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Frictional Resistance of Self Ligating Versus Conventional Brackets in Wet Environment: Effects of Arch-Wire Cross Section and Alloy

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Abstract

Introduction: This study aimed to measure and compare the frictional resistance generated by 4 bracket types (Gemini, Smartclip, Clarity advanced & clarity sl) in combination with 3 different wire alloys (stainless steel, nickel titanium, and beta-titanium) of 3 different cross-sections (0.016, 0.017 × 0.025, and 0.019 × 0.025 inch) in wet environment.

Methods: Four types of pre adjusted edgewise MBT Maxillary canine brackets with 0.022 x 0.028 –inch slot is used. A total of 324 bracket-wire samples were studied in presence of artificial saliva and for each test, new bracket and archwire assembly is used. Frictional resistance is measured using universal testing machine at 0˚ angulation. The data were analyzed statistically using ANOVA test followed by post hoc Tukey test.

Results: Self ligating stainless steel brackets (Smart clip) shows the least frictional resistance followed ceramic self ligating (Clarity SL), conventional stainless steel (Gemini) and ceramic brackets (Clarity advanced). Beta titanium archwire shows higher frictional resistance than nickel titanium and stainless steel archwire. Irrespective of bracket type and archwire alloy 0.016 inch archwire shows least frictional resistance followed by 0.017 × 0.025, and 0.019 × 0.025 inch archwire.

Conclusion: Self ligating bracket possess lower frictional resistance than conventional brackets**.**

Keywords: Friction, Brackets, Archwire size, Archwire alloy

Introduction

In mid-1930, Stolzenberg introduced the first self ligating bracket, Russell attachment.[1] These brackets do not need ligature, it consists of trap door mechanism to hold the arch wire in place. Self ligating brackets can be divided into 2 types- active and passive, depending on their mechanism of closure.[2]Active self-ligating brackets has spring clip that create pressure against the archwire while there is a slide in passive self-ligating brackets which allows archwire to move freely inside the slot lumen as it exerts no pressure against the archwire and it is even claimed that passive self ligating brackets generates less friction than active ones.[3] In recent years there is increased use of self-ligating brackets as several declarations have been made about their advantages over conventional brackets system. They have been reported to have less frictional resistances during sliding mechanics and needed less chair-side assistance. The literature review shows that friction is influenced mostly by the nature of ligation[4] and there is a significant decline in frictional resistance for self-ligating brackets, in comparison to conventional bracket designs.

Friction is the tangential force that resists or retards the relative motion of two objects in contact. In orthodontic literature there are numerous variables that affects the level of friction at bracket –archwire interface like wire and bracket materials, bracket slot width ,surface conditions of archwires and, wire section, interbracket distance, torque at the wire-bracket interface, type and force of ligation, use of self-ligating brackets, influence of oral functions and saliva.[5-6]

Higher level of frictional resistance is a clinical challenge to orthodontists as it decreases the effectiveness of the mechanics and tooth movement efficiency, because a large amount of force applied by the orthodontist is wasted to overcome friction instead of tooth movement. Maximizing reproducibility and efficiency of the appliance, is the best solution is to control friction as it is not likely to get rid of from materials in the near future.[7] Efficiency refers to the percentage of force delivered with respect to the force applied and reproducibility refers to the ability of the practitioner to activate a wire so that a wire-bracket couple will behave in a predictable manner.[7] The frictional force will decrease as the efficiency increases and hence the amount of force that is delivered to tooth will resemble more closely to the force that is applied to them.

Previously numerous studies[8-10] have been done to investigate the friction between bracket and archwire but they have used dry conditions with no lubrication, condition that is different from the clinical situation. To study friction between brackets and wire it is necessary that the experimental conditions should be as similar as possible to clinical situation. Therefore to better reproduce the clinical scenario artificial saliva can be used in experiment.[11]

Therefore, the aim of this study is to compare the frictional forces in wet environment generated by 4 types of brackets (Gemini, smartclip, clarity advanced & clarity sl) in combination with 3 different wire alloys (stainless steel, nickel titanium, and beta-titanium) of 3 different cross-sections (0.016, 0.017 × 0.025, and 0.019 × 0.025 inch).

