An Evaluation of Asymmetrical T-Loop Effects in Deep Bite Cases with Finite Element Analysis

Asimetrik T-Loop'un Derin Kapanış Vakalarında Etkisinin Sonlu Elemanlar Analizi ile Değerlendirilmesi

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ABSTRACT

Introduction: To examine tooth movements by activation of continuous asymmetrical T-loop arch wire for simultaneous incisor retraction and intrusion with 3D finite element analysis.

Methods:.018 inch Roth brackets(MiniDiamond,Ormco,Glendora,Calif.),molar tubes(GAC International Inc. Bohemia,NY,USA),.016x.022 TMA (Ormco,Orange,Calif)asymmetric T-loop arch wire were modelled.Tooth movements resulting from the activation of the asymmetric T-loop arch wire positioned between the upper lateral and canine teeth were investigated.

Results: The changes in the anterior region(upper central and lateral teeth) forces caused movement in the mesial direction.In the labiopalatinal direction, palatinal tipping was observed while the incisors were retracting.The assessment of the posterior group(upper canine,second premolar, first molar, second molar) revealed that crowns of all posterior teeth moved towards palatinal direction except second molar.In addition, mesialization in the posterior region occured more parallel to the posterior from the canine tooth.The maximum amount of movement in the vertical direction was detected in the lateral tooth,followed by the central tooth.The direction of the movement in the posterior group was opposite to the incisors.

Discussion and Conclusion: With the asymmetrical T-loop archwire,intrusion and retraction of the incisors can be performed simultaneously; however some extrusion takes place in the posterior region.

Keywords: *Deep bite, T-loop, incisor intrusion, incisor retraction*

ÖZ

Giriş ve Amaç: Eş zamanlı kesici diş retraksiyonu ve intrüzyonu amacıyla aktivasyonu yapılan asimetrik T-loop devamlı ark telinin meydana getirdiği diş hareketlerini 3 boyutlu sonlu elemanlar analizi ile incelemek.

Yöntem ve Gereçler: .018 inç Roth braketler (MiniDiamond, Ormco, Glendora, Calif.), molar tüpler (GAC International Inc. Bohemia, NY,USA), .016x .022 TMA (Ormco, Orange,Calif)asimetrik T-loop ark teli modellenmiştir.Üst lateral ve kanin dişler arasına yerleştirilen asimetrik T-loop ark telinin aktivasyonu sonucu oluşan diş hareketleri araştırılmıştır. Maksiller dişlerin eğimindeki değişiklikler ve dişlerin ilk yer değiştirmesi "X","Y", "Z" eksenlerinde analiz edilmiştir.

Bulgular: Ön bölgede (üst santral ve lateral dişlerde) meydana gelen kuvvetler mezial yönde harekete neden olmuştur. Labiopalatinal yönde, lateral diş retrakte olurken palatinal yönde devrilme gözlenmiştir. Posterior grup dişleri (üst kanin, ikinci premolar, birinci molar, ikinci molar) değerlendirildiğinde, ikinci molar diş hariç tüm posterior dişlerin kronlarının palatinal yöne doğru hareket ettiği görülmüştür. Ayrıca posterior bölgede mezializasyon kanin dişten posteriora doğru gidildikçe daha paralele yakın olmaktadır. Dikey yönde maksimum hareket miktarı lateral dişte, ardından santral dişte tespit edilmiştir. Arka grup dişlerdeki hareketin yönü kesici dişlere ters yöndedir.

Tartışma ve Sonuç: Asimetrik T-loop ark teli ile kesici dişlerin intrüzyonu ve retraksiyonu aynı anda yapılabilir; ancak arka bölgede bir miktar ekstrüzyon meydana gelmektedir.

