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Effect of Brackets' Types on the Amount of Movement and Rotation of Canine during Retraction: A Simulated *In vitro* Study

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ABSTRACT

Background: *This in vitro study aimed to evaluate the effect of brackets' materials on the distance moved by canine and rotation during sliding.* ***Materials and methods:*** *Extracted human maxillary canine tooth was used as facsimile to fabricate forty acrylic canine teeth with special mold. These teeth were bonded with 0.018 × 0.030-inch orthodontic brackets with different materials namely; stainless steel, titanium, ceramic and plastic one and impeded in wax in metal boxes. A 0.016 × 0.022 inch straight stainless steel archwire were ligated to the brackets with loose stainless-steel ligature wire. Sliding of canine along the archwire was performed using nickel-titanium closed coil spring after wax softening at 50ºC. The distance moved by canine and the amount of rotation were assessed and compared among bracket types using one-way ANOVA and Tukey's high significant difference tests.* ***Results:*** *Distance moved by canine was significantly more with stainless steel followed by titanium, plastic then ceramic one. On the other hand, canine rotated significantly more with ceramic brackets followed by plastic, titanium then stainless steel one.* ***Conclusion:*** *Canine moved more with stainless steel brackets with less rotation while it was just the opposite with ceramic brackets.*

Keywords: Orthodontic brackets, Canine retraction, Rotation

INTRODUCTION

Angle developed series of orthodontic appliances to correct different cases of malocclusions, the last one was the edgewise appliance [1]. He adopted the idea that the dental arches should occupy the dentitions, so he treated his cases without teeth extraction. Tweed, one of Angle's student, followed Angle's footsteps till he got undesirable facial appearance in many cases treated with non-extraction method. After many failure cases, Tweed decided to re-treat these cases with extraction of first premolars [2,3]. At the beginning, he did en-masse retraction of the anterior teeth using elastics after anchorage preparation; then he favored the two steps retraction i.e., retraction the canines first then the incisors to lessen the anchorage loss.

To close the extraction space, the anterior teeth can be retracted using friction (sliding) or frictionless mechanics. Daskalogiannakis [4] defined sliding mechanic as "a mechanotherapy involving sliding of bracket along the archwire during tooth movement i.e., the classic pearls on a chain as example, the archwire generates the counter moment necessary for bodily movement of tooth; friction forces are present when tooth movement is performed by sliding mechanics".

Many factors affected the rate of teeth movement in sliding mechanic. Some related to the brackets like the materials from which they were manufactured, slot size, bracket width, brackets prescription and inter-bracket distance. Other related to the archwires like the materials, cross section types, surface texture and gauge of the archwire. On the other hand, other factors might play role in sliding mechanic like the ligation methods (ligature elastic or wire), intra-oral condition (saliva, acquired pellicle, plaque, corrosion, etc.) [5-38].

Many Iraqi researches studied the amount movement and the rotation of canine during friction [39-42] and frictionless [43] mechanics, with different brackets type of 0.022-inch slot [44], different archwire gauges [45] and different ligation methods [46].

The purpose of the present study was to measure the distance moved and rotation of canine during sliding mechanic using 0.018-inch slot and different bracket types ligated with loose ligature wire.

MATERIALS AND METHODS

A freshly extracted human maxillary canine was used as facsimile to construct forty acrylic teeth of similar shape using heavy body and light body condensation silicone impression material (Zhermack, Italy) and crown flask as impression tray.

After setting, the impression was filled with molten rim wax and the two halves were closed tightly by screwing the two flask halves together and left for one hour at room temperature for wax solidification. Then the two halves were separated and the wax mold of the canine tooth was removed, small wax flashes were cut off, and the wax teeth were stored in distilled water. This procedure was repeated to get forty wax mold canines (Figure 1).

