Evaluation of the Effect of Different Points of Orthodontic Force Application (A Typodont Study)

ABSTRACT

Aims: To determine the effect of different points of force application on dimensional positions and the ratio of space closure of maxillary canine using sliding mechanics. **Mater–ials and Methods:** The study included eight groups which were categorized according to the differences in the points from which the retraction force was applied. A 180 gm was applied by short elastic chain to retract the right maxillary canine on 0.018×0.025" rectangular stainless steel (SS) wire and along 13mm available space. In both vertical and horizontal direction, photographs were taken by digital camera and the angle between canine extension bar and bite plane extension bar was measured by protractor to determine tipping and rotation whereas rate of space closure was measured by digital vernia. **Results:** The results showed that the maximum rate of space closure was achieved when elastic chain was attached between molar hook to canine hook and the minimum degree of tipping was achieved when elastic chain attached between premolar bracket to canine hook while minimum rotation occurred when the attachment was between premolar hook to canine hook. **Conclusions:** Changing the distance between the points of force application significantly affects the rate of space closure, tipping and rotation. The use of hook significantly increases the rate of space closure and decreases tipping and rotation.

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Key words: Sliding, tipping, rotation.

Space closure is a routine procedure in orthodontic practice, researchers always interested in determining efficient methods of retracting canines.[1] Canines can be retracted by frictional and non–frictional mechanics.[1, 2] Frictional mechanics is the sliding of a tooth along an arch wire by application of a force.[3] Sliding mechanics produces friction at bracket–wire–ligature interface. Frictional forces which act in opposite direction to the desired movement are generated whenever force is applied.[4] In clinical terms, any force applied to achieve a desired movement must exceed the frictional force inherent in the appliance.[5] If frictional forces could be reduced, tooth movement could be accomplished with lighter forces.[6] A large number of variables affecting friction between bracket and wire.[7] These variables may be either mechanical or biological.[8] This study was concerned to evaluate one of these variables which was the difference in the point of force application and its effects on dimensional positions and the ratio of space closure of maxillary canine using sliding mechanics. It had been found that orthodontic tooth movement can be compared to a stimulus–response model, where the stimulus is the applied force system and the response is the resulting tooth movement,[9] accordingly a

Typodont model system was used in this study.

Aims of the Study:

To determine the effect of different points of force application whether these points were located anteriorly or posteriorly on dimensional positions and the ratio of space closure of maxillary canine using sliding mechanics.

MATERIALS AND METHODS

Typodont simulation system (Ormco, Japan) was prepared according to manufacturer's instructions. The metal teeth (all teeth except first premolars and third molars) were situated in well–aligned position in a wax model (maxillary arch) that fixed to articulator. Preformed molar bands (Dentaurum, Germany) with gingival hook and extraoral tube were cemented on the molars by using orthodontic glass ionomer cement, and preadjusted Roth stainless steel brackets of slot size (0.022×0.030" Dentaurum, Germany) for central, lateral, canine and second premolars were bonded to the Typodont teeth by using epoxy steel adhesive.[10] The metal teeth were situated according to manufacture in such away that they represent Class II division 1 malocclusion. Precise final alignment of teeth was done by using stainless steel rectangular arch wire of 0.018×0.025" size which was ligated to the teeth by elastomeric ligature. The criterion for success alignment is passive insertion.

Construction of Acrylic Bite Plane as Guidance:

A primary impression had been taken for a Typodont teeth then pouring with dental plaster material. Perforated special tray was made and another impression is taken with alginate impression material to prepare master cast. Wax was applied on master cast to cover all teeth including the incisal and occlusal third of facial surfaces, incisal edges and occlusal surfaces of all teeth, distal aspect of the lateral incisors, mesial aspect of the second premolars, simulated palatal surface and till the distal extension of the Typodont base, then the wax was replaced by hot cure acrylic resin.[10] So the four anterior teeth, premolars and molars became immobile and canine area became free from acrylic coverage to facilitate sliding movement.