Anahtar Kelimeler: *Derin kapanış, T-loop, keser intrüzyonu, keser retraksiyonu*

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INTRODUCTION

Deep bite has defined as a condition of excessive overbite, where the vertical measurement between the maxillary and mandibular incisal margins is excessive when the mandible is brought into habitual or centric occlusion.[1] Excessive overbite should be corrected in order to obtain a harmonic facial expression and a balanced occlusion and function in individuals with skeletal and/or dental deep bite.[2] Deepbite can be treated orthodontically by intrusion or flaring of the incisors, extrusion or passive eruption of the buccal segments, or a combination of these.[3-5] The choice of treatment depends on several factors. Extrusion of the posterior teeth is not indicated in patients with normal incisor display or normal or long lower facial height; its effectiveness and stability is controversial in nongrowing patients with average to low mandibular plane angles.[5-8] Intrusion of maxillary incisors is preferred in patients with excessive incisor and gingival display and a large interlabial gap and it is effective for a stable occlusion in the orthodontic treatment of the adults rather than extrusion of molars.[5,9-11]

The cases requiring selective incisor intrusion include the cases where the vertical dimensions of the face increased, extrusion of the molar teeth is not desired, and/or the upper incisors are crossing the occlusal plane and the upper lip.[9] Many techniques have been used for this and their effects have been revealed.[12-14] Hilgers[15] introduced the "Asymmetrical T loop" in 1992 which provides simultaneous incisor retraction and intrusion (Figure 1); this bending is implemented in order to perform incisor retraction and intrusion, which are two important stages in long-lasting orthodontic treatment, both significantly shortens the treatment time and reduces the need for the use of additional mechanics.

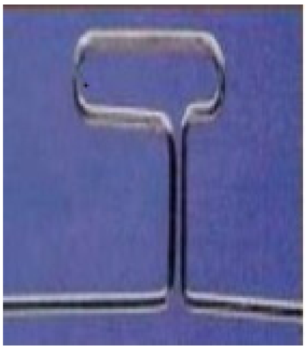

Figure 1. Preactivation of the asymmetrical T loop.

However, there are a few case presentations and a FEM study[16] but not any clinical study showing the asymmetric T-loop effects.[15,17] Techalertpaisan et al.[16] studied continious T-loop force system with and without vertical steps by FEM method. Unlike the asymmetrical T-loop introduced by Hilgers,[15] in this study, the T-loops were positioned between the canine and premolar teeth and the loop sizes were different with a 0.5- 1 mm vertical step. They evaluated M/F ratio and load deflection ratio under different forces and different activation distances.[16] Girsa et al. also studied about the T-loop effects with different pre-activation curves in lingual orthodontics. As the applied force is lingual to the center of resistance, lingual orthodontics is different in order to labial orthodontics.[18]

The aim of this study was to evaluate initial tooth displacement through "Asymmetrical T-loop" by means of the finite element method and investigate the clinical applicability.

MATERIAL and METHOD

This research was performed in Orthodontics Department of Gazi University Faculty of Dentistry and Ay Tasarım Limited Company. Cone-beam computed tomography scans were used for three dimensional reconstruction of the maxilla and maxillary dentition. The model included the maxilla with premolar extracted maxillary dentition and the asymmetrical continious T-loop arch placed in the brackets. The displacement of the maxillary teeth is examined by activation of the arch wire in three dimensional shape (3D) (Figure 2). The research was carried out by performing static linear analysis with 3D finite element analysis method.

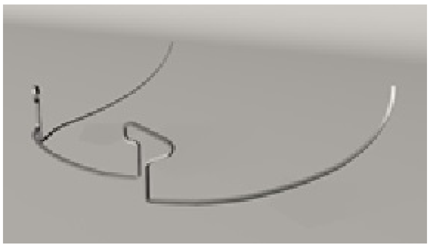

Figure 2. Lateral view of the preactivation .016x .022 TMA wire simulation

Material values(modulus of elasticity and Poisson's ratio) describing their physical properties are given to each of the structure that make up the models (Table 1).[19-24]

Table 1. The Young module and Poisson rate of anatomic structures and materials used in the study[19-24]

	Young module (Mpa)	Poisson Rate
Beta-titanium[20]	62000	0,3
Bracket (stainless steel)[23]	200000	0,29
Suture[24]	1	0,47
Enamel[19]	8400	0,33
Cortical bone[21]	14700	0,3
Trabecular bone[22]	1370	0,3
Periodontal ligament[20]	$0{,}68x10^{-5}$	0,45

All models are assumed to be linear, homogeneous and isotropic. The number of elements was selected by considering the dimensions of the jaw bone model that we selected, as much as the program allows in order to obtain realistic results.

The number of elements and nodes used in the mathematical model containing the scenarios are 644018 and 166694, consecutively.