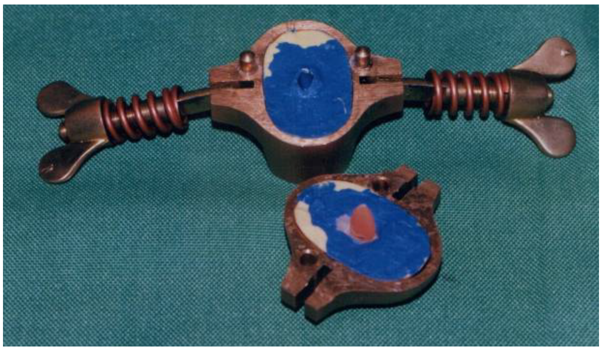

Figure 1 Crown flask (with impression and wax tooth)

The wax mold canines were sent to the dental laboratory to fabricate acrylic teeth from hot cure acrylic in the same manner as denture fabrication. The excess acrylic was removed by a stone bur mounted on a handpiece and the teeth were finished by sand paper of varying degrees of roughness. The final smooth teeth were stored in a closed container full of distilled water.

For standardization of bracket position for all samples, the natural canine was bonded with Roth prescription metal size 0.018 × 0.030-inch maxillary canine bracket with the slot being 5 mm away from the cusp tip and the vertical arrow on the bracket parallel to the long axis of the tooth and painted with separating medium (Vaseline) and laid down horizontally in the mixture of dental stone in plastic mold with the bracket facing upwards.

At the same level of canine bracket, two Roth prescription metal size 0.018 × 0.030-inch maxillary premolar brackets were fixed and after complete set of the stone, a 30-mm piece of 0.018 × 0.025 inch straight stainless-steel wire was ligated to the canine and premolar brackets (Figure 2).

Figure 2 Canine and premolar brackets attached to the archwire

The natural tooth was then removed leaving an empty bed for the acrylic teeth. Each acrylic tooth was seated in the empty bed and the same piece of stainless steel wire with a canine bracket ligated to it was inserted in the slots of the premolar brackets. Four types of canine brackets (Roth prescription slot size 0.018 × 0.030 inch) were bonded to the acrylic teeth with cyanoacrylate adhesive material (Figure 3). After leaving the bracket for ten minutes to achieve complete setting of the adhesive material, the archwire was removed and the final groups of this study were as followed:

Group I: 10 Stainless steel brackets (Dentaurum, Germany), width=3.4 mm.

Group II: 10 Titanium brackets (Dentaurum, Germany), width=3.1 mm.

Group III: 10 Ceramic brackets (Dentaurum, Germany), width=3.9 mm.

Group IV: 10 Plastic brackets (TP Orthodontics, USA), width=4.0 mm.

Figure 3 Canine bracket attached to the acrylic tooth

Twelve metal boxes with 88 mm length, 48 mm width and 30 mm height were constructed from copper, because of its efficiency in thermal conduction, to occupy eight brass posts with 8 mm length, 4 mm width and 30 mm height fixed with Epoxy adhesive material. To simulate the natural dentition, the distance between the posts was 18.5 mm be similar to the distance between the distal surface of the bracket of maxillary lateral incisor and the mesial surface of the bracket of maxillary second premolar. The posts were fixed at a distance of 10 mm from the walls of copper box to get a consistent amount of heat distribution throughout the wax.

At a distance of 7 mm from the upper edge of each post, a molar tube (Rematitan®, slot 0.018 × 0.030 inch, Dentaurum, Germany) was fixed using cyanoacrylate adhesive; this distance provided 6 mm clearance between the apex of the tooth and base of the box in order to prevent the friction between the apex of the tooth and the base of the box during movement. A unique hook was made for molar tube to be at a distance of 19 mm from canine bracket hook.

The acrylic canine teeth were then inserted in the boxes by ligating their brackets to the 0.017 × 0.025-inch straight archwire with elastic ligature (Figure 4). A mixture of utility wax and base plate paraffin wax, with equal amount, was prepared according to the method of Tanne et al. [23] and Ryan et al. [27] and poured in consecutive layers into the copper boxes in order to overcome the problem of cooling shrinkage and to get flat surface of the wax. The height of the wax should be about 2 mm below cemento-enamel junction so throughout heating, the wax will be expanded to get in touch with the echelon of cemento-enamel junction of the teeth.

