Evaluating the Amount of Tooth Movement and Root Resorption during Canine Retraction with Friction versus Frictionless Mechanics Using Cone Beam Computed Tomography

Mohamed Makhlouf[1*], Amr Aboul–Ezz[2], Mona Salah Fayed[2], Hend Hafez[1]

[1]National Research Centre, Orthodontics, Cairo, Egypt; [2]Cairo University, Orthodontics, Giza, Egypt

Abstract

BACKGROUND: The current study was carried out to compare the amount of tooth movement during canine retraction comparing two different retraction mechanics; friction mechanics represented by a NiTi closed coil spring versus frictionless mechanics represented by T - loop, and their effect on root resorption using Cone Beam Computed Tomography (CBCT).

METHOD: Ten patients were selected in a split-mouth study design that had a malocclusion that necessitates the extraction of maxillary first premolars and retraction of maxillary canines. The right maxillary canines were retracted using T - loops fabricated from 0.017 X 0.025 TMA wires. The left maxillary canines received NiTi coil spring with 150 gm of retraction force. Pre retraction and post retraction Cone Beam Computed Tomography were taken to evaluate the amount of tooth movement and root resorption using three-dimensional planes.

RESULTS: T - loop side showed statistically significant higher mean anteroposterior measurement than NiTi coil spring side, indicating a lower amount of canine movement pre and post a canine retraction. Concerning the root resorption, there was no statistically significant change in the mean measurements of canine root length post retraction.

CONCLUSION: The NiTi coil spring side showed more distal movement more than the T-loop side. Both retraction mechanics with controlled retraction force, do not cause root resorption.

Introduction

Orthodontic treatment objectives may indicate extraction of the first premolar either for the relief of crowding, reduction of dento-alveolar protrusion and improving the facial esthetics, or correction of inter arch mal-relationships through dental camouflage. Hence canine retraction is one of the main procedures carried out during orthodontic treatment. Since the canine retraction procedure takes the longest duration of the entire orthodontic treatment, the main goal of this stage is to achieve a rapid and controlled canine retraction with minimal anchorage loss [1].

Two main canine retraction mechanics are known; Friction (sliding) mechanics or frictionless (sectional) mechanics. The friction created between archwire and bracket when pulling the canine distally using sliding mechanics may be influenced by many factors. Among those factors; surface conditions of archwire and bracket slot, wire section, torque at the wire - bracket interface, type and force of ligation, use of self - ligating brackets, inter-bracket distance, saliva, and influence of oral functions [2]. Various techniques for canine retraction have been introduced including Nickel Titanium closing coil, Elastomeric chains, and lace backs. On the other hand, frictionless mechanics imply the use of the sectional method as the use of Burstone's T - loop, Rickett's spring, or Gjessing's spring.

Researchers were interested in investigating the effect of different force levels on the rate of canine retraction using sectional springs. And many authors have described various designs of canine retraction springs, their suitability and efficiency [3][4].

Ziegler et al. (1989) [5], reported a more controlled tooth movement with less distal tipping with sectional mechanics than with the sliding mechanics.

The technique and efficiency of tooth movement with sliding mechanics have been studied by Drescher et al. (1989, 1990) [6][7] and a rate of retraction ranging from 0.21mm/month [8] to 0.81 mm/month [9], according to the used technique and retraction force were reported by researchers.

So far, the debate is ongoing for the best mechanics for canine retraction and has not been yet resolved. With the advancement of Cone Beam Computed Tomography (CBCT), more detailed and accurate measurements of tooth movement in the three planes of space are now possible.

Consequently, this study aimed to use CBCT in evaluating the rate of tooth movement during canine retraction when using sectional mechanics versus continuous mechanics.

Method

The sample for this study comprised of Ten adult patients in a split-mouth design (seven females, three males) with Class I or II division 1 malocclusion, and a treatment plan that necessitates the extraction of maxillary first premolars and retraction of permanent maxillary canines with moderate to minimum anchorage demand.