The teeth were modeled according to the morphological values in the Wheeler Atlas.[25] Locations of all teeth at "X", "Y", and "Z" axes were created by assigning the type, torque and rotation values in the Roth prescription in accordance with the facial axis principle of Andrews.[26,27] The "X" axis represents the transversal direction, movements in the mesiodistal direction for anterior group teeth and buccopalatal movements for posterior group teeth are shown on the "X" axis. The "Y" axis represents the sagittal direction, the displacements in the labiopalatal direction for anterior teeth, and the displacements towards the mesiodistal direction for posterior group teeth are shown on the "Y" axis. The "Z" axis represents the vertical direction, displacements in the inciso/occluso-apical direction for anterior and posterior teeth are shown on the "Z" axis.

The brackets were placed on the long axis of the tooth, in the middle 1/3 of the mesio-distal width of the clinical crown and in the midpoint of the clinical crown in height. The anterior and the posterior segment are connected with 8 ligatures.

Dimensional measurements of .018 inch slot Roth brackets and first and second molar tubes were performed through Mitutoyo Absolute System 150 mm digital caliper manually in accordance with the original shape and dimensions, Rhinoceros 4.0 (McNeel Inc., Seattle, WA, USA) three-dimensional modelling software.

A .016x .022 titanium molybdenum alloy (TMA) wire was used in the study. Wires and bends were manually modeled in 3D modeling software Rhinoceros 4.0 (McNeel Inc., Seattle, WA, USA) with original shapes and dimensions. The continuous archs containing the asymmetric T-loop used in this study were created as described by Hilgers [15] (Figure 3).

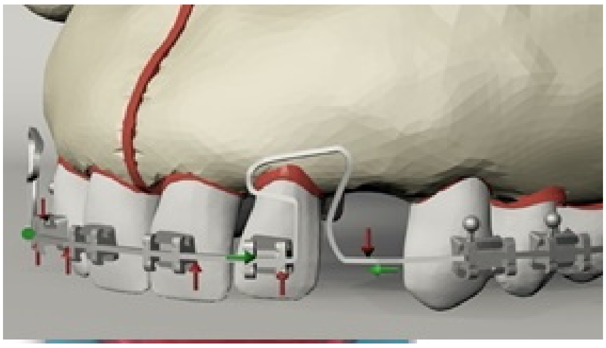

Figure 3. Lateral view of the activated asymmetrical T-loop archwire attached to molar tubes and brackets. The forces affecting the activated asymmetric T-loop are shown with green and red arrows.

Asymmetrical T-loop archwire was bent to form a 5 mm vertical step, 2 mm anterior loop and 5 mm posterior loop from the TMA wire, and a Spee curve is provided with increasing inclination from the premolar teeth (Figure 1, Figure 2).[15]

After giving the Spee curve the distance of the distal end of the wire to the horizontal reference plane was 8 mm. A 2 mm of sagittal and 2 mm of vertical activation is applied to the wire during activation. During vertical activation, the short anterior loop was compressed and the long posterior loop was opened (Figure 4-5-6). [15] The forces acting on the wire are shown in Figure 3 .

Figure 4. Compression is applied to the shorter mesial loop.

Figure 5. Longer distal loops are opened.

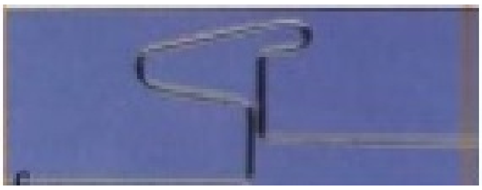

Figure 6. Loop image after reactivation.

The models made in Rhino were transferred to Fempro software by preserving the 3D coordinates, and the models were fixed at 6 Degrees of Freedom (DOF) from the posterior and upper regions of the bone. Coefficient of Friction value between bracket and wires is defined as 0.2. Wire movements were defined by the "Predescribed Displacement" method by taking the geometry of the bend into account.

Hilgers[15] suggested torque bending of the wire in the mouth to prevent tipping during incisor retraction; however, the literature did not mention the amount of torque value that had given (Figure 7-8). In this study, 30 ° of labio-palatinal torque was applied to the anterior part of the wire to provide nearly parallel retraction of the incisors in order to balance the uncontrolled incisor tipping that had occurred in the sagittal plane after the activation of the asymmetrical T-loop arch wire.

