Bionatura
Latin American Journal of Biotechnology and Life Sciences

Bionatura Issue 4 Vol 8 No 1 2023

Article

Evaluation of frictional forces between aesthetic brackets and archwires in wet conditions (An in-vitro study)

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Available from: http://dx.doi.org/10.21931/RB/CSS/2023.08.04.29

Abstract: Frictional resistance occurs whenever sliding happens, negatively impacting treatment outcomes and duration. It is a clinical challenge and must be dealt with efficiently to achieve the best orthodontic results. Aims of this study: compare and evaluate the static frictional forces under the wet condition to mimic the oral environment produced by using a polycrystalline ceramic bracket, monocrystalline ceramic bracket, 0.014 of an inch nickel-titanium (Rhodium coated archwires, and ilusio aesthetic archwires), and 0.019 x 0.025 of an inch stainless steel (Rhodium coated archwires, and ilusio aesthetic archwires).

Ninety-six aesthetic brackets (48 monocrystalline and 48 polycrystalline brackets) were used and stored in different incubation media (distilled water and acid challenge); each 16 bracket-archwire combinations were tested 6 times by Instron testing machine under wet conditions.

Polycrystalline ceramic brackets combined with 0.014-inch NiTi rhodium-coated archwires produced significantly low mean static frictional force in an acidic environment. Furthermore, no significant mean static frictional forces difference between monocrystalline and polycrystalline ceramic brackets if combined with 0.014 of an inch NiTi ilusio or 0.019 x 0.025 of an inch SS rhodium coated archwires. Conclusion: Coupling polycrystalline ceramic brackets with 0.014 of an inch NiTi rhodium coated rather than ilusio archwires in an acidic environment is advisable. At the same time, it is wise to combine with polycrystalline ceramic brackets the 0.019 x 0.025 of an inch SS ilusio archwires in distilled water rather than to combine with monocrystalline brackets.

Keywords: friction, ceramic bracket, aesthetic archwire, wet condition, instron machine.

INTRODUCTION

The request aimed at esthetic orthodontic appliances is growing, and the progress of materials that existing standard esthetics aimed at the patient and a passable clinical routine for the clinician is desirable [1, 3]

The difficulty has been resolved by an overview of esthetic brackets prepared of ceramic or composite, which are attractive standard [2]**,** ceramic brackets currently prepared of alumina either in polycrystalline or monocrystalline systems [3]**.** Ceramic brackets now signify an esthetic alternate. While the use is narrow, they abrade the enamel, fracture simply, and have higher friction, growing resistance to sliding[4]**.**

An esthetic archwire is extremely wanted to counterpart esthetic bracket in clinical orthodontics[5]collected mostly of poly-tetrafluoro-ethylene to pretend tooth color [6]**.** Friction is the opposition to motions that occur when an object transfers tangentially in contrast to another [7]**.** Mechanotherapy connecting the brackets' movement compared to the wire, friction at the bracket-wire boundary may stop the realization of optimum force levels in the supporting tissues [8]**.** It suggested that about 50% of the force functional to slide a tooth was used to overcome the friction. One of the factors that affect frictional resistance includes the saliva [9]**.**

MATERIALS AND METHODS

Ninety-six brackets were used in this study, divided into forty-eight monocrystalline ceramic (sapphire) 0.022″ pre-adjusted Roth brackets (Pure, Ortho Technology, Tampa, Florida, USA) and forty-eight polycrystalline ceramic bracket 0.022″ pre-adjusted Roth bracket (Reflection, OrthoTechnolog, Tampa, Florida, USA), ligated with conventional elastomeric ligatures of round cross sections clear color (Clear Ligature Ties, Ortholine company, Arizona, USA)

Two different types of aesthetic archwires, rhodium coated archwire (Fantasia™, IOS company, Stafford, USA) and ilusio archwires (ilusio™, dp orthodontic company, Silsden, UK) with two different sizes of archwires (0.014 of an inch nickel titanium archwire and 0.019× 0.025 of an inch stainless steel wire) were used in combination with brackets and incubated in different incubation media.

Fabrication of the experimental blocks:

An experimental model was specially designed for this study; a large plastic block was cut by utilizing a Computerized Numerical Control laser cutting machine (CNC) [10]**,** and the block was cut into sixty small plastic blocks with dimensions of 30 mm length, 18 mm width, and 6 mm height.