The levelling and alignment was performed using series of levelling archwires (0.014, 0.016, 0.016 X 0.022 - inch nickel titanium archwire) until reaching 0.016 X 0.022 - inch stainless steel archwire to begin the space closure phase. The interval between each archwire was between three to four weeks interval.

Figure 1: The left side with NiTi coil spring

After the levelling and alignment phase, the canine retraction was performed on the left side using a NiTi coil spring (Jinsung, Korea) and on the right side using a T-loop retraction spring after cutting the wire distal to the maxillary right lateral incisor to resemble an area of frictionless mechanics on the right maxillary canine. The necessary anchorage was made according to each treatment demands.

Figure 2: Insertion of the T-loop with activation of 3 mm

Before retraction, a lower alginate impression (Kromopan via L. Longo 18 - 50019 Sesto Fiorentino-Frenze-Italy) was taken and poured in dental stone (®ORTOGUIX III, Protechno, Spain) for fabrication of splint made of a thermoplastic material of 1.5 mm thickness as recommended by Ghoneim, 2010 [11].

T - loop closing coil spring was fabricated from a straight 0.017 X 0.025 TMA wire according to Nanda [12] using a fabrication template for standardisation, and pre-activated according to Marcotte [13], the angle between the mesial and distal arms of the T-loop was standardised to be 47 degrees. Anti-Rotation bends were made at both mesial and distal arms. The T-loop was inserted and ligated into the right maxillary canine using ligature wire, and a3 mm activation was achieved using the Boley gauge.

On the right side, a closing coil spring 8 mm in length was attached to the first molar, and a force of 150 grams was used for retraction. The maxillary left premolar and first molar were ligated together as an anchoring segment; the left maxillary canine was distally ligated with conventional ligature wire to prevent distal rotation during retraction.

The patients were seen every four weeks. The force was measured and activated to keep it constant all over the retraction phase. The post retraction CBCT was taken after four months and treatment was continued according to the treatment plan for each patient.

The following points, lines and planes were identified on each CBCT image:

SPH (Sphenoid - ethmoidal): A point representing the junction of the sphenoid and ethmoid bones and is located in the anterior cranial fossa.

PTMr – PTMl (Pterygomaxillary): the lowest point of each teardrop-shaped Pterygomaxillary

_____

fissure at both sides.

U3IPr – U3IPl (maxillary canine incisal point): the tip of the incisal edge of each maxillary canine.

U3RPr – U3RPl (maxillary canine root point): the apex of the root of each maxillary canine.

FP (Frontal plane): established by SPH, PTMr and PTMl points.

The canine anteroposterior movement was measured as the perpendicular distance from (U3IPr or U3IPl) to the FP (Frontal plane), and calculated using the following equation:

Canine distalization = U3 APpost – U3 APpre

Figure 2: CBCT volumetric image showing the maxillary canine anteroposterior position measurements about frontal plane

The maxillary canine length was measured as the perpendicular distance from (U3IPr or U3IPl) to (U3RPr or U3IRPl) and calculated using the following equation:

Vertical length = U3 RESP post – U3 RESP pre

Statistical analysis

Data were presented as mean, standard deviation (SD) and standard error (SE) values. Data were explored for normality using Kolmogorov-Smirnov and Shapiro - Wilk tests; the results revealed that all measurements were normally distributed (parametric data). Levene's test was used to test the homogeneity of variance between the two sides. Non - significant results of Levene's test indicate homogeneity of variance. Paired t-test was used to compare between parametric data in the left and right sides as well as to compare between the data pre - and post-treatment.

The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Version 20 for Windows.

Results

Comparing the anteroposterior position of the canine pretreatment showed none statistically significant difference between both sides (Table 1).