Materials And Methods

Four types of pre adjusted edgewise MBT Maxillary canine brackets[12] (3M Unitek) with 0.022 x 0.028 –inch slot were tested: conventional stainless steel (3M-Unitek, Gemini™ Series), stainless steel self-ligating (3M-Unitek, Smart clip™ Series), conventional ceramic (3M-Unitek, Clarity Advanced™ Series), Ceramic self-ligating (3M-Unitek, Clarity - SL™ Series). Three types of orthodontic wire alloys were tested: stainless steel (True Arch Stainless steel™ Ormco), Nickel Titanium (True Arch Ni-Ti™ SDS Ormco), and Beta Titanium (TMA™, SDS Ormco). All the brackets were tested with each type of wire alloy in 3 different cross sections: 0.016, 0.017 × 0.025, and 0.019 × 0.025 inch. The sample size was calculated using the formula:

$n = [(Z_{1-\alpha})\sigma]^2/L^2$,

Where power of the study is 80%, 'Z' is the two-sided Z value for 95% confident interval which is equal to 1.96, 'σ' is the standard deviation & 'L' is the level of precision. The results showed that a minimum of 9 evaluations were needed in each bracket arch wire combination. A total of 324 bracket-wire samples were investigated [Table 1].

For conventional brackets, a stainless steel ligature wire (Libral Traders Pvt. Ltd.) of thickness 0.008-inch was used. For simulating the clinical procedure of tying stainless steel ligatures, it was turned seven times by Mathieu plier and then insert under the bracket. If ligature was turned more than seven times, it will result in wire turning on itself.[13] To replicate the oral environment artificial saliva (WET MOUTH™ from ICPA Pharmaceuticals Ltd) was dripped at a rate of 1ml/min on bracket archwire set up from a syringe.[14]

The friction generated by the testing unit was measured with a universal testing machine Model no. 1135. The frictional forces were recorded generated from the 2 types of ligation systems at zero degree angulation by sliding the wire into the aligned brackets. The testing unit consists of fixtures used to hold the test specimen during test and allows for bracket/wire linear and rotational movement. 50mm length of straight arch wire[13] is used and ligated passively with stainless steel ligature for conventional brackets and for self-ligating brackets by closing the cap. The machine applied a linear force on the arch wire bracket combination for pulling the wire out of bracket by maintaining crosshead speed at 4mm/min for 2 minutes.[15] The bracket and wire assembly was replaced with a new one after each test. 9 non repeated evaluations were done for each wire-bracket combination. Each wire specimen was drawn through 1 bracket only and each bracket was tested only once so as to eliminate the effect of wear. The load cell registered the amount of force required to move the arch wire along the bracket slot. This was electronically transmitted to the computer and recorded graphically. It records the movement of bracket in millimeters per second and frictional force values between bracket and archwire in newton (N). At the end of 2 minutes, the mean frictional readings were noted down as the frictional force between the bracket and arch wire alloy except the initial peak of movement.

Statistical Analysis

SPSS version 20.0 is used for analyzing the data. Distribution of the variables was evaluated with Shapiro wilk test, which showed the normal distribution of data. Mean and standard deviation is calculated for changes in the frictional force value of each bracket wire combination. As data is normally distributed ANOVA with post-hoc Tukey test is used to compare effect of bracket type, archwire alloy, and section on the frictional resistance. The significance level was set at $P < .05$.

Results

The descriptive statistics including mean, standard deviation and F value of frictional forces for each bracket-archwire combination are shown in [Table 2] and interaction between different bracket and arch wire combination with 95% confidence interval in [fig 1].