Bite Plane Extension Bar (PEB):

It is an L–shape bar made from 0.018×0.025" stainless steel rectangular wire. The short arm is inserted in the rugae area of the acrylic bite. This bar emerges upward for 10 mm then it was bends and extends facially 20 mm to make right angle with canine extension bar.[10]

Canine Extension Bar (CEB):

It is also an L–shape bar, the short arm is welded to distal aspect of canine's that's extended upward incisally for 10 mm then it bends at right angle to extend anteriorly 20 mm, and 5 mm over canine cusp tip and under the bite plane extension bar by about 5 mm. These two bars are used as a guide for determining position, degree of tipping and rotation of canine. This method is a modification of Huffman and Way[11] procedure.

Force Application Procedure:

Elastic chain short type was used. It applied about 180 gm force to slide the right maxillary canine on 0.018×0.025 stainless steel wire and along 13 mm available space.[12] This force was measured by tension gauge. A stopper hook was fixed on the wire between the second premolar and first molar. The Typodont model was immersed in digital water bath of 54 °C for

about 5 minutes, then in both vertical and horizontal directions, photographs were taken by using digital camera and the angle between PEB and CEB was measured by protractor directly on the photograph to measure the rotation and tipping[13] while the rate of space closure was measured by digital vernia. For each group, the procedure was repeated ten times and before each repeating procedure, the angle between PEB and CEB should be 90° from both vertical and horizontal direction.[14] Eight groups were involved in this study: G1s: Molar hook to canine hook, G2s: Stopper hook to canine hook, G3s: Premolar hook to canine hook, G4s: Premolar bracket to canine hook, G5s: Molar hook to canine bracket, G6s: Stopper hook to canine bracket, G7s: Premolar hook to canine bracket, and G8s: Premolar bracket to canine bracket.

Statistical analysis was done by: 1) Descriptive statistics to show minimum and maximum mean values, standard deviation and error; 2) Analysis of variance (ANOVA) to analyze the previous measurement; and 3) Duncan Multiple Analysis Range Test to locate the significant differences among the groups.

RESULTS

Rate of Space Closure (RSC):

The ANOVA showed significant difference at $p \leq 0.001$ as in Table (1). The results of Duncan Multiple Analysis Range Test showed that G1s group had the highest mean and had significant difference at $p \leq 0.001$ with other groups. Also, group G8s had the lowest mean value. The remaining groups were distributed on statistical levels between the highest and lowest mean with significant and/or non difference as in Table (2).

Table (1): ANOVA test for rate of space closure.

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	103.743	7	14.820	67.045	$p \leq 0.001$
Within Groups	15.916	72	0.221		
Total	119.659	79			

Table (2): Duncan's test for the rate of space closure.

Groups	No.	Mean* + SE	Duncan Groups**
G1s	10	6.00 + 0.10	A
G2s	10	4.90 + 0.06	B
G3s	10	4.83 + 0.14	B
G4s	10	4.30 + 0.20	C
G5s	10	3.50 + 0.23	D
G6s	10	3.00 + 0.20	E
G7s	10	3.00 + 0.14	E
G8s	10	2.42 + 0.10	F

*Mean measurements in millimeter. ** Different letters mean significant difference at $p \leq 0.001$. S: Mean space closure.

Tipping:

The ANOVA test showed significant difference at $p \leq 0.001$ as in Table (3). Duncan Multiple Analysis Range Test showed that G4t group had the lowest mean and had significant difference at $p \leq 0.001$ with other groups (except G3t, G2t and G1t). Also, group G5t had the highest mean value. The remaining groups were distributed on statistical levels between highest and lowest mean with significant difference as in Table (4).

Table (3): ANOVA test for tipping.

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	489.688	7	69.955	94.499	$p \leq 0.001$
Within Groups	53.300	72	0.740		
Total	542.988	79			

Table (4): Duncan's test for tipping.

Groups	No.	Mean* + SE	Duncan Groups**
G4t	10	1.50 + 0.17	A
G3t	10	2.00 + 0.15	A
G2t	10	2.00 + 0.25	A
G1t	10	2.00 + 0.25	A
G8t	10	4.00 + 0.32	B
G7t	10	6.00 + 0.30	C
G6t	10	7.00 + 0.30	D
G5t	10	8.30 + 0.40	E

*Mean measurements in millimeter. ** Different letters mean significant difference at $p \leq 0.001$. T: Mean tipping.