Table 1: Descriptive statistics & significant changes for the maxillary canine anteroposterior measurement pre - retraction on both sides

Side Measurements	NiTi coil spring side			T - loop side			*P*-value
	Mean	SD	SE	Mean	SD	SE	
AP (mm)	51.1	4.1	1.3	51.1	4.8	1.5	0.976

* Significant at P ≤ 0.05 using paired t-test; **(AP)** Antero-posterior canine position.

Concerning the NiTi coil spring side, there was a statistically significant decrease in the mean measurement of the anteroposterior (AP) position of the canine post-retraction indicating distal canine movement. There was no statistically significant difference in canine length pre and post retraction (Table 2).

Table 2: Descriptive statistics & significant changes for the maxillary canine anteroposterior measurement and Canine length pre - & post - retraction with the Ni-Ti coil spring

Period	Pre-retraction			Post-retraction			*P*-value
Measurements	Mean	SD	SE	Mean	SD	SE	
AP (mm)	51.1	4.1	1.3	48	3.8	1.2	0.001*
RESP (mm)	26.4	2.1	0.7	26.2	2.1	0.7	0.637

* Significant at P ≤ 0.0 using Paired t-test **(AP)** Antero-posterior canine position; **(RESP)** canine length.

On the other hand the T - loop side showed non - statistically significant change in the anteroposterior position and length of the canine (Table 3).

Table 3: Descriptive statistics & significant changes for the maxillary canine anteroposterior measurement and canine length pre- & post- retraction with the T - loop

Period	Pre-retraction			Post-retraction			*P*-value
Measurements	Mean	SD	SE	Mean	SD	SE	
AP (mm)	51.1	4.8	1.5	50.8	4.7	1.5	0.642
RESP (mm)	27.5	1.8	0.6	26.4	2.4	0.8	0.067

* Significant at P ≤ 0.05 using paired t-test; **(AP)** Antero-posterior canine position; **(RESP)** canine length.

On comparing between both sides post retraction, T - loop side showed statistically significantly higher mean (AP) measurement than NiTi coil spring side, indicating a lower rate of canine movement than the NiTi coil spring side (Table 4).

Table 4: Descriptive statistics & significant changes for the maxillary canine anteroposterior measurements post- retraction in the two sides

Side	NiTi coil spring side			T-loop side			*P*-value
Measurements	Mean	SD	SE	Mean	SD	SE	
AP (mm)	48	3.8	1.2	50.8	4.7	1.5	0.010*

* Significant at P ≤ 0.05 using paired t-test; **(AP)** Antero-posterior canine position

_____

Discussion

The extraction of first permanent premolars for correction of various malocclusions has become an integral part of the orthodontic treatment procedures. Techniques of space closure are various. However they can be classified under two main mechanics; the sectional mechanics which involves frictionless tooth movement, and the continuous mechanics involving friction tooth movement.

A controlled tooth movement is always the goal of an orthodontist especially during the phase of canine retraction. Depending upon the relationship of the line of action of the force to the centre of resistance of the tooth, prediction of tooth movement in the three planes of space is possible [13]. A split-mouth technique was used in the present research aiming at standardisation of all variables as patient cooperation, oral hygiene and bone thickness. Canine retraction began after levelling and alignment; this was to eliminate any asymmetry between the two quadrants.

A standardised protocol was developed where the right canine was retracted using T - loop representing the sectional mechanics technique, and the left side was retracted using NiTi coil spring representing the continuous mechanics technique.

T - loops were constructed from 0.017 X 0.025 TMA straight wires, gable bends and anti-rotational bends were incorporated in the design. The selected design insured the delivery of high moment-to-force ratios and low horizontal force as reported by Thiesen et al. [14]. The spring design was fabricated as described by Nanda [12] and pre-activated as described by Marcotte [13]. The T - loop spring was activated 3 mm per visit to deliver approximately 150 gm of force, this activation protocol was recommended by Keng et al. [15].