Analysis of frictional forces by bracket type

The mean values of frictional force among the bracket types using various arch wire alloy/size combinations in wet state tested by ANOVA and post hoc Tukey test shows results are statistically significant ($P < 0.001$). Stainless steel self ligating brackets (Smart Clip) shows the lowest frictional forces for all arch wire alloy/size combinations with values ranging from 3.04444 ± .229734 to 19.06667 ± .951315 N. The second lowest frictional force values was shown by ceramic self ligating brackets(Clarity SL) with values ranging from 4.55556 ± .287711 to 21.11111 ± .584047 N. The conventional stainless steel (Gemini) and conventional ceramic (Clarity advanced) brackets shows the highest frictional forces. The frictional forces values for conventional stainless steel (Gemini) were in range of 5.25556 ± .466667 to 38.98889 ± .648931 N and values for conventional ceramic (Clarity advanced) brackets range from 9.13333 ± .696419 to 34.83333 ± .543139 N.

Analysis of frictional forces by arch wire alloy

Among the three arch wire alloys compared in this study stainless steel arch wire shows the lowest frictional force value and highest by TMA arch wire for all combinations. While comparing frictional forces individually for SS, NiTi, and TMA arch wires with different brackets combinations, the SS arch wire shows the lowest frictional force values for Stainless steel self ligating brackets (Smart Clip) with value 3.04444 ± .229734 N and highest for conventional ceramic (Clarity advanced) brackets with value 27.48889 ± .671648 N. The NiTi arch wire shows the lowest frictional force values for Stainless steel self ligating brackets (Smart Clip) 4.31111 ± .388730 and highest for conventional ceramic (Clarity advanced) brackets with value 32.92222 ± .599537 N. The TMA arch wire shows the lowest frictional force values for Stainless steel self ligating brackets (Smart Clip) with value 5.43333 ± .830662 N and highest for conventional stainless steel brackets(Gemini) with value 38.98889 ± .648931N [Table 3, Fig 2] . ANOVA and post hoc Tukey test results shows that the mean values of frictional force among the arch wire alloy using various brackets and arch wire size combinations in wet state are statistically significant ($P < 0.001$) except for NiTi and TMA in clarity SL bracket for 0.016 inch wire.

Analysis of frictional forces by arch wire size

For all bracket wire combinations the 0.016 inch arch wire shows the lowest frictional forces values among the three arch wire sizes compared and highest by the 0.019x0.025 inch arch wire. While comparing frictional forces individually for three arch wires sizes with different bracket and arch wire alloy combinations, the lowest frictional forces value for 0.016 inch arch wire is 3.04444 ± .229734 N in combination with Smart clip bracket and SS arch wire alloy and highest value is 15.15556 ± .487625 N in combination with Clarity advanced bracket and TMA arch wire alloy. The lowest frictional forces value for 0.017x0.025 inch arch wire is 5.02222 ± .281859 N in combination with Smart clip bracket and SS arch wire alloy and highest value is 27.97778 ± .481606 N in combination with Gemini bracket and TMA arch wire alloy. The 0.019x0.025 inch arch wire shows the lowest frictional values with Smart clip bracket and SS arch wire alloy that is 7.73333 ± .278388 N and highest in combination with Gemini bracket and TMA arch wire alloy with value 38.98889 ± .543139 N. The mean frictional forces values of 4 bracket type depending on arch wire size tested is given in [table 4, Fig 3].

Discussion

For rapid tooth movement and optimal tissue response, proper magnitude of force during orthodontic tooth movement is needed and friction leads to decrease in amount of force actually received by a tooth.[16] Thus, larger forces are needed for movement of tooth having high magnitude of friction compared with one having less frictional force values. Quinn and Yoshikawa[17] in their study conclude that rate of tooth movement rise up to a certain limit only as forces increases, but after some time increment in force leads to no appreciable increases in movement of tooth. Hence conclude that tooth movement take place more effectively at an optimal range of forces. Therefore, it is important to understand frictional forces between bracket and arch wire so that the appropriate magnitude of force can be used for appropriate movement of tooth and optimum biologic response.