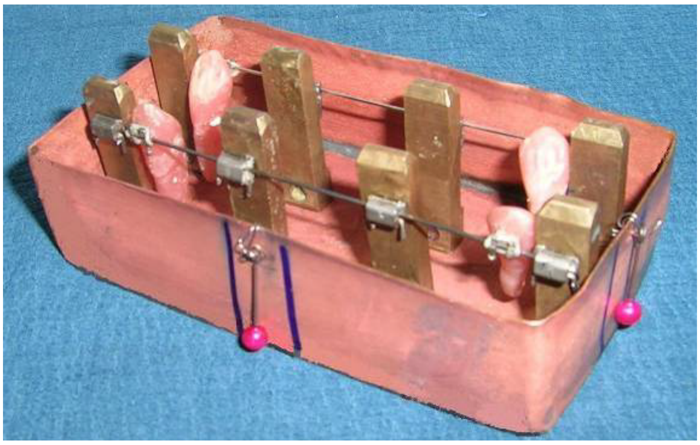

Figure 4 Test apparatus with 4 acrylic teeth ligated to 0.017 × 0.025 stainless steel archwire

Each group composed of three boxes, two of them contained four teeth and the third one contained two teeth). The bracket of these teeth was ligated to a 0.016 × 0.022-inch straight archwire by preformed short stainless-steel ligature wire ties (0.010 inch, Dentaurum, Germany) twisted 8 turns then untwisted 90º to become slackened and to permit the archwire to slide without restraint, then the surplus was cut and tucked behind the archwire using a Mathieu artery forceps [22]. The archwires were cinched back at both ends for stabilization.

The assembly was stored in distilled water at a temperature of 37°C in the water bath to simulate the environment of temperature and humidity of the mouth. The temperature was checked periodically by a thermometer gauge.

In order to start tooth movement, the boxes were kept in a water bath at 50°C for one hour to permit heat distribution throughout the wax [23], then hastily a 12 mm NiTi closed coil spring (Rematitan®, Dentaurum, Germany) was placed and activated 7 mm [44-46] to give 205 g force to retract the canine. At that time, the boxes were gone back to the water bath for 20 minutes at the same temperature (Figure 5).

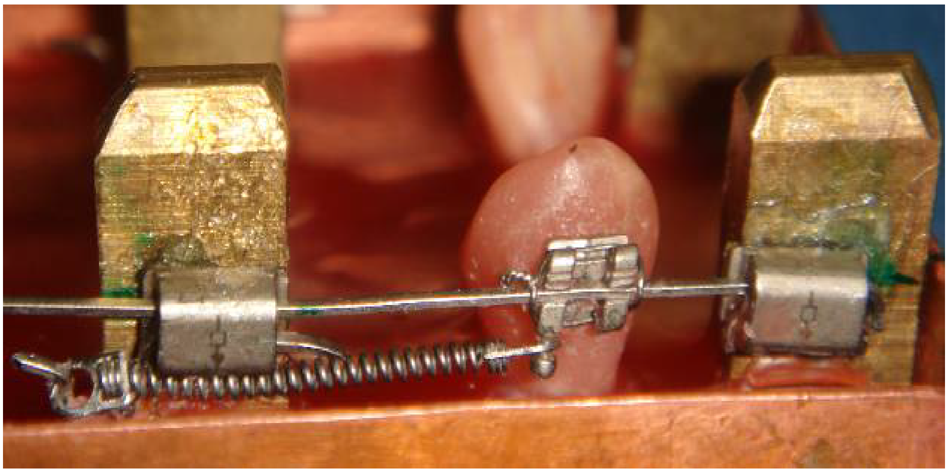

Figure 5 Retracted by NiTi closed coil spring for the four groups

Using an electronic digital vernier, the distance from mesial side of molar tube to the canine bracket was measured prior to tooth movement and at the end of time after tooth movement, the difference regarded as the amount of tooth movement [44-46].

