Bionatura
Latin American Journal of Biotechnology and Life Sciences

Bionatura Issue 4 Vol 8 No 1 2023

Article

Evaluation of the effect of different toothpastes on the frictional resistance of aesthetic archwires: an in vitro study

Hussein Ali Mohammed Zekri[1,], Alan Issa Saleem[2], Abeer Basim Mahmood[3], Dina Hamid Obaid[4]*
[1,2,3,4] Department of Orthodontics, College of Dentistry, University of Baghdad, Iraq.
* *Correspondence: hussien_a2010@yahoo.com*
Available from: http://dx.doi.org/10.21931/RB/CSS/2023.08.04.27

ABSTRACT

there has been a trend for using aesthetic orthodontic treatment by many patients recently. The aim of this study was to evaluate the brushing effect of three brands of toothpaste on the frictional resistance of two brands of aesthetic archwires (in wet conditions). in this study, two brands of fully coated aesthetic archwires, Teflon-coated and Epoxy-coated archwires, were utilized in the study. Forty segments from the straight ends of each archwire were cut (total of 80 wires), inserted into ceramic brackets and ligated with the conventional figure "O" elastomeric ligatures (bonded on CNC blocks). Every ten pieces for each type of aesthetic archwire were brushed for one minute daily for thirty days with three types of toothpaste (Ortho. Kin, GUMOrtho and LACALUT White & Repair) and distilled water (except ten pieces for each type of aesthetic archwire were brushed only with distilled water and without toothpaste). These CNC blocks were tested using an Instron Tinius Olsen machine with distilled water. The tests used for statistical analysis were an Independent t-test and an ANOVA test at a 0.05 level of significance. The study showed no significant difference in static and kinetic frictional resistance between the coated archwire and the kinds of toothpaste. The orthodontists can use either Epoxy or Teflon-coated archwires for patients undergoing orthodontic treatment (working stage) who are using either type of toothpaste (Ortho. Kin, GUMOrtho or LACALUT White & Repair) for maintenance of oral hygiene.

Keywords: Aesthetic archwires, Friction, Toothpaste

INTRODUCTION

Brackets, bands, archwires and auxiliaries (elastic ligatures, elastic chains, etc.) are the main components of fixed orthodontic appliances that make them under the effect of biodegradation and ions release when placed inside the mouth of the patients, the most changeable parts in the fixed orthodontic appliance are archwires, as the orthodontists choose the required gauge and type in accordance to the stage of orthodontic treatment. Therefore, Nickel-Titanium and heat-activated archwires are utilized during the leveling and alignment stage, while stainless steel is utilized during working stages [1–2].

The metallic and silvery appearances of most orthodontic appliances are unaesthetic. Therefore, with the manufacturing of aesthetic brackets (composite and ceramic), the aesthetic problem is partially solved. However, conventional archwires also have an unaesthetic metallic appearance, and in order to overcome this aesthetic problem, several companies manufactured coated metallic and fiber-reinforced archwires [3–4].

Several previous studies found that the coating material is unendurable and could be damaged by the forces of mastication and enzyme activities inside the mouth. Moreover, this coating material might cleave and crack, showing the underlying metallic wire, and its color might change during orthodontic treatment [5–6].

An orthodontic sliding mechanic usually used to close spaces is formed by the motion of orthodontic brackets along the archwire or by archwire sliding through brackets and molar tubes. The frictional resistance from the contact between orthodontic brackets and archwires is considered the primary problem affecting sliding mechanics [7]. The amount of frictional resistance is higher when using plastic and ceramic brackets than when using metallic brackets [8]. The frequency of tooth brushing and the type of toothpaste used during brushing may affect the surface characteristics of the materials used in dentistry. These toothpastes usually have bleaching agents, fluoride, abrasive systems, certain pigments and other materials that aim to enhance the tooth quality. Different types of toothpaste (specially manufactured for orthodontic treatment) have been introduced to the markets that may affect orthodontic brackets and archwires [9–10]. For these reasons, this study was prepared in order to evaluate and compare the effect of brushing with different kinds of toothpaste on the frictional resistance between aesthetic (ceramic) brackets and aesthetic archwires (Epoxy and Teflon-coated archwires) to find which toothpaste generates the least amount of friction during sliding mechanics in a patient undergoing aesthetic orthodontic treatment.

The null hypothesis in this study is that there are no significant differences in frictional resistance between aesthetic brackets and aesthetic archwires after brushing with different types of toothpaste.