Present study shows that for all bracket and wire combinations stainless steel self ligating brackets has least mean frictional resistance during sliding mechanics while frictional resistances of Conventional ceramic bracket was highest of the four bracket systems compared. Sims et al[18] and Shivapuja et al[19] evaluated the frictional resistance between conventional ligating and self-ligating bracket system and found results similar to our study that self ligating brackets possess lower frictional resistance value and additional benefit of reduction in arch wire insertion and removal time which addresses both economic and ergonomic considerations. Turnbull and Birnie[20] shows that average time saved with self ligating brackets per patient were nearly 1.5 minutes of clinical activity. Conventional method of ligation using stainless steel ligature wires or polymeric O-rings press the archwire to the bottom of slot by applying force thus increases friction[21] while passive self ligating brackets create a fourth mobile wall which allow free movement of wire inside the bracket resulting reduced friction.[22] Our findings agree with several previous studies which concluded that stainless steel self ligating bracket possess low frictional resistance than conventional stainless steel bracket[23,24] and ceramic brackets possess higher frictional resistance than stainless steel brackets.[25,26] Lower surface roughness of stainless steel brackets is appreciable in scanning electron micrographs images which is a possible reason for their low frictional resistance.[26] Conversely Fleming and O'Brien[27] in his study cited nine randomized clinical trials and two systematic reviews concluded that there is no finding either in overall treatment or phase I of therapy, the self-ligating brackets leads to enhanced efficiency. A Systemic review by Chen et al[2] shows that there is no significant differences in occlusal characteristics or in treatment time between self ligating and conventional brackets, only 1.5˚ less proclination of mandibular incisors is seen with self ligating brackets.

Our study results show that there is increase in frictional force values as the wire size increases for all bracket and wire combinations. In addition round wire generate less frictional forces than rectangular wires. The mean frictional values of 0.019 × 0.025 inch archwire is highest followed by 0.017 × 0.025 inch and then by 0.016 wire sizes for the three arch wire size compared. The findings of our study are agreed to the previous studies finding that frictional forces increase as the diameter of wires increases, and it is smaller for round wires than rectangular wires.[16,28-36] In larger wires there is increase in bracket-wire interface which affects the frictional force values.[1] While in 1991 Bednar[37] al concluded that with increase in wire size, friction increases for stainless steel brackets and decreases for ceramic brackets.

The present study results shows that Beta-titanium archwires produced the highest friction in all three sizes for all bracket type followed by nickel-titanium archwires and then by stainless steel wires, with the difference between them being statistically significant. Our results are in agreement with several previous studies[6,13,25,34,38] which states that frictional resistances of stainless steel wires are lower than nickel-titanium and beta titanium wires. However, in a study conducted by Loftus et al[39] and Cacciafesta et al[40], they concluded that frictional resistance of beta titanium wire is highest but there is no significant difference between nickel titanium and stainless steel arch wire frictional resistance. Bazakidou et al[13] observed that nickel-titanium possess more friction than beta-titanium while Prososki et al[41] concluded that nickel-titanium provides lower frictional forces values, followed by stainless steel and then beta-titanium wires The differences between the studies might be due to different experimental set ups, presence of artificial or natural saliva, different angulation between bracket and arch wire.

In this study carboxymethylcellulose (CMC) based artificial saliva was used for simulating the clinical scenario, as concluded by Leal et al[42] that mucin and CMC-based artificial saliva is a reliable substitute of human saliva. Using artificial saliva also eliminate the need of saliva donor and chances of contamination. Ligation for all conventional brackets was done by one investigator, according to standardized procedure for minimizing the bias

However, the selection of wires and brackets should be based on clinical needs. Like larger amount of frictional forces is needed for expression of torque in brackets or in finishing and detailing but may be undesirable for leveling and aligning stages of treatment and smaller amount of frictional forces is needed during leveling and aligning but may be undesirable for expressing torque in the bracket or achieving other goals of finishing and detailing.[9]

Conclusion

1. Frictional forces of self ligating brackets are lower than the conventional brackets and stainless steel brackets possess lower frictional forces than ceramic brackets.
2. Frictional forces increase as the diameter of wire increases and are smaller for round wires than rectangular wires.
3. Beta titanium wires shows highest frictional resistance and lowest by stainless steel archwire.

