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Assessment of Friction Among Nickel Free Orthodontic Brackets and Archwires Combinations in Wet Condition (An *In-vitro* Comparative Study)

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ABSTRACT

Background: Exposure to nickel-containing orthodontic appliances may cause intraoral or extraoral allergic reactions in patient with nickel-allergy. It is important to select a bracket and archwire combination that are nickel free and efficient during orthodontic treatment.

Objective: to evaluate the static and kinetic frictional force generated by two types of nickel free metal brackets and three types of nickel free archwires in wet condition.

Materials and Method: two types of brackets (cobalt chromium and nickel free stainless steel), coupled with three archwires (nickel free stainless steel, rhodium coated stainless steel, and titanium molybdenum) were used, ligated with conventional figure "O" elastomeric ligatures.

Friction of 6 bracket/archwire combinations was measured by (Instron) machine with presence of artificial saliva. Each bracket/wire was tested only once to eliminate the influence of wear. A new elastomeric ligature on each trial was used to minimize the influence of elastic deformation.

Independent t-test and ANOVA test, were used to statistically analyze the results at a 0.05 level of significant.

Results: there are a statistically significant difference in friction generation between the brackets and among the archwires.

Conclusion: the best bracket/archwire combination for the patients with nickel hypersensitivity are nickel free stainless-steel brackets with nickel free stainless steel archwire.

Keywords: Nickel hypersensitivity, Nickel allergy, Nickel free brackets, Nickel free archwires

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INTRODUCTION

Adverse reactions arising from fixed and removable orthodontic appliances use considered a concern for the orthodontists in the healthcare field [1], as most of these appliances comprise metallic alloys and the majority of these alloys contain nickel with amount ranging from 8% in stainless steel to more than 50% in the nickel-titanium alloys [2]. Nickel is considered an immunologic sensitizer that is strong in triggering an allergic reaction and it is the most common allergen than all other metals [2,3], therefore it may result in contact hypersensitivity which is the type IV delayed hypersensitivity reaction that occur at minimum 24 hours after the patient exposure [2,4].

The prevalence of nickel allergy is 1-3% in males and 10%-30% in females, the higher prevalence in females was related to the environmental exposure like the ear piercing [5] or wearing of jewelries [6].

The concerns about the biocompatibility from using these nickel alloys in the oral cavity for a prolonged period have encouraged studying an alternative material. Therefore, nickel-free, or stainless steels with a reduced amount of nickel have been used for the orthodontic treatment [7,8]. These materials considered as a hypoallergenic material made with low nickel concentration and have the ability of liberating minimum quantities of nickel ions, therefore they considered typical for patients with nickel hypersensitivity [4]. It is crucial to study the characteristic and behavior of these hypoallergenic materials to choose the better alternative to the conventional one.

One of these characteristic is the amount of friction generation; friction must be controlled during the orthodontic treatment because when the friction is high, the clinician should apply a higher mechanical forces in order to overcome this frictional force [9], besides, the application of high force in order to overcome the friction may cause an anchorage loss [10], and hence a negative effect on the outcome of the treatment and its duration [11].

For that reason this study was conducted to evaluate and compare the frictional force generated between different types of metallic nickel free orthodontic brackets and archwires to find which bracket/archwire combination generate the least amount of friction during orthodontic treatment, and hence, selecting the best combination for the patient with nickel allergy.

The null hypothesis is that there are no significant differences between the brackets and among the archwires in the amount of frictional force generation.

MATERIALS AND METHOD

Materials

Two types of nickel free metallic brackets for the upper right 1st premolars of slot size 0.022”x0.030” (Roth prescription) were investigated: 30 cobalt chromium brackets (Topic, Dentarum company, Germany), and 30 nickel free stainless steel brackets (Mini-Sprint, Forestadent company, Germany), coupled with three types of nickel free archwires with a gauge of 0.018” x 0.025”, the straight ends of the archwires were cut and used for the friction test as follows: 20 pieces of nickel free stainless steel archwires (Noninium®, Dentarum Company, Germany), 20 pieces of rhodium coated stainless steel archwires (Fantasia, IOS Company, USA), and 20 pieces of titanium molybdenum archwires (Rematitan® Special, Dentarum Company, Germany). The bracket/archwire combinations were ligated by the conventional elastomeric ligatures of round cross sections (metallic silver, medium size, Ortho Technology, USA).