For assessing the degree of rotation of the canine during its retraction, a top view image was taken using digital camera (Figure 6) and the angle between lines one along the bracket wing and one along the archwire was measured using FotoCanvas program on computer [44-46].

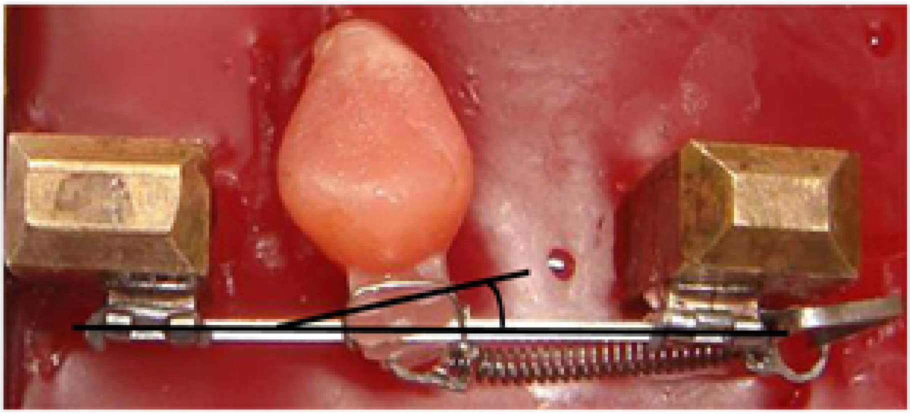

Figure 6 Measuring canine rotation

Statistical analysis

Data were collected analyzed using the Statistical Package of Social Sciences, version 20. Descriptive statistics included the means, standard deviations and minimum and maximum values while inferential statistics included Shapiro-Willk test (to test the normality of data distribution), one-way ANOVA and Tukey's HSD tests to examine any significant difference between the four groups.

In the statistical evaluation, the following levels of significance are used:

$P > 0.05$ Non-significant

$0.05 \geq P > 0.01$ Significant

$P \leq 0.01$ Highly significant

RESULTS

Firstly, the normality of the distribution of the data was tested using Shapiro-Willk test and the results proved normally distributed data. Table 1 demonstrated the amount of distance moved by canine. Generally canine moved more distance with stainless steel and titanium brackets and less with plastic and ceramic one. ANOVA test revealed statistically high significant difference among the groups. Reviewing Table 2, Tukey's HSD test revealed high significant difference between stainless steel and other brackets. On the other hand, non-significant difference was shown between the other brackets.

Table 1 Descriptive statistics and comparison the distance moved by the canine and its rotation among different types of brackets

Variables	Bracket types	Descriptive statistics				Comparison	
		Mean	S.D.	Min.	Max.	F-test	p-value
Distance (mm)	I	3.88	0.23	3.5	4.2	63.413	0
	II	2.68	0.23	2.3	3		
	III	2.63	0.254	2.2	2.9		
	IV	2.65	0.259	2.1	3		
Rotation	I	4.835	0.31	4.34	5.34	46.335	0
	II	5.398	0.465	4.51	5.93		
	III	6.591	0.297	6.1	7.1		
	IV	6.172	0.361	5.74	6.83		

The amount of rotation of canine during its movement was expressed in Table 1. The canine rotated more with ceramic and plastic brackets followed by titanium and the least rotation was presented in steel one. Again, ANOVA test revealed statistically high significant difference among the groups. Tukey's HSD test showed a non-significant difference between the ceramic and plastic brackets while the other groups differed highly significantly between each other.

Table 2 Tukey' HSD test after ANOVA

Variables	Groups		Mean Difference	p-value
Distance (mm)	I	II	1.2	0
	I	III	1.25	0
	I	IV	1.23	0
	II	III	0.05	0.967
	II	IV	0.03	0.993
	III	IV	-0.02	0.998
Rotation	I	II	-0.563	0.007
	I	III	-1.756	0
	I	IV	-1.337	0
	II	III	-1.193	0
	II	IV	-0.774	0
	III	IV	0.419	0.066

DISCUSSION

Although recent evidence based orthodontic researches showed high preference for one-step (en-masse) retraction [47], some orthodontists still worked with two-step sliding mechanics.