Many retraction devices could be used to represent the continuous mechanics technique, However the choice of nickel-titanium closing coil springs used in this study was based on the fact that they do not exhibit rapid force decay such as seen with elastomeric chains or elastic modules, and deliver a constant light force which has been reported to be favorable in space closure [9][16]. It has been proven that excessive force application during space closure can produce adverse effects such as loss of incisor torque control and loss of tip and rotational control of upper molars with relative extrusion of their palatal cusps [16][17]. The low constant force of nickel-titanium springs may be more biologically compatible than the intermittent high forces delivered by elastomeric chains.

The force of 150 gm employed in the present study followed the recommendations of many authors who applied forces between 100 gm and 200 gm for canine retraction [18]. Boester and Johnston [19] found that 150 gm of retraction force gave the highest canine retraction rate Yet Ren et al. [20] have concluded that there is no evidence on an optimal force level.

In this study, cone beam computed tomography (CBCT), which is a three - dimensional tool was utilised in an attempt to overcome the limitations of the traditional two - dimensional projections. On discussing the obtained results from the three-dimensional analysis, the canine anteroposterior position before distalization and after distalization reveals the mean distance the canine travelled over the experimental period which can measure the rate of canine retraction at every side. The NiTi coil spring side showed a mean difference of 0.775 mm per month with a total distance of 3.1 mm in a period of 4 months, This rate of retraction comes into agreement with Dixon et al., [9] However other authors reported faster rates of canine retraction reaching 1.04 mm per month as reported by Nightingale and Jones [10], and 1.81 mm per month reported by Hyashi et al., [21]. Probably their higher rate of canine retraction could be due to the use of round cross-sectional wires with smaller diameters than the one used in this study.

The T - loop side showed a mean difference of 0.1 mm per month with a total distance of 0.3 mm in 4 months. The very low rate of canine retraction on this side was probably due to introducing a high moment – to - force ratio which was greater in value than the moment of force produced by activation of the T - loop to deliver 150 gm of retraction force, this ended up by achieving distal root movement with minimal crown movement. This justification comes into agreement with Thiesen et al. [14] who proved that T - loops constructed from 0.17 X 0.25 TMA wires yielded lower levels of horizontal forces, and that gable bends delivered high moment to force ratios.

Concerning canine length and root resorption, our statistically non - significant results are in agreement with those results in previously conducted studies held by Brusveen et al. [22] and Perona et al. [23].

In conclusion: the NiTi coil spring side showed more distal movement than the T - loop side; and friction and frictionless retraction mechanics with controlled retraction force, do not cause root resorption.

References

1. Leonardi R, Annunziata A, Licciardello V. Soft tissue changes following the extraction of premolars in non growing patients with bimaxillary protrusion. Angle Orthod. 2010; 80:211-216. https://doi.org/10.2319/010709-16.1 PMid:19852663

2. Reznikov N, Har-Zion G, Barkana I, Abed Y, Redlich M. Measurement of friction forces between stainless steel wires and

_____

"reduced-friction" self ligating brackets. Am J Orthod Dentofacial Orthop. 2010; 138:330-8. https://doi.org/10.1016/j.ajodo.2008.07.025 PMid:20816303

3. Boester CH, Johnston LE. A clinical investigation of the concepts of differential optimal force in canine retraction. Angle Orthod. 1974; 44: 113-9. PMid:4597626

4. Gjessing P. Biomechanical design and clinical evaluation of a new canine retraction spring. Am J Orthod. 1985; 87:353-362. https://doi.org/10.1016/0002-9416(85)90195-2

5. Ziegler P, Ingervall B. A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. Am J Orthod.1989; 95:99-106. https://doi.org/10.1016/0889-5406(89)90388-0

6. Drescher D, Bourauel Ch, Schumacher H A. Frictional forces between bracket and arch wire. Am J Orthod Dentofacial Orthop. 1989; 96:397-404. https://doi.org/10.1016/0889-5406(89)90324-7