Method

Preparation of the experimental blocks

Each bracket was fixed on a plastic block at a reproducible position (the intersection of two crossed scratches one horizontal and one vertical) and adhered by a cyanoacrylate adhesive agent to be used for the friction test. During the fixation, a straight stainless steel wire with a gauge of 0.021”x0.025” was used to align the brackets on that plastic blocks in order to eliminate the torque (the tip was already zero) as a factor affecting frictional force so that the bracket remain passive above the block.

Preparation of artificial saliva

For this study, the artificial saliva formula that had been used was the modified Carter’s solution with the following components and concentrations [12]: 0.7 g NaCl, 1.2 g KCl, 0.26 g Na_2HPO_4, 0.2 g K_2HPO_4, 1.5 g $NaHCO_3$, 0.33 g KSCN, 0.13 g, 1000 ml deionized water, and urea. The pH value of the artificial saliva was 6.75 ±0.15 (the pH value adjusted by using lactic acid and NaOH).

Grouping of the sample

In this study the friction had been assessed between six groups of bracket/archwire combinations as follows:

Cobalt chromium brackets- Nickel free stainless-steel wires.

Cobalt chromium brackets- Titanium molybdenium wires.

Cobalt chromium brackets- Rhodium coated stainless steel wires.

Nickel free stainless-steel brackets- Nickel free stainless-steel wires.

Nickel free stainless-steel brackets- Titanium molybdenium wires.

Nickel free stainless-steel brackets- Rhodium coated stainless steel wires.

The friction tests

For the assessment of friction, the Instron

H50KT Tinius Olsen testing machine with a load cell of 10 Newton was used. The test was carried out at room temperature ranged (20-21°C), the plastic block was clamped by the lower part of the machine which was fixed, while the wire was seated in the bracket slot and ligated by using elastic module and the free end of the wire was clamped by the load cell of the machine which was movable.

The wire was pulled through the bracket slot at distance of 5 mm with a speed of 5 mm per minute. In the meantime a plastic syringe was used to drip the artificial saliva (modified Carter's solution had been used) on the bracket/archwire combination during the friction test, with only 3 ml of saliva was dripped in each test for standardization.

The computer that connected to the testing machine displayed the frictional force by using QMat 4.53 T series software in the form of a force-distance graph that showed the peak force which represent the maximum frictional force (static friction), and the mean frictional force registered on every 0.75 mm distance of the tested wires (kinetic friction), and all the forces generated in Newton which then converted to grams by the following equation

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

Each of the 6 bracket/wire combinations had been tested 10 times, each bracket was tested only once, and each wire specimen was drawn through one bracket only to eliminate the influence of wear, besides, a new elastomeric ligature on each trial was used to minimize the influence of elastic deformation.

RESULTS

Statistical analysis for the data was done by using SPSS23 (Statistical Package of Social Science, version 23). The levels of significance for the statistical evaluation were: Non-significant difference NS $P>0.05$, significant difference S $0.05 \geq P>0.01$, highly significant difference HS $P\leq 0.01$, and the very highly significant difference VHS $P\leq 0.001$.

First, the normality of the data distribution was checked by Shapiro-Wilk test; the data were normally distributed; hence, parametric tests had been used as follows

Descriptive statistics

The descriptive statistics (means, standard deviations, minimum and maximum values) of the frictional force of each group presented in Table 1. The frictional force values of tested samples expressed in grams (g).

For the static friction

In both types of brackets the TMA wires had the highest mean value of friction force, while the nickel free stainless-steel wires had the least.