MATERIALS AND METHOD

160 pre-adjusted Roth type polycrystalline ceramic brackets (80 upper right 1st premolars and 80 upper right 2ed premolars) with slot dimensions 0.022"x0.028" inch, incorporating -7° torque and 0 angulation (DTC company, USA) coupled with two types of fully coated stainless steel archwires with a gauge of 0.019x0.025: 40 segments of epoxy coated stainless steel archwires (G&H Orthodontics, USA) and 40 segments of Teflon coated stainless steel archwires (DTC, USA). Conventional round cross sections of elastomeric ligatures

(medium size, clear, Ortho Technology, USA) were used for ligation of the bracket/archwire combinations. Three types of toothpaste were used: Ortho.KIN toothpaste (KIN company, Spain), GUM Ortho (GUM company, Spain) and LACALUT white& repair (LACALUT company, Germany).

Preparation of the experimental blocks

Every two ceramic brackets were fixed on the CNC blocks at a specific position (the point of intersection of two vertical lines with the horizontal line) and bonded by a cyanoacrylate adhesive agent for use during the brushing procedure. During this procedure of bonding, a straight stainless-steel wire with a gauge of 0.021"x0.025" was utilized to make sure that the brackets were properly aligned on the CNC blocks to eliminate the torque (the tip was already zero) so that the brackets remained passive (torque consider as a factor affecting frictional force).

Specimen preparation

The archwires were drawn from their package, and using a digital vernier, 35mm segments in length from the straight ends were measured and marked using a permanent marker. Then, the marked segments using a wire cutter were cut.

Grouping of the samples

This study had two main groups: 40 pieces of epoxy and 40 pieces of Teflon-coated archwires. Each group was brushed with three different toothpastes: 10 pieces Ortho. Kin, 10 pieces GUMOrtho, 10 pieces LACALUT White & Repair and 10 pieces control (brushing without toothpaste only with distilled water), as shown in Figure 1.

