Steel	10	0.435	0.092	0.27	0.570
		TEFLON coated	10	0.361	0.034	0.33	0.435
		Elastic ligature	10	0.521	0.058	0.45	0.630

Table (2):Descriptive statistics of the kinetic frictional coefficient of the arch wires

Bracket material	Arch wire material	Ligature material	No	Mean	SD	Min	Max
Stainless Steel	**Stainless Steel**	StainlessSteel	10	0.124	0.011	0.27	0.570
		TEFLON coated	10	0.144	0.087	0.33	0.435
		Elastic ligature	10	0.200	0.018	0.45	0.630
	***β*–titanium**	Stainless Steel	10	0.465	0.1	0.111	0.660
		TEFLON coated	10	0.471	0.058	0.390	0.570
		Elastic ligature	10	0.583	0.072	0.435	0.705

Table (3):Duncan's statistics of the static frictional coefficient of the arch wires

Bracket material	Arch wire material	Ligature material	No	Mean	SD	Duncan's Analysis
Stainless Steel	**Stainless Steel**	Stainless Steel	10	0.117	0.009	**A**
		TEFLON coated	10	0.139	0.023	**A**
		Elastic ligature	10	0.188	0.014	**B**
	***β*–titanium**	Stainless Steel	10	0.435	0.092	**D**
		TEFLON coated	10	0.361	0.034	**C**
		Elastic ligature	10	0.521	0.058	**E**

ANOVA Test: F = 83.785 , P < 0.01; Different letters means significant difference.

Table (4): Duncan's statistics of the kinetic frictional coefficient of the arch wires

Bracket material	Arch wire material	Ligature material	No	Mean	SD	Duncan's Analysis
Stainless Steel	**Stainless Steel**	Stainless Steel	10	0.124	0.011	**A**
		TEFLON coated	10	0.144	0.087	**AB**
		Elastic ligature	10	0.200	0.018	**B**
	***β*–titanium**	Stainless Steel	10	0.465	0.1	**CD**
		TEFLON coated	10	0.471	0.058	**C**
		Elastic ligature	10	0.583	0.072	**E**

ANOVA Test: F= 76.765 , P < 0.01; Different letters means significant difference.

DISCUSSION

The results of this study expressed the superiority of stainless steel arch wire material over *β*–titanium. These results coordinate with the result of other studies which showed that *β*–titanium arch wire is typically associated with higher levels of friction when compared with Stainless steel arch wire [16–18], the reason behind this accordance between authors lies in two main scientific explanations: The First represents the older theory that was applied by the other researchers [18,19], who set the main reason to be the increased surface roughness of *β*–titanium wire as compared with Stainless steel arch wire, a theory that was later reinforced by scanning electron microscope and laser spectroscopic picture made by Kusy *et al*.,[18] and Wichelhous *et al*., [20] respectively, the microscopic examination of the wires before and after sliding indicated several surface differences between the wire materials. Stainless steel appeared initially to have a polished surface, but after sliding, it exhibited wear tracks. *β*–titanium wire had a considerably evident grain structure which was polished and worn by sliding.

The second explanation which was recently applied by other researchers [16,21] consider the surface roughness to be a minor contributor to the increase in friction of *β*–titanium wire as compared to Stainless steel wire, the main reason, as they concluded, is attributed to the adherence of the wire material to the surface of the bracket slot during sliding, although both Stainless steel and *β*–titanium arch wires tend to demonstrate adhesive wear, β–titanium wires exhibited more severe adhesion.

Kusy *et al*., [22] carried out a more detailed investigation on that line using an X–ray elemental analysis and concluded that cold welding (as a result of adhesion) caused particles of *β*–titanium wire to adhere to the Stainless steel brackets, the β–titanium arch wire oxide layer breaks down, reacts, adheres, and breaks away, resulting in a stick slip phenomenon.

A third possible explanation was applied by Thorstenson and Kusy [23] and Hayashi *et al*., [24] who assumed that the increase of frictional value of β–titanium over stainless steel wires might arise from the significant differences in their relative wire stiffness. The *β*–titanium wire at 42 % the stiffness of the Stainless steel wire, may be flexed with the bracket displacement and thus might require greater displacement to demonstrate a proportionately larger reduction in the sliding resistance.

CONCLUSIONS

The frictional coefficient of the stainless steel arch wire, bracket and ligature combination is highly preferable in orthodontic treatment.

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