For the kinetic friction

In both types of brackets the TMA wires had the highest mean values of frictional force. While the rhodium wires had the least value when coupled with the cobalt chromium brackets, and nickel free stainless-steel wires had the least value when coupled with nickel free stainless-steel brackets.

Inferential statistics

Comparison between the brackets

As illustrated in Table 2; Independent t-test

Table 1: Descriptive statistics.

Brackets	Wires	No.	Mean	Std. Deviation	Minimum	Maximum
			Static Friction			
Co-Cr	Ni free SS	10	87.04	28.97	50.82	146.12
	TMA	10	146.72	21.94	99.59	170.61
	Rhodium	10	94.45	36.89	37.76	171.94
Ni free SS	Ni free SS	10	77.44	23.49	40.41	120.2
	TMA	10	105.34	33.25	38.78	164.69
	Rhodium	10	100.18	47.59	39.49	190.82
			Kinetic Friction			
Co-Cr	Ni free SS	10	110.15	35.69	66.62	187.06
	TMA	10	124.82	17.66	97.89	145.98
	Rhodium	10	80.88	30.59	30.83	129.69
Ni free SS	Ni free SS	10	78.32	28.65	31.02	128.78
	TMA	10	98.96	19.72	54.72	125.48
	Rhodium	10	78.76	33.47	28.1	115.89

Table 2: Independent t-test for comparison between the brackets.

Wires	t	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
Static/Ni free SS	0.814	.426 (NS)	9.6	-15.18	34.38
Static/TMA	3.286	.004 (S)	41.39	14.92	67.85
Static/Rhodium	-0.301	.767 (NS)	-5.73	-45.74	34.27
Kinetic/Ni free SS	2.2	.041 (S)	31.83	1.43	62.23
Kinetic/TMA	3.089	.006 (HS)	25.86	8.27	43.44
Kinetic/Rhodium	0.148	.884 (NS)	2.19	-28.01	32.25

Table 3: ANOVA test for comparison among wires that coupled with cobalt chromium brackets and nickel free SS brackets (static friction).

Brackets		Sum of Squares	Mean Square	F	Sig.
Co-Cr	Between Groups	21165.84	10582.92	11.84	0.000(VHS)
	Within Groups	24135.48	893.91		
Ni free SS	Between Groups	4407.27	2203.63	1.69	0.204(NS)
	Within Groups	35300.69	1307.43		

was used, the test showed a statistically highly significant difference between the two brackets in the mean values of both static and kinetic frictional force when coupled with TMA wires ($p \leq 0.001$), and a statically significant difference in static friction between the two brackets when coupled with the nickel free stainless steel wires ($p \leq 0.01$), as with both wires cobalt chromium brackets generated higher friction.

Comparison among the wires

First, Levene's test was performed to check the homogeneity of data; for the static friction, the data were homogenous, therefore, ANOVA test was used. While, for the kinetic friction; the data concerning the frictional force of the wires coupled with nickel free stainless-steel brackets were not homogenous, therefore, Welch test was used.

For the static friction

ANOVA test (Table 3) showed a very highly significant difference among the wires when coupled with the cobalt chromium brackets ($p \leq 0.001$), and according to the Post Hock Tukey's test (Table 4) the difference was between TMA wires and nickel free stainless steel wires ($p \leq 0.001$), and between TMA wires and rhodium wires (it was HS as the $p \leq 0.01$), in both situations, the TMA wires had the highest mean value (146.72 g).

For the kinetic friction

Welch test (Table 5) was used for the comparison among the wires that tested with nickel free stainless-steel brackets, and it showed a non-significant difference ($p > 0.05$). While, for the comparison among the wires coupled with cobalt chromium brackets; ANOVA test (Table 6) was performed (as the data were homogenous), and it showed a statistically highly significant difference among the wires ($p \leq 0.01$), as according to the Post Hock Tukey's test (Table 7) the difference was between the TMA and rhodium wires (it was HS as $p \leq 0.01$); as the TMA wires had the highest mean value (98.96 g).