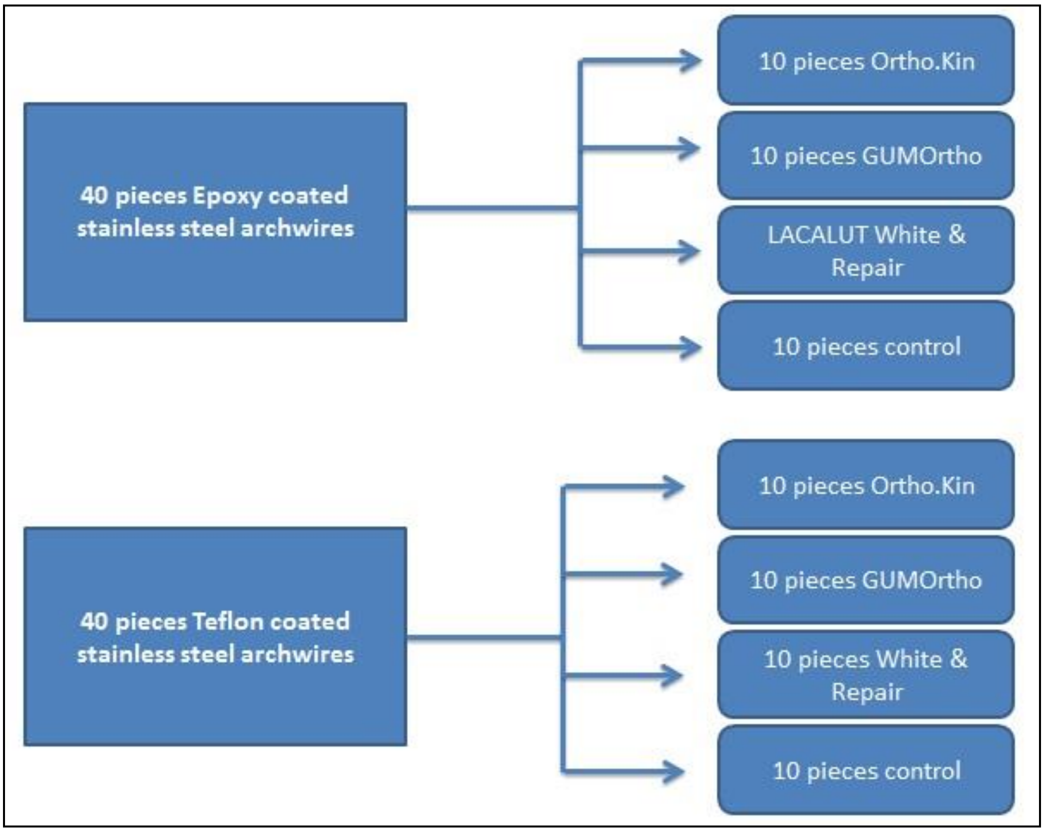

Figure 1: Sample grouping

Brushing procedure

Pea-sized (0.25g) amounts of toothpaste (0.75g for brushing 3 times daily) were used for each sample except for the control group without toothpaste. The soft-bristled rotary toothbrush was fixed at a constant distance by a special costume-made holder machine**.** This machine consists of a holder that holds the electric toothbrush with a number of screws used for loosening and tightening the handle of a toothbrush; at the center of the machine, there is a holder for the CNC blocks that can move at a constant speed right and left to resemble the hand motion during brushing of teeth, this right and left movement are guided by large screw that acts as a railway and powered by an electric motor. All these contents are contained within an aluminum frame that makes the machine very stable at the time of brushing. The electric toothbrush had a built-in feature in which a slight rocking happened within the toothbrush when 30 seconds elapsed, which was very helpful in calculating the brushing cycle.

Each block was brushed with (0.75g) and 3ml of distilled water for 1 minute daily for 30 days (equivalent to brushing two teeth for 20 seconds 3 times daily). The brushed block was left in touch with the toothpaste slurry for an extra 1 minute after brushing to improve toothpaste contact with the brackets and archwire. After that, the brushed block was rinsed with distilled water for 20 seconds (except for the control group brushed without toothpaste), then placed in the distilled water and kept in the pre-heated incubator at a constant temperature of 37°C. This brushing procedure was repeated daily for 1 month. One toothbrush was used for every 10 samples in each group. The electric toothbrush had a built-in feature in which a slight rocking happened within the toothbrush when 30 seconds elapsed, which was very helpful in calculating the brushing cycle. The load applied during brushing is standardized by the presence of a special sensor built into the electric toothbrush and indicated by the appearance of a red light, which is not acceptable pressure.

Friction test

After finishing the brushing procedure in 30 days, all the CNC blocks were collected for testing,

the **Instron** H50KT Tinius Olsen testing machine was used in this study, the loading cell of the machine was 10N. The lower part of that machine (which was already fixed) was used to hold the CNC blocks, while the upper part (the load cell, which is the movable part) was used to hold the free end of the wire. The data were entered into the computer, which was connected to the Instron machine; these data contained the wire length, which was 35mm, the load cell, which was 10N, and the distance along which the wire was pulled through the slot of the bracket, which was 5mm with a speed of 5mm/minute. The test was started after all the data had been entered, and the wire was pulled in the vertical direction by the upper part of the Instron machine (the load cell of the Instron machine) until a 5mm distance of the wire was pulled from the slot of the bracket**.** During testing a plastic syringe was utilized to drip the distilled water on the bracket/wire combination, 3ml/minute of distilled water was utilized in each test for standardization. At the lower part of the Instron machine, a piece of cotton was placed to prevent the distilled water from wetting the inner part of the Instron machine. The software QMat 4.53 T series was used in the computer connected to the Instron machine. This software was used to display the frictional force in the shape of force- a distance graph (the first peak of the fore represents the static friction, while, the kinetic friction is measured by calculating the mean of the fictional force that is recorded every 0.75mm distance from the graph. All the forces displayed in QMat 4.53 T software were in Newton after that transformed to grams by the equation:

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

RESULTS

The program SPSS26 (Statistical Package of Social Science, version 26) was utilized for statistical data analysis. The significance levels used for statistical evaluation: Non-significant difference $P>0.05$, significant difference $0.05 \geq P>0.01$.

Initially, the test used for checking the normality of data distribution was the Shapiro-Wilk test; the data were normally distributed; therefore, parametric tests were used as follows.

Descriptive statistics

The descriptive statistics (means, standard deviations, minimum and maximum values) of the frictional force for each group are presented in Tables 1 and 2. The frictional force values for the samples were expressed in grams (g).

For static friction

In both brands of coated archwires, brushing with KIN toothpaste produced the highest mean friction value, while brushing without toothpaste (control) had the least mean value of frictional force (Table 1).

Wires	Toothpaste	NO.	Mean	Std.Deviation	Minimum	maximum
Epoxy	KIN	10	591.47	61.07	422.53	730.62
	GUM	10	559.75	78.04	436.74	682.73
	LACALUT	10	560.16	49.65	467.35	649.03
	CONTROL	10	505.52	70.39	418.43	616.36
Teflon	KIN	10	603.36	93.31	453.11	738.85
	GUM	10	561.98	103.47	459.25	767.34
	LACALUT	10	589.91	105.64	441.88	796.92
	CONTROL	10	554.63	63.53	466.31	657.15

Table 1: Descriptive statistics of static friction (g)

For kinetic friction

Both brands of coated archwires brushing with KIN toothpaste produced the highest mean friction value while brushing without toothpaste (control) had the least mean value of frictional force (Table 2).