Setting of the brackets:

A section of 0.0215″ ×0.025″ straight stainless steel archwire was used to align the bracket arranged the acrylic block [11-13]. This procedure would remove the tip and torque of brackets, as these factors could disturb the frictional resistance test [13]. The bracket was threatened by the archwire, which bent into an L-shape bend vertical to the bracket slot. The bend was to bear good grasping during fixation on an acrylic block and to guarantee that the bracket slot is parallel to the block surface and flawlessly passive[14]. The cyanoacrylate adhesive agent was used to adhere to all the brackets [15].

Grouping of the experimental models:

The plastic blocks were prepared into 16 groups according to the study groups. From each archwire, two straight portion segments were obtained from the distal ends with a length of 35 mm [16], getting a total of 96 sections (48 pieces for 0.014 of an inch nickel-titanium aesthetic wire and 48 pieces for 0.019× 0.025 of an inch stainless steel aesthetic wire. Sixteen groups were obtained according to bracket-archwire combinations to be prepared for the friction test.

Storage of the Samples:

The sample was divided into two groups rendering to the incubation media (distilled water storage and acid challenge group). In the distilled water storage group, the group of bracket-archwire combinations will be stored in the incubator at 37° C for 30 days with day-to-day refreshment [17], while before conducting the acidic challenge experiment, the bracket-archwire combinations of the second group were kept in distilled water by 37°C / 24 hours and the acidic solution (pH=2.5) of 500 ml was arranged by gradually adding 1.5 ml of HCl [1M] in distilled and the acidity of the solution was then tested using a digital pH-meter, for 30 days, all samples in this group were occupied in the acidic solution three times a day for five minutes each, with equal intervals of two hours between sessions. The samples were kept in distilled water (pH=6) at 37°C representing the rest of the day to simulate a wet oral environment [17].

Friction test:

The Instron H50KT Tinius Olsen testing machine was used in this study to assess friction; the machine's loading cell was 10 N. [18], as shown in Figure 1, and the machine's lower part (the fixed part) held the plastic block. In contrast, the upper part (the loading cell, which was the movable part) clamped the free end of the wire [19].

Figure 1: The loading cell

The data were entered into the computer connected to the machine after the fixation. The length of the wire was 35 mm [20], and the distance along which the archwire was dragged over the bracket slot was 5 mm at a speed of 5 mm/minute [21]. Meanwhile, during the friction test, distilled water was dripped onto the bracket-wire combination using a plastic syringe; only 3 ml/min of distilled water was dripped in each test for standardization [22], using QMat 4.53 T series software (Tinius Olsen, Horsham, USA). The computer associated with the testing machine displayed the frictional force in the formula of a force-distance graph, with static friction indicated by the first peak of the force. All of these forces were generated in Newton and, at that point, changed to grams using this equation:

Friction in gm = [Friction in N ÷ 9.8] x 1000 [23].

Each of the sixteen bracket/wire combinations was experienced six times, with a new bracket and wire used in each trial to avoid wear and new elastomeric ligatures used to reduce the stimulus of elastic deformation.

Statistical analysis:

Data were analyzed with SPSS (statistical package of social science), a One-way ANOVA test was used to relate the static frictional force between the different bracket-archwire combinations, and Tukey's HSD test was used to test any statistically significant difference between each two groups.

RESULTS

The data was distributed normally with P-values greater than 0.05. The descriptive statistics showed that in the distilled water group**,** as shown in Table 1 with both types of brackets (the monocrystalline and polycrystalline), The SS rhodium-coated archwires had the highest mean values of the static frictional force. In contrast, NiTi rhodium archwire had the least friction in both brackets. On the other hand, both SS ilusio and NiTi ilusio archwires with polycrystalline brackets showed intermediate mean static frictional force values.

