Original Research

A comparative study of frictional resistance of stainless steel, nickel titanium, TMA, timolium and CNA archwires with stainless steel brackets - an in vitro study

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ABSTRACT

Many factors contribute to the frictional resistance of pre adjusted edgewise appliances, including the bracket and arch wire material. The present study was conducted to evaluate the difference in magnitude between the friction generated by stainless steel, Nickeltitanium, TMA, Timolium and CNA archwires with stainless steel brackets under dry condition. Fifteen segments of 0.019X0.025 inch of each arch wire type were ligated to 0.022 X 0.028 inch slot stainless steel brackets with 0.010 inch stainless steel ligature wires and frictional resistance was evaluated using instron universal testing machine. Multiple range test by Tukey HSD procedure was used for statistical analysis.TMA wires exhibited highest frictional resistance while stainless steel exhibited least resistance with stainless steel brackets.CNA, NiTi and Timolium wires exhibited intermediate frictional values. The results of the study concluded that the least amount of friction was generated bystainless steel wires compared to other arch wires tested.

INTRODUCTION

In the past few decades, a number of wire alloys with a wide spectrum of mechanical properties have been introduced, adding versatility to orthodontic treatment. Selecting the appropriate archwire requires a thorough knowledge of the biomechanical properties of the archwire. Frictional resistance generated at the bracket archwire interface is one of the important properties of the archwires that affects its clinical performance.

Friction is the resistance to motion that occurs when an object moves tangentially against another object[1]. Friction may exist in two forms- static friction, which is the resistance that prevents actual motion and dynamic friction or kinetic friction, which exists during motion[2].Friction between archwire and bracket is thus inherent to sliding mechanics. Friction reduces the rate of tooth movement, increases the amount of force required and cause anchorage loss[3].Many studies were conducted in the past and various factors influencing the friction including the type of bracket and archwire material, slot dimensions, torque at the bracket wire interface, wire size and morphology, clearance between slot and the wire, type of ligation, and type of force applied have been identified [2-7].

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Stainless steel is preferred by the orthodontist because they have high stiffness, good formability, greater ease of welding , the ability to readily overcome sensitization and has good corrosion resistance. In order to meet the orthodontists demands to have an appliance system that was relatively resistant to permanent deformation and provide a large range of activation titanium based alloys Nickel Titanium and TMA started gaining popularity[8]. Timolium, an α titanium vanadium alloy with its smooth surface, reduced friction, low modulus, and better strength can be considered an introductory breakthrough in clinical orthodontic practice[9]. One of the latest alloys to be introduced to orthodontics is the Connecticut Nanda Archwire (CNA) or Beta III CNAarchwires are supposed to have high spring back and flexibility, low load deflection rate, excellent formability and smooth polished surface[10].

Friction plays a major role during alignment and leveling and also during space closure. Up to 60 per cent of the applied force is dissipated as friction [11].which reduces the force available for tooth movement such that an adequate translating force must be applied in order to overcome the frictional force[12]. Timolium & CNA are a recent introduction in the field of orthodontic alloy archwire materials, and proper literature regarding the frictional properties of this archwire alloy are lacking. Therefore a comparative study was undertaken to measure the frictional resistance of stainless steel, NiTi, TMA, Timolium and CNA archwires with stainless steel brackets.

AIMS AND OBJECTIVES

1. To evaluate the frictional resistance of stainless steel archwires in stainless steel brackets – in dry condition.
2. To evaluate the frictional resistance of Nickel Titanium archwires in stainless steel brackets – in dry condition.
3. To evaluate the frictional resistance of TMA archwires in stainless steel brackets –in dry condition.
4. To evaluate the frictional resistance of Timolium archwires in stainless steel brackets – in dry condition.
5. To evaluate the frictional resistance of CNAarchwires in stainless steel brackets – in dry condition.
6. To compare and evaluate the frictional resistance of stainless steel, Nickel Titanium, Timolium, TMA and CNA archwires in stainless steel brackets - in dry condition .