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Figure Legends

Fig. 1: Friction mean and SD of all bracket-alloy for 3 wire section tested with 95% confidence interval

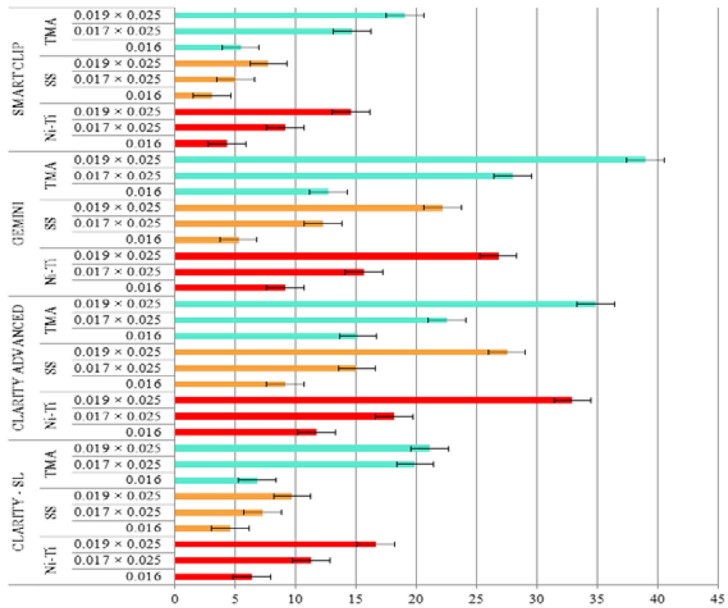

Fig. 2: Radar chart showing mean frictional forces values (N) for 4 bracket type depending on arch wire alloy tested