Wires	Toothpaste	NO.	Mean	Std.Deviation	Minimum	Maximum
poxy	KIN	10	529.93	76.67	423.51	648.03
	GUM	10	527.96	47.19	487.83	613.32
	LACALUT	10	512.48	64.21	439.84	641.83
	CONTROL	10	478.03	53.5	394.93	578.61
Teflon	KIN	10	592.15	107.67	442.94	768.42
	GUM	10	554.02	99.54	458.21	757.13
	LACALUT	10	569.62	90.46	441.89	753.18
	CONTROL	10	524.13	81.14	409.22	644.92

Table 2: Descriptive statistics of kinetic friction (g)

Inferential statistics

Comparison between the two wire types

Independent t-test showed no significant difference between epoxy and Teflon coated wires after brushing with the three types of toothpaste and without toothpaste (control) of both the static and kinetic frictional force **(Table 3).**

Type of friction	Toothpaste	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
STATIC	KIN	-1.462	18	0.161	-51.55	-125.64	22.54
	GUM	-0.055	18	0.957	-2.24	-88.35	83.86
	LACALUT	-0.807	12.79	0.434	-29.79	-109.68	50.08
	CONTROL	-1.636	18	0.119	-49.06	-112.06	13.94
KINETIC	KIN	-1.488	18	0.154	-62.18	-150.01	25.63
	GUM	-0.779	12.86	0.45	-27.14	-102.46	48.17
	LACALUT	-1.63	18	0.121	-57.16	-130.86	16.53
	CONTROL	-1.501	18	0.151	-46.12	-110.69	18.45

Table 3: Independent t-test for Comparison between the wires

Comparison among the toothpastes within the wire groups

In the beginning, Levene's test was used to check the homogeneity of data. This test showed that all data were homogenous for static and kinetic friction. Therefore, an ANOVA test was used.

3.3.3 For static friction

The ANOVA test showed no significant difference among the toothpastes within the wires groups (p>0.05) (Table 4).

WIRES		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
EPOXY	Between Groups	20463.35	3	6821.115	1.583	0.21
	Within Groups	155164.87	36	4310.135		
TEFLON	Between Groups	15856.41	3	5285.471	0.611	0.612
	Within Groups	311487.4	36	8652.427		

Table 4: ANOVA test for the Comparison among the toothpastes (static friction)

For kinetic friction

The ANOVA test showed no significant difference among the toothpastes within the wires groups (p>0.05) (Table 5).

WIRES		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
EPOXY	Between Groups	17330.35	3	5776.783	1.531	0.223
	Within Groups	135828.41	36	3773.011		
TEFLON	Between Groups	24402.32	3	8134.107	0.897	0.452
	Within Groups	326320.14	36	9064.448		

Table 5: ANOVA test for the Comparison among the toothpastes (kinetic friction)

DISCUSSION

Recently, patients seeking aesthetic orthodontic treatment have increased in number, which has made the orthodontic industries manufacture various types of aesthetic materials (brackets and archwires) [11]. In order to maintain good oral hygiene, patients should be instructed for daily brushing of their teeth with toothpaste [12]. Various types of toothpaste are available and manufactured by different companies, so it is important to know how brushing with toothpaste affects the frictional resistance of aesthetic archwires (coated archwires); for this reason, this study has been designed.

Using a wide slot size during sliding mechanics is more advantageous in reducing the frictional resistance, so this was the reason for choosing the 0.022x0.028-inch slot dimension in study [13]. However, the size of bracket slot 14 did not affect the amount of frictional resistance. The archwires that had been selected for this study were rectangular stainless steel archwires with a gauge of 0.019x0.025 inch, as the sliding mechanics and closure of spaces can be used by these archwires [15]. The wire pulling along the bracket slot by the Instron machine during testing was at the speed of 5 mm/minute**,** as previous studies showed there was no significant difference in testing of the friction when the speed ranged between 0.5 and 50mm/min [16].

An important factor that affects fiction is the type of ligation, as it can decrease the amount of friction and it can increase it. For standardization in this study, the elastic modulus were ligated in the conventional manner (figure "O" pattern), as there is a difficulty in load standardization created when using stainless steel ligatures and attaining a consistent ligation force even for trained clinicians [17]. Moreover, the choice of elastic modules was made to simulate the clinical conditions as they are the most common ligation type used in orthodontic treatments.