MATERIALS AND METHODS

The archwires evaluated in the study are stainless steel archwire (Ormco,Glendora,CA.), Nickel titanium (American orthodontics, Sheboygan,Wis.), TMA (Ormco, Glendora, CA.), Timolium (TP Orthodontics, LaPorte, Ind), and CNA archwire (American orthodontics, Sheboygan,Wis). (FIG-1).A total of seventy five arch wire segments of 30mm length &0.019 x0.025 inch cross section.(Fifteen of each sample) was tested in seventy five stainless steel brackets. The samples were divided into five groups Group I-stainless steel , Group II- NiTi, Group III- TMA, Group IV – Timolium& Group – V – CNA archwire .The brackets used were maxillary first premolar brackets, master series (American orthodontics, Sheboygan,Wis) 0.022 x 0.028 slot size. Arch wires were ligated to the brackets slotwith 0.010 inch soft stainless steel ligature wire.

Fig 1-a Timolium archwire

Fig 1-b Nickel titanium

Fig.1-c *TMA archwire*

Fig.1-d Stainless steel archwire

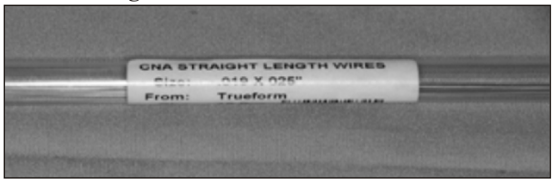

Fig.1-e CNA archwire

Seventy five 4 inch x 2 inch colour coded acrylic plates to differentiate the five study groups were selected. At one end of the plate horizontal and vertical lines were drawn. The brackets were stabilized by means of an industrial adhesive at the point of intersection of the two lines. The wire of about 30 mm length was taken and placed in the bracket and ligated with stainless steel ligatures twisted until its tightened and then untwisted a quarter turn. (Fig-2).

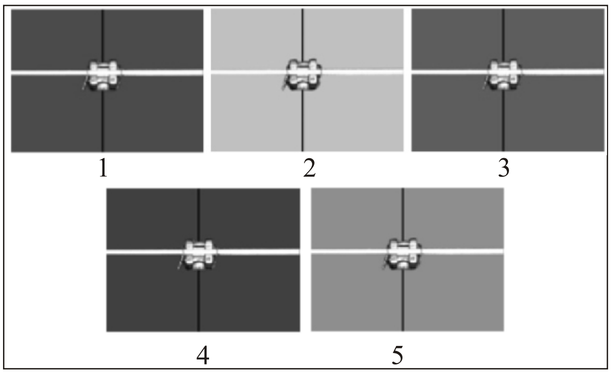

Fig. 2: 1- Stainless steel, 2-Nickel Titanium 3- CNA, 4- Timolium, 5-TMA

The frictional force was measured with a universal testing machine (Instron Corp., Canton, Mass.) during in vitro translatory displacement of bracket relative to wire (Fig-3). A 500 Kg load was used to determine the frictional force levels, the machine was adjusted in the tensile mode and the force levels were measured in Kgs in a digital read out. The Instron testing machine not only measured the kg of tensile force required to pull the wire through fixed bracket, but also gave the tracking distance as a digital read out in mm.

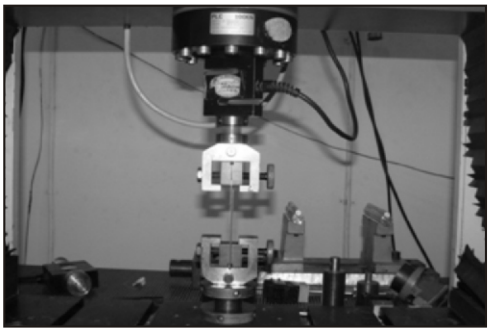

Fig : 3 Instron universal testing machine.

The acrylic plate was mounted on to the lower grip of instron testing machine. The free end of the arch wire was fixed to the upper grip of universal instron testing machine which was connected to the load cell. (Fig-4)

Fig : 4 Sample mounted in the testing machine.