	Bracket	**Archwire material**	**Archwire type**	**Descriptive statistics**					
				N	**Mean**	**SD.**	**SE.**	**Min.**	**Max.**
DW.	**Mono**	NiTi	Rhodium	6	62.742	17.026	6.951	45.060	83.770
			Ilusio	6	80.198	21.048	8.593	61.120	116.930
		SS	Rhodium	6	193.683	9.390	3.834	182.850	209.590
			Ilusio	6	170.937	43.423	17.727	109.440	223.850
	Poly	NiTi	Rhodium	6	70.463	14.067	5.743	49.740	91.320
			Ilusio	6	119.723	46.248	18.881	81.830	202.040
		SS	Rhodium	6	211.377	54.160	22.111	112.930	265.000
			Ilusio	6	115.593	8.768	3.580	107.510	129.790

Table 1: Descriptive statistics of distilled water's static frictional forces (gm)

In acid challenge group (table 2) it was found that SS rhodium and SS ilusio archwires had the highest mean values of the frictional force measurements of static frictional forces which were 197.5 gm ± 59.23 gm and 197.32gm ± 38.89 gm with monocrystalline bracket, while SS ilusio and SS rhodium archwires had intermediate mean values of frictional forces with polycrystalline bracket which were 174.49 gm ± 52.11 gm and 158.78 gm ± 26.82 gm, respectively.

	Bracket	**Archwire material**	**Archwire type**	**Descriptive statistics**					
				N	**Mean**	**SD.**	**SE.**	**Min.**	**Max.**
Acid	Mono	NiTi	Rhodium	6	93.063	20.359	8.312	70.380	127.100
			Ilusio	6	79.825	17.645	7.203	56.020	98.870
		SS	Rhodium	6	197.502	59.235	24.183	141.730	278.300
			Ilusio	6	197.325	38.888	15.876	136.630	250.000
	Poly	NiTi	Rhodium	6	74.628	16.965	6.926	46.990	95.810
			Ilusio	6	78.197	13.983	5.708	59.770	95.000
		SS	Rhodium	6	158.758	26.822	10.950	135.610	200.800
			Ilusio	6	174.495	52.111	21.274	121.320	260.100

Table 2: Descriptive statistics of an acidic medium's static frictional forces (gm).

In comparison, NiTi ilusio and NiTi rhodium archwires had the least mean values of frictional forces which were 79.82 gm ± 17.64 gm and 93.06 gm ± 20.36 gm, respectively with monocrystalline brackets, on the other hand the polycrystalline bracket with the NiTi ilusio and NiTi rhodium archwires had the least mean values of frictional forces which were 78.19 gm ± 13.98 gm and 74.62 gm ± 16.96 gm respectively.

The one-way analysis of variance on ranks (ANOVA) test used for comparison the mean static frictional difference amongst the groups, and it revealing that there was a non-significant difference on the mean static friction when combine the mono-crystalline brackets with 0.014 of an inch aesthetic NiTi archwires and 0.019 x 0.025 of an inch aesthetic SS archwires in different incubation media, and there were a significant differences between PNRD and PNID groups, and PNID and PNRA groups **(table 3)**, the test also divulged that there was a highly significant difference between polycrystalline brackets with SS rhodium archwires and ilusio SS archwire in distilled water medium, NiTi rhodium coated archwire had higher frictional force in acidic media than in distilled water media, while SS rhodium coated and NiTi ilusio had a non-significant difference when combined with both polycrystalline and monocrystalline bracket in different incubation media, the acidic medium had a non-significant difference on the mean frictional force with 14 of an inch NiTi bracket-archwire combinations **(table 4)** or with 0.019 x 0.025 of an inch SS bracket_arch wire combinations **(table 5)**.

Between groups	Mean Difference	p-value
PNRD-PNID	-49.260	0.021 (S)
PNRD-PNRA	-4.165	0.993 (NS)
PNRD-PNIA	-7.733	0.957 (NS)
PNID-PNRA	45.095	0.037 (S)
PNID-PNIA	41.527	0.060 (NS)
PNRA-PNIA	-3.568	0.995 (NS)

Table 3: Post-hoc Tukey's HSD test for the groups PNRD, PNID, PNRA, and PNIA.

Groups	Mean	F-test	p-value
MNRA	93.063	1.288	0.3059 (NS)
PNRA	74.628		
MNIA	79.825		
PNIA	78.197		

Table 4: ANOVA of mean static frictional difference for the groups MNRA, PNRA, MNIA, and PNIA.

Groups	Mean	F-test	p-value
MSRA	197.502	1.014	0.4073 (NS)
PSRA	158.758		
MSIA	197.325		
PSIA	174.495		

Table 5: ANOVA of mean static frictional difference for the groups MSRA, PSRA, MSIA, and PSIA.