Table 4: Post Hock Tukey's test (to investigate between which wires was the difference regarding the static friction).

Dependent Variable	Wires	Wires	Sig.
Co-Cr brackets	Ni free SS	TMA	0.000(VHS)
		Rhodium	0.845 (NS)
	TMA	Ni free SS	0.000 (VHS)
		Rhodium	0.002 (HS)
	Rhodium	Ni free SS	0.845 (NS)
		TMA	0.002 (HS)

Table 5: Welch test for comparison among the wires that coupled with nickel free SS brackets (kinetic friction).

Brackets	Statistica	Degree of freedom1	Degree of freedom2	Sig.
Ni free SS	2.336	2	17.074	0.127 (NS)

Table 6: ANOVA test for comparison among wires that coupled with cobalt chromium brackets (kinetic friction).

Brackets		Sum of Squares	Mean Square	F	Sig.
Co-Cr	Between Groups	10010.08	5005.04	5.955	0.007(HS)
	Within Groups	22693.72	840.51		
	Total	32703.8			

Table 7: Post Hock Tukey's test (to investigate between which wires was the difference regarding the kinetic friction).

Dependent Variable	Wires	Wires	Sig.
Co-Cr brackets	Ni free SS	TMA	0.503(NS)
		Rhodium	0.080(NS)
	TMA	Ni free SS	0.503(NS)
		Rhodium	0.006(HS)
	Rhodium	Ni free SS	0.080(NS)
		TMA	0.006(HS)

DISCUSSION

Nickel hypersensitivity is a serious condition that all of us may be faced in the orthodontic clinic upon the patient wear orthodontic appliances that have metallic parts contain nickel in their composition. Therefore, it is important to seek for an alternative metal with reduced or no nickel content to be used in these appliances but with the same efficiency of the conventional one. In regard to fixed orthodontic appliances, it is crucial to study the characteristic and behavior of their basic component which are the brackets and archwires (that can be safely used for patients with nickel allergy) in order to choose the better alternative to the conventional one.

One of these characteristic is the amount of friction generated by these component; in addition to what mentioned previously about the many adverse effects of increased frictional force, friction may affect the biocompatibility of the metallic components; as when the friction is heavy between the brackets and the archwire the wear of metallic surfaces will increase, and hence, increases the ion release that will induce the hypersensitivity. This effect may be less noticeable in the metals with highly reduced nickel content, but it is crucial for the coated metals that supposed to be safe for these patients like the rhodium coated archwires.

Comparison between the brackets

The results of this study showed a statistically significant difference in the generation of friction between the brackets, as the cobalt chromium brackets generate higher static and kinetic friction with all wires types (except for the static friction when coupled with rhodium wires) inspite of there was no statistically significant difference between them in the regard of their surface roughness according to the study by Obaid et al. [13].

This difference may be attributed to the difference in their designs, as the manufacturer of the nickel free stainless steel bracket claimed that this bracket manufactured with rounded slot edges that play a role in the reduction of the frictional force [14], as the contact of the archwire with the walls is reduced to only two points of contact. Additionally, it permits offsetting the contribution of the ligature elastic to the total friction as agreed with [15].

The second reason behind the lower friction of nickel free stainless steel bracket may be attributed to its width; as the nickel free stainless steel bracket is narrower (3.59mm) than cobalt chromium bracket (3.98mm), therefore, the area of surface contact between the archwire and the brackets is less. That is agreed with Pacheco et al. [16]. Besides, the stretching of the elastomeric ligature is less with the narrower brackets. This fact agreed with Kapila et al. [17] and Hain et al. [18].