The orthodontic patients should brush their teeth 3 times daily and spend at least 10 seconds on each tooth [18]. In this study, each sample was brushed for 1 minute daily (equivalent to brushing two teeth for 20 seconds 3 times daily)

An electric toothbrush was used in this study as some previous studies found that this toothbrush was much better than using a manual toothbrush for plaque removal and reducing gingival inflammation [19].

This study used brushes with soft bristles, as they are better than medium or stiff bristles. Brushes with soft bristles are less traumatized on gingiva or root surfaces than medium or hard bristles**.** In addition, brushes with hard bristles have less flexibility than soft ones and do not clean the line angles of the teeth efficiently like the brushes with soft bristles [20–21].

The use of one toothbrush for every 10 samples for each group in this study, as the manufacturer of the toothbrushes recommended the replacement of toothbrushes after 2-3 months (this period is approximately equal to the period of brushing 10 samples for 10 minutes daily in 30 days) [22–23].

In this study, the result showed that there was no significant difference in the frictional resistance between epoxy and Teflon-coated archwires following the brushing with the 3 types of toothpaste (Ortho. Kin, GUMOrtho and LACALUT White & Repair) and also following the brushing without toothpaste (control) for both static and kinetic frictional resistance as illustrated in Table 2, this is agreed with the findings of [24–25].

However, the Teflon-coated archwires showed slightly higher mean values following brushing with all the 3 types of toothpaste (Ortho. Kin, GUMOrtho and LACALUT White & Repair) and even following brushing without toothpaste (control) than epoxy epoxy-coated archwires of both static and kinetic frictional resistance.

This study revealed that the frictional resistance (both static and kinetic frictional resistance) after brushing with toothpaste (Ortho. Kin, GUMOrtho and LACALUT white and repair) was approximately similar to the control subgroups (brushing without toothpaste) for both brands of aesthetic archwires (Teflon and Epoxy) (showed no significant difference).

The fluoride contents for the utilized toothpaste differed (1450 ppm for Ortho. Kin, 1490 ppm for GUM ortho and 1360 ppm for LACALUT White & Repair). This may lead to the conclusion that fluoride contents do not affect the frictional resistance between aesthetic archwires and brackets. This is agreed with the findings of [26–27].

The Ortho. Kin and GUM ortho toothpastes contain cetylpyridinium chloride (CPC), while LACALUT White & Repair toothpastes do not. Therefore, cetylpyridinium chloride (CPC) material does not affect the frictional resistance between aesthetic archwires and brackets. Moreover, LACALUT White & Repair kinds of toothpaste contains hydroxyapatite crystals and whitening agents, while Ortho. Kin and GUM ortho toothpaste do not contain these materials. Therefore, hydroxyapatite crystals and the whitening agents do not affect the frictional resistance between aesthetic archwires and aesthetic brackets. We did not find supporting data in the literature to confirm the above conclusions (that should be noted); thus, further studies are required. However, the brushing with Ortho. Kin toothpaste generated slightly higher mean static and kinetic frictional resistance values for Epoxy and Teflon-coated aesthetic archwires.

Limitations of the study

1. Like other in vitro studies, this study could not represent what happened clinically nor simulate the natural oral environment, so it remains out from the effect of the oral environment (such as the presence of saliva, PH variation, plaque, food debris, oral bacterial flora, calculus and others) on the surface characteristics of utilized materials and the amount of friction that produced during the orthodontic treatment.
2. Few previous studies regarding the effect of different kinds of toothpaste on the frictional resistance of aesthetic archwires limit comparisons.

Conclusion

Under the conditions of the present study and according to its findings, it can be concluded that:

1- There is no difference between Epoxy and Teflon-coated aesthetic stainless steel archwires (in frictional resistance) after teeth brushing (with and without toothpaste).

2- There is no difference between any types of toothpaste (Ortho. Kin, GUMOrtho or LACALUT White & Repair) on the frictional resistance of Epoxy and Teflon-coated aesthetic stainless steel archwires.

Funding

The study was self-funded

Acknowledgments

A special thanks to LACALUT IRAQ for supporting my research work.

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Received: May 15, 2023/ Accepted: June 10, 2023 / Published: June 15, 2023
Citation: Zekri, H. A., Saleem., A. I., Mahmood. A. B., Obaid, D. H. Evaluation the effect of different toothpastes on the frictional resistance of aesthetic archwires: an in vitro study. Revista Bionatura 2023;8 (2) 63. http://dx.doi.org/10.21931/RB/CSS/2023.08.04.27