Before testing each bracket, the wire and ligature were cleaned with 95% alcohol and air dried. Each wire was pulled through the bracket slot by a distance of 7 mm at the rate of 5mm/minute and the force levels were recorded from the digital marker. The arch wires and brackets were tested such that a new bracket and wire combination was used for every test and then discarded. A fresh ligation was used for each combination.

The recorded values that represented frictional resistance in Newton, was converted to grams.The kinetic frictional forces generated by all five types of archwires are shown in (Table-1).A statistical comparison of these observations is also provided (Table-2,3&4)

STATISTICAL ANALYSIS

Mean and standard deviation were estimated for each study group.Mean Values were compared by One Way ANOVA. Multiple range tests by Tukey HSD procedure was employed to identify the significant groups at 5% level.In the present study P<0.05 was considered as the level of significance.

S.No.	Frictional resistance in gms				
	SS	NITI	TMA	TIMOLIUM	CNA
1	190.111	234.432	502.001	551.118	242.231
2	160.112	298.982	491.712	484.112	231.342
3	155.234	264.642	515.45	505.412	211.543
4	184.643	229.762	511.478	494.712	271.765
5	191.712	198.762	488.419	515.456	281.453
6	160.112	212.778	561.431	521.404	198.765
7	172.761	235.843	589.719	491.664	204.654
8	184.562	289.743	503.414	502.617	212.765
9	191.742	274.643	484.515	491.712	222.732
10	221.663	196.654	546.414	546.432	217.654
11	167.412	241.668	561.478	476.412	241.775
12	175.613	271.662	507.123	526.413	216.432
13	183.612	231.332	489.716	502.001	216.331
14	159.412	275.665	561.412	532.019	241.412
15	174.432	255.437	516.231	5O8.354	222.324
Mean	**177.521**	**252.032**	**535.364**	**516.636**	**228.44**

Table -1 : Comparison of the frictional resistance of Stainless steel, NiTi, TMA, Timolium and CNA archwires with Stainless steel brackets.

RESULTS

Stainless steel archwires (Group- I) exhibited the lowest frictional resistance (177.522 17.788gms) while TMA archwires (Group- III) exhibited the greater frictional resistance (535.364 40.329gms.).The other groups Group II - Niti archwire, Group IV – Timolium archwires & Group V - CNA archwires exhibited intermediate friction.

Mean Values in Group III and in Group IV were significantly higher than the mean values in Group II , Group V and in Group I .Furthermore the mean values in Group V and Group II were significantly higher than the mean value in Group I (P<0.05). However, there was no significant difference between mean values in any other groups.

DISCUSSION

Fixed orthodontic appliance technique always involves some degree of sliding between bracket and arch wire. Whenever sliding occurs frictional resistance is encountered and 40-60% of applied force is thus dissipated reducing the resultant force available for tooth movement. A greater force will be required to effect tooth movement which may lead to anchor loss[8, 11.] There are many variables that affect the amount of frictional resistance generated. Studies have concluded that increasing the archwire dimension resulted in increased frictional resistance[13]. According to a study conducted by Tselepsis, friction increased with bracket

FRICTION	SUM OF SQUARES	Df	MEAN SQUARES	F Ratio	P Value
BETWEEN GROUPS	1738963.281	4	434740.8203	436.3451	.0001
WITHIN GROUPS	69742.8556	70	996.3265		
TOTAL	1808706.137	74			

Table -2 : Results of One Way Anova to compare the frictional forces for five different archwires with Stainless Steel Bracket

to archwire angulation[4]. Stainless steel with high values for strength, low friction, continues to be the mainstay archwire in orthodontic mechanotherapy. In a full slot archwire stainless steel wires do not have sufficient flexibility to express torque completely. Titanium alloys like Niti and TMA were introduced as they had sufficient flexibility for the complete expression of torque. NiTi and TMA generated low, consistent force, when compared with other alloys because of its load deflection characteristics. But NiTi and TMA generated high frictional forces [9].Timolium and CNA are much newer wire materials, and there are very few studies conducted to evaluate their frictional properties and the present study was mainly done to fill this lacuna.