7. Drescher D, Bourauel C, Schumacher H A. Optimization of arch guided tooth movement by the use of uprighting springs. Eur J Orthod. 1990; 12:346-353. https://doi.org/10.1093/ejo/12.3.346 PMid:2401343

8. Nightingale C, Jones SP. A clinical investigation of force delivery systems for orthodontic space closure. J Orthod. 2003; 30:229-36. https://doi.org/10.1093/ortho/30.3.229 PMid:14530421

9. Dixon V, Read MJF, O'Brien KD, Worthington HV, and Mandall NA. A randomized clinical trial to compare three methods of orthodontic space closure. J Orthod. 2002; 29:31-6. https://doi.org/10.1093/ortho/29.1.31 PMid:11907307

10. Nightingale C, Jones SP. A clinical investigation of force delivery systems for orthodontic space closure. J Orthod. 2003; 30:229-36. https://doi.org/10.1093/ortho/30.3.229 PMid:14530421

11. Ghoneim M. Three dimensional evaluation of the effects of skeletally anchored Haas expander. M.Sc Thesis. Cairo University, 2010.

12.. Nanda R. Biomechanics in clinical orthodontics. 1st ed. W.B. Saunders company, 1997: 166-167.

13. Marcotte MR. Biomechanics in orthodontics. 1st ed. B.C Decker Inc. 1990: 63-65.

14. Thiesen G., Rego MV, Menezes LM, Shimizu RH. Force systems yielded by different designs of T: loop. Aust J Orthod. 2005; 21:103-110.

15. Keng FY, Quick AN, Swain MV, Herbison P. A comparison of space closure rates between preactivated nickel–titanium and titanium–molybdenum alloy T-loops: a randomized controlled clinical trial. Eur J Orthod. 2012; 34:33–38. https://doi.org/10.1093/ejo/cjq156 PMid:21415288

16. Samuels RHA, Rodge SJ, Mair LH. A comparison of the rate of space closure using a nickel-titanium spring and an elastic module: A clinical study. Am J Orthod Dentofacial Orthop. 1993; 103: 464-67. https://doi.org/10.1016/S0889-5406(05)81798-6

17. Eid F. A comparative study to reveal the effects of different orthodontic force magnitudes during canine retraction. D.D.S Thesis, Cairo University, 1988.

18. Storey E, Smith R. Force in orthodontics and its relation to tooth movement. Aust Dent J. 1952; 56:11-18.

19. Lotzof LP, Fine HA, Cisneros GJ. Canine retraction: a comparison of two preadjusted bracket systems. Am J Orthod Dentofacial Orthop. 1996; 110:191-6. https://doi.org/10.1016/S0889-5406(96)70108-7

20. Ren Y, Maltha JC, Jagtman AM, Optimum Force Magnitude for Orthodontic Tooth Movement: A Systematic Literature Review. Angle Orthodontist. 2003; 73:86-92. PMid:12607860

21. Hayashi K, Uechi J, Murata M, Mizoguchi I. Comparison of maxillary canine retraction with sliding mechanics and a retraction spring: a three-dimensional analysis based on a midpalatal orthodontic implant. Eur J Orthod. 2004; 26: 585-589. https://doi.org/10.1093/ejo/26.6.585 PMid:15650067

22. Brusveen EM, Brudvik P, Bøe OE, Mavragani M. Apical root resorption of incisors after orthodontic treatment of impacted maxillary canines: a radiographic study. Am J Orthod Dentofacial Orthop. 2012; 141(4):427-35. https://doi.org/10.1016/j.ajodo.2011.10.022 PMid:22464524

23. Perona G, Wenzel A. Radiographic evaluation of the effect of orthodontic retraction on the root of the maxillary canine. Dentomaxillofac Radiol. 1996; 25(4):179-85. https://doi.org/10.1259/dmfr.25.4.9084270 PMid:9084270

_____