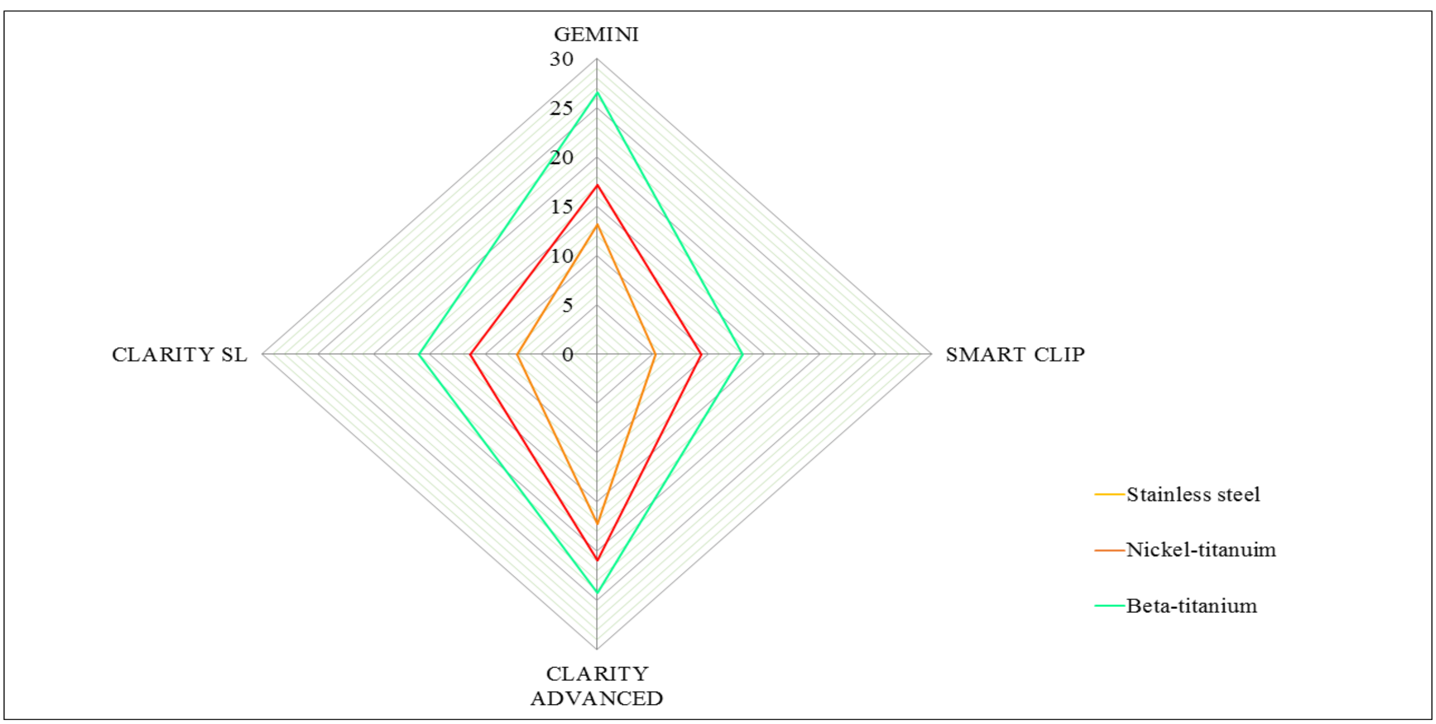

Fig. 3: Radar chart showing mean frictional forces values (N) for 4 bracket type depending on arch wire size tested

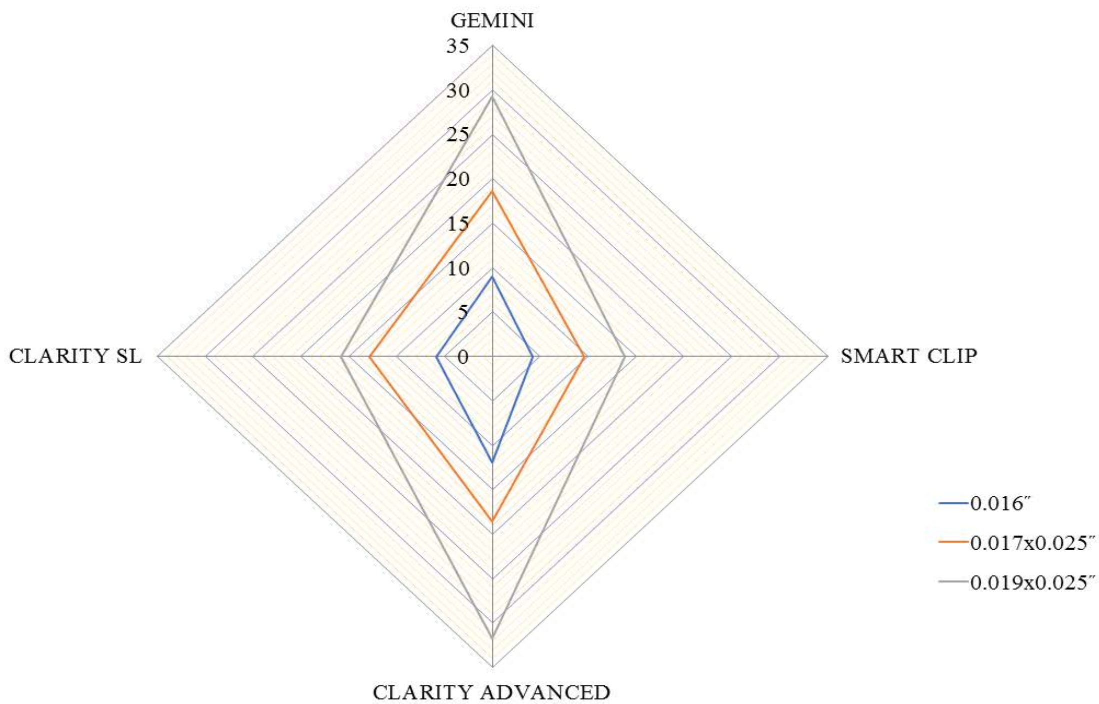

Table 1: Study Design

Brackets	Stainless steel (SS)			Nickel Titanium (NITI)			Beta Titanium (TMA)		
	.016	.017 × .025	.019 × .025	.016	.017 × .025	.019 × .025	.016	.017 × .025	.019 × .025
Gemini	9	9	9	9	9	9	9	9	9
Smart Clip	9	9	9	9	9	9	9	9	9
Clarity - SL	9	9	9	9	9	9	9	9	9
Clarity Advanced	9	9	9	9	9	9	9	9	9