Various methods have been used in vitro to evaluate the frictional resistance of archwires against brackets with the most accepted one being the method proposed by Garner, Allai, and Moore[14.] The present study evaluated dynamic friction, and the values clearly indicated greater friction at the archwires bracket interface when TMA wires are used.

In comparison with the other four alloy archwires. The least archwire-bracket interface friction was observed with stainless steel archwires as reported in the earlier literatures [11, 14, 16]. Timolium, with an intermediate nature can be considered superior to TMA but inferior to stainless steel Nitinol and CNA in its frictional characteristics. Clinically, the net force required for translatory movement will be lower

Variable	Value Lable	Mean	Std dev	Cases
For Entire population		341.9986	156.3393	75
Group	I	177.5218	17.7880	15
Group	II	252.0301	37.3065	15
Group	III	535.3641	40.3286	15
Group	IV	516.6363	32.9493	15
Group	V	228.4407	23.6938	15
Total Cases = 75				

Table -3 : Oneway/variables value by GROUP (1, 5) /ranges (Tukey) Summaries of values by levels of groups.:

for stainless steel and higher when TMA wires are used. From the present study the rank order of wires in descending order of frictional properties can be summarised as- TMA>Timolium>Nitinol> CNA > Stainless steel

Earlier scanning electron microscopic and laser studies have concluded that the surface roughness of Nickel Titanium and TMA wires were greater than Stainless steel or Cobalt chromium wires thereby further increasing the frictional forces [13, 14].In a study conducted by Vinod Krishnan et al scanning electron microscopy evaluation of surface characteristics revealed a smooth surface with little surface irregularity and horizontal wire drawing lines for Timolium archwires. TMA, with a large number of uniformly distributed pores exhibited a very rough surface [9]. These findings agree with the frictional characteristics observed in the present study.

Earlier studies have concluded that when high stiffness is required during sliding mechanics stainless steel should be used over Nitinol or TMA because of their advantage of both low friction and high stiffness[14].Cash et al in their study concluded that TMA wires are usually not considered the wire of choice for closing space because its frictional resistance higher than that of Nickel Titanium or stainless steel [17].

Kusy RP et al compared TMA, Timonium, and CNA for their frictional properties and they concluded that friction at the bracket arch wire interface appeared to be higher when TMA wires were used. Timolium and CNA archwires exhibited comparatively lesser frictional forces probably because of their smooth polished surface[18].

Results obtained from the present study indicated highest frictional force values with Beta-Titanium wires, stainless steel wires exhibited the least friction and CNA, Niti and Timolium wires had intermediate frictional values. Timolium and CNA archwires had lesser friction when compared to TMA probably because they had an increased surface smoothness as confirmed by earlier studies[9].

This study was an invitro study and hence the role of saliva and other biological factors was not considered. Further studies using saliva and salivary substitutes should be done to precisely determine the role of saliva in friction during orthodontic treatment as saliva acts as lubricant and reduces the friction. Further studies should be carried out including the other variables such as bracket material, slot size, archwire angulations to understand the frictional characteristics of the newer archwires.

GROUP	MEAN ± S.D	P - Value	Significant groups At 5 % level
I	177.522 ± 17.788	<0.0001 . Sign	III vs V,I,II IV Vs V,I,II II Vs I V Vs I
II	252.030 ± 37.307		
Iii	535.364 ± 40.329		
IV	516.636 ± 32.949		
V	228.441 ± 23.694		

Table -4 : Mean standard deviation and test of significance of mean values among different study groups

CONCLUSION

The following conclusions are made from the study; TMA wires exhibited highest frictional resistance with stainless steel brackets. Stainless steel wires exhibited the least frictional resistance with stainless steel brackets. The CNA, NiTi and Timolium archwires exhibited intermediate frictional forces. To obtain the least amount of friction stainless steel wires with stainless steel brackets and stainless steel ligature is recommended.

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