Rotation:

The ANOVA test showed significant difference at $p \leq 0.001$ as in Table (5). Duncan Multiple Analysis Range Test showed that G3r group had the lowest mean and had significant difference at $p \leq 0.001$ with other groups (except G4r and G2r). Also, group G5r had the highest mean value. The remaining groups were distributed on statistical levels between the highest and lowest mean with significant and/or non–significant difference as in Table (6).

Table (5): ANOVA test for rotation.

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	2258.488	7	322.641	150.163	$p \leq 0.001$
Within Groups	154.700	72	2.149		
Total	2413.188	79			

Table (6): Duncan's test for rotation.

Groups	No.	Mean* + SE	Duncan Groups**
G3r	10	15.10 + 0.40	A
G4r	10	15.30 + 0.60	A
G2r	10	16.30 + 0.30	A
G1r	10	18.00 + 0.51	B
G7r	10	21.00 + 0.55	C
G8r	10	22.00 + 0.42	C
G6r	10	27.00 + 0.32	D
G5r	10	30.00 + 0.50	E

*Mean measurements in millimeter. ** Different letters mean significant difference at $p \leq 0.001$. R: Mean rotation.

DISCUSSION

Rate of Space Closure (RSC):

The results of RSC could be attributed to; the use of hooks as in G1s, G2s, G3s and G4s that produces high RSC because the force applied near the center of resistance of canine.[15] Also the use of hook instead of bracket tie wings will eliminate the pressing action on the wire[16] which will increase the friction that can minimize tooth movement.[17] Lastly, since the force was applied at a distance from the center of resistance so we have a moment force. Accordingly, increasing or decreasing the distance between the 2 points of force will increase or decrease RSC because this will increase or decrease the magnitude of moment force by decreasing or increasing the moment arm since moment is force acting at a distance.[18] So, G1s showed the highest RSC while G8s showed the least mean.

Tipping:

Tipping is a constant phenomenon during sliding and it always occurs when orthodontic force is applied to a tooth[19] because the orthodontic force is applied at a distance from the center of resistance of canine[1] and the presence of clearance between bracket slot and arch wire.[20] So the groups G4t, G3t, G2t and G1t in which the hooks were used for attachment showed low degree of tipping since it makes the application of force near the center of resistance.[21] It is well known that force is a vector which characterized by having both magnitude and direction.[7] So the high degree of tipping showed in groups G6t and G7t might be due to the method in which the elastic chain was attached in a direction similar to that direction of vector that cause tipping. In addition, the increased distance between the 2 points of elastic chain attachment will increase the magnitude of moment force and thus generate more friction that cause high degree of tipping[22] as occur in group G5t. Lastly, all the mentioned causes of tipping might work together and participated in the resultant tipping.

Rotation:

Rotation is the twisting of tooth around its long axis.[23] In this study the canine rotated in a disto–palatal, mesio–buccal directions. The presence of clearance might be a cause.[20] Also the force was applied at a distance more buccally from the centre of resistance.[24] So a moment force will be generated. Accordingly, any change in the distance between the 2 points of force will significantly affect rotation because this will affect the magnitude of moment force by affecting the moment arm.[18] So, G3r showed least rotation while G5r showed the highest rotation. Since the arch wire is the same for all groups, so the effect of clearance is the same but the groups in which hooks are used show little rotation G4r, G2r and G1r.

CONCLUSIONS

In this study, the arch wire, brackets and method of ligation are the same for all groups. The differences were in the use of different points of force application (hooks to hooks or hooks to bracket tie wings) and the changing in the distance between these points. It was concluded that changing the distance between the points of force application significantly affects the rate of space closure, tipping and rotation. The use of hook significantly increases the rate of space closure and decreases tipping and rotation. Tipping and rotation are occurred whenever sliding mechanics is used. There was no ideal method which achieved the maximum rate of space closure with no tipping and rotation, so the orthodontist must choose the suitable method for each case.

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