The effect of bracket width on the amount of frictional force still a controversy in orthodontic; as there are studies in consistent with the present study reported that the amount of friction is directly proportional with the width of the bracket [16-18]. On the other hand, there are studies reported that the friction with the wider brackets is lower11,19. This was attributed according to Drescher et al. [11] and Tidy et al. [19] to the reduction of tipping with wider brackets, and hence reduction in binding and resistance to sliding. However, there are studies claimed that the friction does not affected by the width of the brackets [20,21].

Therefore, the null hypothesis is rejected, as there is a significant difference between the two brackets in regard to the amount of frictional force generation.

Comparison among the archwires

The results of friction test showed that both the static and kinetic friction with TMA wires is higher than the friction with the nickel free stainless steel wires and rhodium coated stainless steel wires when coupled with both cobalt chromium and nickel free stainless steel brackets. There are two scientific explanations to the increased friction with TMA wires:

The first explanation is the effect of the chemical composition of TMA wires; this attributed to the high titanium content of these wires, as they have 80% titanium in their content, and the increased content of titanium causes an increase in the surface reactivity of the alloy which make the wire to “cold-weld” itself in the brackets slots, and hence, make the sliding more difficult.

This explanation agreed with other studies [22,23]. This phenomenon is called “stick-slip” movement and happened mostly when the TMA wires coupled with the steel brackets. Kusy et al.

[22] reported after making an x-ray elemental analyses that the material of the TMA wires had been adhered to the bracket's slots, and hence, generate higher friction.

The second explanation which is the surface roughness of TMA wires; as TMA wires had the highest surface roughness when compared with nickel free stainless-steel wires and rhodium coated stainless steel wires [13]. Many studies in agreement with this study reported that TMA wires generated high friction because of their high surface roughness [24,25].

For the wire that generate the least amount of friction; is the nickel free stainless steel wire (except for the kinetic friction when it coupled with the cobalt chromium brackets), this may be attributed to the smoothness of this wire; as according to Obaid and AL-Dabagh et al. [13], this wire had the smoothest surface when compared with the TMA wires and rhodium coated stainless steel wires.

Therefore, the null hypothesis is rejected, as there is a significant difference among the three archwires in regard to the amount of frictional force generation.

Clinical consideration

In this study, two metallic brackets with traces amount of nickel were used; nickel free SS brackets generate lower friction than cobalt chromium brackets which give them the priority as a favorable alternative to the conventional brackets for nickel allergy patients. For the archwires, TMA wires showed higher friction than the other two wires which make them less desirable among the three wires. Inspite that most studies showed that TMA wires generate the higher amount of friction (regardless of the types of wires that TMA had been compared with), TMA wire was selected for this study to assess if the newer bracket material will produce a different result with them or not.

Whilst, nickel free SS wires generate low amount of friction when coupled with either brackets which make them the first choice and most favorable for the patient with nickel hypersensitivity. For rhodium coated SS wires; they were in the middle between the other two wires, their friction was lower than TMA wires but higher than nickel free SS wires and the same for, which make them the second choice for the patients with nickel allergy.

Strength of the study

Till now there is no previous study assesse and compare the frictional force that generated by the same materials that had been used in this study.

LIMITATION OF THE STUDY

As it is an in-vitro study, it is difficult to reproduce the actual oral conditions, like, the movement of the teeth inside the bone, the effect of muscular force and occlusal force, presence of calculus. As these various conditions have a considerable effect on the amount of the frictional force.

CONCLUSIONS

Nickel free SS brackets generate lower frictional force (static and kinetic) than the cobalt chromium brackets.

TMA archwires generate higher frictional force (static and kinetic) than both nickel free SS and rhodium coated SS archwires when coupled with both cobalt chromium and nickel free SS brackets, while nickel free SS archwires generate lower static friction.

As nickel free SS brackets generate lower friction than cobalt chromium one, and as the nickel free SS wires generate the lower amount of friction (static and kinetic) when coupled with this nickel free steel brackets; the best bracket/ archwire combination for the patients with nickel hypersensitivity is nickel free SS brackets coupled with nickel free SS archwires.

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