Many orthodontists prefer retracting canines on round wires, Yassir [45] found that the amount of movement and rotation of canine during retraction in simulated *in vitro* study with 0.018-inch stainless steel wire was more than that with 0.019 × 0.025-inch wire using 0.022-inch slot.

The amount of play between the bracket and the archwire will be decreased as the gauge of the wire increased. Frank and Nikolai [9] suggested canine retraction on heavy, rectangular wire with edgewise mechanics. In the present study, 0.016 × 0.022-inch stainless steel archwire was used on 0.018 × 0.030-inch slot because [12]:

(a) It offered control in all three planes of space, whereas round wire gives control only in two planes.

(b) Stainless steel archwire produced the least frictional force during *in vitro* tooth movement in comparison with nickel titanium and beta titanium archwires.

(c) During sliding mechanics, high stiffness of the archwire is required.

During canine retraction using sliding mechanics, it is preferable to ligate the archwire in the canine's bracket with loose ligature wire because it provides superior tooth movement with minimal undesirable tooth rotation [46]. In comparison with ligature elastic, ligature wire seated the archwire securely in the slot of the bracket resulting in a sufficient moment (about two and a half times that provided by ligature elastics) to decrease the canine rotation during its sliding along the arch-wire [24].

The effect of four types of brackets on the amount of movement and rotation of canine was studied in the present study. Reviewing Table 1, stainless steel brackets showed the highest amount of movement followed by titanium, plastic and then ceramic brackets; this comes in agreement with the findings of Giri, et al. [38].

Pratten, et al. [20] reported that steel brackets possessed low frictional forces in comparison with ceramic brackets because of their smooth surface of the slot. Ceramic brackets had greater frictional resistance to sliding in comparison with all brackets' types. This is because of the crystalline structure of ceramic brackets containing many pores making their surface relatively rough hence increasing the friction and make tooth movement slow.

Tanne, et al. [23] found a decrease in tooth movement with ceramic brackets in comparison with metal one and on examination under scanning electron microscope, the ceramic brackets' slot and edges were more porous and rougher than the metal brackets. On the other hand, the archwire was scratched by the ceramic brackets in contrary to metal one.

There is a conflict about the friction generated by titanium brackets with regards to stainless steel brackets, one reported comparable frictional characteristics, while other [37] reported more friction generated with titanium brackets and this in accordance with the present findings.

Plastic brackets characterized by high friction between the slot and metal archwire and this will reduce the tooth movement, so they were not recommended in complex cases. This finding agrees with Riley, et al. [8] and Tselepis, et al. [25] and disagree with Lima, et al. [36] who reported an opposite finding.

Regarding the effect of bracket width on the frictional resistance and teeth movement, Frank and Nikolai [9] and Kapila, et al. [17] reported a direct relation between the friction and bracket width. Kamiyama and Sasaki [6] and Dresher [16] found the reverse findings while Andreasen and Quevedo [5] and Tanne, et al. [23] reported no relation between them. In the present study, the ceramic and plastic brackets possessed greater width than stainless steel and titanium brackets and showed slower teeth movement supporting the previous findings [9,17].

Regarding the rotation of the canine, the highest rotation was presented with ceramic brackets followed by plastic, titanium and the least with stainless steel brackets (Table 1). The point of force application of the closed coil spring on ceramic bracket was more mesial than the other three bracket types because of the wide design of the ceramic bracket's hook [44]. For plastic brackets, slot distortion caused by water absorption led to dimensional instability, so the wire may not engage the slot perfectly leading to increased rotation.

CONCLUSION

Although this study was performed in-vitro and in softened wax that was far from the oral environments and bone surrounding the teeth, one can conclude that stainless steel bracket is the best one for sliding mechanics with more canine movement and less rotation and just opposite to the ceramic one.

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