DISCUSSION

The effect of distilled water:

The distilled water was used in the wet condition of this study in an attempt to simulate the oral cavity environment; in a previous in vitro study, distilled water has been used as a lubricant and as an adhesive, according to **Pratten et al. (1990)** [24], this was dependent on the loading force acting at the bracket-archwire areas of contact, because when the load was low (when there was a clearance between the brackets and the archwire), the distilled water would act as a lubricant, preventing tight contacts between surfaces [9-24,25] , therefore, decreasing the friction and this was highly affected by the type of ligation used as established by the study [26]**,** when the load was high, there was no clearance between the brackets and the archwire, the distilled water was pushed out of the areas of bracket-archwire contact, increasing friction because sliding in this case would be solely dependent on the surface characteristics of the tested materials, there would be a direct contact between the brackets and archwire; a similar situation occurred in our study, where high mean static frictional force values for PSRD and MSRD groups were observed, this fact could be established by many studies [22-25,27], conversely, studies have shown that distilled water aids in the reduction of frictional force [28-29]**,** similar results were found in our study, where mean static frictional force values for PSID and MSID were relatively low, despite a study finding that distilled water had no effect on frictional force [30]**,** these controversy could be due to different materials and methodology that were used between the studies.

The effect of acid challenge:

Various studies disagreed about the properties of acidity rate on the effectiveness and features of orthodontic alloys. Furthermore, [31] reported that higher acidity (lowering pH) increased elements released from the alloy, causing corrosion, which increased friction between wires and brackets, whereas [32] claimed that the acidity of the oral environment had no outcome on the properties of the alloy. The results of this study displayed that the MNRD group created significantly lower frictional forces than the MNRA group. This could be because the acidic-challenged archwire group had more surface irregularities, roughness, pitting, breakdown, and the highest static and kinetic frictional forces. As acidity increases, the tendency toward breakdown and surface roughness of orthodontic appliances increases, and friction tends to be highest for rough surfaces. These results were similar to a study [33], while disagreed with another [34]. Furthermore, in the existing study, the incubation of the wires in acidic media showed there were no significant differences in the mean static frictional force values between 0.019 x 0.025 of an inch SS rhodium coated or illusion archwires when combined with polycrystalline or monocrystalline ceramic brackets because all exhibited of relatively high mean static frictional force values.

The effect of the bracket's type:

The outcomes of the study exposed big diversity of discrepancy in the mean values of static frictional forces between monocrystalline and polycrystalline ceramic brackets when united with together 0.014″ NiTi and 0.019″ x 0.025″ SS (rhodium coated and ilusio) aesthetic archwires, with the polycrystalline brackets had the highest mean value of static friction produced in water storage group, this possibly will be added to the point that polycrystalline brackets had a greater coefficient of friction than monocrystalline brackets, this was due to their more porous surface and rougher [35], while the lowest mean value of static frictional force was generated by monocrystalline brackets in distilled water storage group, this might be attributed to the round slot of monocrystalline ceramic brackets as opposed to the sharp, rectangular slot of polycrystalline ceramic brackets, this was due to the progress of ceramic monocrystalline brackets with round, flatter slot surfaces and slot bases, which would decrease frictional resistance in distilled water storage medium[36]. The current study indicated that the PNRD group produced a significantly lower mean frictional force difference when compared with the PNID group. This might result from the interaction of complex material type properties difference between rhodium-coated archwires compared to ilusio archwires combined with polycrystalline bracket surface material that produced a lower frictional force. The current study also indicated that the PNID group produced a significant mean frictional force difference compared to the PNRA group. Besides, [37] initiated that friction of polycrystalline brackets slowly improved in distilled water because of corrosion; the highest mean frictional values were experimental in the monocrystalline brackets in acid medium. At the same time, they have flatter surfaces than the polycrystalline brackets. Studies advise that hard edges formed by the side of the intersection of the base and the slot's walls with the bracket's external surface can produce higher frictional values, agreeing with a study [38] but disagreeing with another [39].