Each bracket wire combination consists of 9 specimens

Wire section in inches

Table 2: Descriptive statistics of frictional forces

Bracket Type	Wire Material		Mean	Std. Deviation	F	Sig.*
Clarity-SL	Ni-Ti	0.016	6.34444	.390868	807.392	<0.001
		0.017x0.025	11.27778	.423609		
		0.019x0.025	16.60000	.739932		
	SS	0.016	4.55556	.287711	328.320	<0.001
		0.017x0.025	7.27778	.454911		

		0.019x0.025	9.70000	.504975		
	TMA	0.016	6.77778	.731057	1280.895	<0.001
		0.017x0.025	19.87778	.674125		
		0.019x0.025	21.11111	.584047		
Clarity Advanced	Ni-Ti	0.016	11.68889	.368932	4135.694	<0.001
		0.017x0.025	18.15556	.527046		
		0.019x0.025	32.92222	.599537		
	SS	0.016	9.13333	.696419	2286.426	<0.001
		0.017x0.025	15.06667	.316228		
		0.019x0.025	27.48889	.671648		
	TMA	0.016	15.15556	.487625	3421.475	<0.001
		0.017x0.025	22.50000	.497494		
		0.019x0.025	34.83333	.543139		
Gemini	Ni-Ti	0.016	9.12222	.386580	4717.882	<0.001
		0.017x0.025	15.67778	.370060		
		0.019x0.025	26.77778	.411636		
	SS	0.016	5.25556	.466667	2483.545	<0.001
		0.017x0.025	12.27778	.613958		
		0.019x0.025	22.16667	.435890		
	TMA	0.016	12.70000	.463681	5421.224	<0.001
		0.017x0.025	27.97778	.481606		
		0.019x0.025	38.98889	.648931		
Smart Clip	Ni-Ti	0.016	4.31111	.388730	1638.026	<0.001
		0.017x0.025	9.14444	.364387		
		0.019x0.025	14.56667	.387298		
	SS	0.016	3.04444	.229734	713.388	<0.001
		0.017x0.025	5.02222	.281859		
		0.019x0.025	7.73333	.278388		
	TMA	0.016	5.43333	.830662	712.955	<0.001
		0.017x0.025	14.65556	.487625		
		0.019x0.025	19.06667	.951315		

Table 3: Mean frictional forces values (N) for 4 bracket type depending on arch wire alloy tested.

Bracket Type	Wire Alloy	No of Observations	Mean	Minimum	Maximum
Gemini	SS	27	13.233	4.6	22.7
	NiTi	27	17.19259259	8.5	27.4
	TMA	27	26.55555556	12.1	39.8
Smart Clip	SS	27	5.266666667	2.7	8.1
	NiTi	27	9.340740741	3.8	15.1
	TMA	27	13.05185185	4.7	21.2
Clarity Advanced	SS	27	17.22962963	8.1	28.3
	NiTi	27	20.92222222	11.2	33.6
	TMA	27	24.16296296	14.6	35.8
Clarity-Sl	SS	27	7.177777778	4.2	10.4
	NiTi	27	11.40740741	5.8	17.9
	TMA	27	15.92222222	5.8	21.9

Table 4. Mean frictional forces values (N) for 4 bracket type depending on arch wire size tested

Bracket Type	Wire Size	No Of Observations	Mean	Minimum	Maximum
Gemini	0.016	27	9.025925926	4.6	13.4
	0.017x0.025	27	18.64444444	11.2	28.6
	0.019x0.025	27	29.31111111	21.4	39.8
Smart Clip	0.016	27	4.262962963	2.7	6.9
	0.017x0.025	27	9.607407407	4.6	15.4
	0.019x0.025	27	13.78888889	7.3	21.2
Clarity Advanced	0.016	27	11.99259259	8.1	15.9
	0.017x0.025	27	18.57407407	14.6	23.5
	0.019x0.025	27	31.74814815	26.6	35.8
Clarity-SL	0.016	27	5.892592593	4.2	7.8
	0.017x0.025	27	12.81111111	6.6	20.8
	0.019x0.025	27	15.8037037	9.1	21.9