The effect of the aesthetic archwire's type:

The results of the existing study shown that, there was a widespread range of variation in the mean values of static frictional forces among the different two archwires types (Rhodium and Ilusio), with the lowest mean value of static frictional force generated by 0.014″ NiTi rhodium coated archwire in both acid and distilled water groups, this could be due to that there was a lot of play between the 0.014″ NiTi coated archwire and the bracket slot, and the accumulated coating material in the bracket slot was not damaged enough during sliding to affect the frictional force; as the play between archwire and slot increases, less friction is generated [40], While the highest mean values of static frictional force were found in SS rhodium coated archwire in both acid and distilled water storage groups, this variance could be due to differences in archwire coating thickness; the rhodium coated wire was almost (0.5 µm) thicker than the true size ilusio archwire; this could have influenced the SS core diameter, which in turn influenced the frictional force value [41], The present study also indicated that PSID group produced a highly significant lower mean frictional forces when compared with MSIA group, this could be because lubricants like distilled water respond with the chromium oxide layer in SS alloys, providing the wire with a lower coefficient of friction, adapting the surface tension, and thus generating an adhesive effect; the outcomes of this study are constant with those of other studies [7-42].

The current study also revealed that MSRD and PSRD groups produced highly significant mean frictional forces when compared with the PSID group; this result might be that the rhodium-coated archwire produced higher frictional force compared with uncoating illusion archwire due to the thickness of the coating.

CONCLUSIONS

In an acidic environment, it is advisable to couple polycrystalline ceramic brackets, the 0.014 of an inch NiTi rhodium coated rather than ilusio archwires, because the ability of such combination to produce significantly low mean static frictional force than that with monocrystalline ceramic brackets.

In distilled water, it is wise to combine with polycrystalline ceramic brackets, the 0.019 x 0.025 of an inch SS ilusio archwires rather than to combine these wires with monocrystalline brackets because of highly significant mean static frictional force difference, therefore it might be to instruct the patient not to drink low pH beverages.

It would be prudent to combine with polycrystalline ceramic brackets, the 0.014 of an inch NiTi ilusio archwires, because of a significant low mean static frictional force difference, so instead, it would be to combine with such type of brackets, 0.014 of an inch NiTi rhodium coated archwires and the patient could drink beverages of low pH.

It would be desirable to combine with polycrystalline ceramic brackets, 0.019 x 0.025 of an inch SS ilusio archwires rather than to combine polycrystalline ceramic brackets with SS rhodium coated archwires because of the highly significant mean static frictional difference between such wires and the patient could not drink beverage of low pH with the first combination.

There is no significant difference between 0.014 of an inch NiTi or 0.019 x 0.025 of an inch SS aesthetic archwires (rhodium coated or ilusio) when combined with monocrystalline ceramic brackets in both distilled water and acidic medium.

There is no significant mean static frictional force difference between monocrystalline and polycrystalline ceramic brackets if combined with 0.014 of an inch NiTi ilusio or 0.019 x 0.025 of an inch SS rhodium coated archwires, and it might be no restriction to the patient in regarding beverages consumption pH variation.

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List of Abb.

MNRD: monocrystalline bracket with nickel titanium rhodium archwire in distilled water.
MNID: monocrystalline bracket with nickel titanium ilusio archwire in distilled water.
MSRD: monocrystalline bracket with stainless steel rodium archwire in distilled water.
MSID: monocrystalline bracket with stainless steel ilusio archwire in distilled water.
PNRD: polycrystalline bracket with nickel titanium rhodium archwire in distilled water.
PNID: polycrystalline bracket with nickel titanium ilusio archwire in distilled water.
PSRD: polycrystalline bracket with stainless steel rhodium archwire in distilled water.
PSID: polycrystalline bracket with stainless steel ilusio archwire in distilled water.
MNRA: monocrystalline bracket with nickel titanium rhodium archwire in acid.
MNIA: monocrystalline bracket with nickel titanium ilusio archwire in acid.
MSRA: monocrystalline bracket with stainless steel rhodium archwire in acid.
MSIA: monocrystalline bracket with stainless steel ilusio archwire in acid.
PNRA: polycrystalline bracket with nickel titanium rodium archwire in acid.
PNIA: polycrystalline bracket with nickel titanium ilusio archwire in acid.
PSRA: polycrystalline bracket with stainless steel rhodium archwire in acid.
PSIA: polycrystalline bracket with stainless steel ilusio archwire in acid

Received: May 15, 2023/ Accepted: June 10, 2023 / Published: June 15, 2023
Citation: Abdulsattar, A. M.; AL-Khatieeb, M. Evaluation of frictional forces between aesthetic brackets and archwires in wet condition (An in-vitro study). Revista Bionatura 2023;8 (2) 63. http://dx.doi.org/10.21931/RB/CSS/2023.08.04.29