The forces were measured by a force gauge by applying a continuous asymmetrical T-loop archwire to the typodont model and bent in order to determine the amount of force applied by the asymmetrical T-loop archwire to the maxillary teeth suggested by Hilgers[28] (Figure 9).

Figure 7. Torque bending image given in the mouth with collet

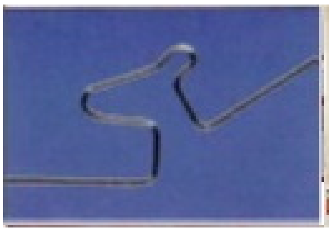

Figure 8. T-loop image after torque bending

Figure 9. Application of the asymmetrical T-loop to the typodont model and measurement was done from the mesial of the lateral bracket with the help of a force gauge. The force gauge shows 75 grams of force.

RESULTS

Displacement results were expressed in millimeters (mm) and examined in 4 different directions including resultant, transversal, sagittal and vertical direction. Displacement amounts were also graphically shown against a color scale.

Movements Appeared at "X" Axis

Movements in the mesiodistal direction for anterior group teeth and buccopalatal movements for posterior group teeth are shown on the "X" axis. Accordingly, (+) direction indicates distal tipping and (-) direction mesial tipping in anterior teeth. In posterior group, (+) direction indicates movement towards buccal direction while (-) direction indicates movement towards the palatal direction. The force appeared as a result of the activation of the arch wire created a (-) mesial force on the apical end and incisal edge of the central tooth, and on the incisal edge of the lateral tooth (Figure 10, Figure 11). The mesial movement at the incisal edge of the lateral tooth was approximately 10 times greater than that of the central tooth (Fig 10) (Table 2). (Movement at the incisal edge of the lateral tooth= -0.004414 mm) (Movement at the incisal edge of the central tooth= -0.000195 mm). The amount of movement at the apical tip and incisal edge of the lateral tooth was similar but in opposite directions. There was a mesial (-0.004414 mm) movement in the lateral tooth crown and a distal (+0.004742 mm) movement at the apical tip. The apical tip of the central tooth moved 8 times more mesially than the incisal edge (Amount of movement at the apical tip of the central tooth=-0.000828 mm) (Fig 10) (Table 2, Table 3).

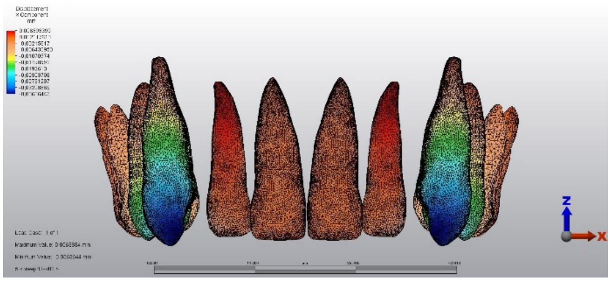

Figure 10. Frontal view of movements occurring in the "X" axis

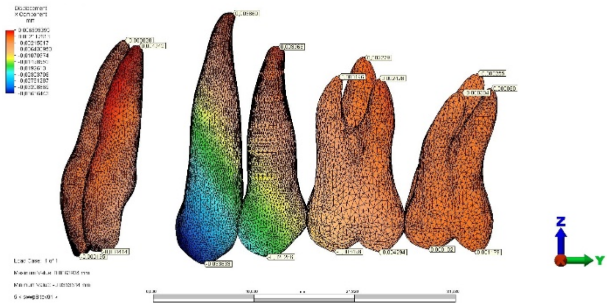

Figure 11. Lateral view of movements occurring in the "X" axis

Table 2. Displacement amounts at "X", "Y", "Z" axis and total displacement amounts on the incisal edges and cusp ends

	"X" axis	**"Y" axis**	**"Z" axis**	**Resultant/Total displacement amounts**
Central incisal edge	-0.1 x 10^{-3}	58x10^{-3}	17x10^{-3}	61x10^{-3}
Lateral incisal edge	-4x 10^{-3}	67x 10^{-3}	21x 10^{-3}	71x 10^{-3}
Canine cusp end	-33 x 10^{-3}	-8 x 10^{-3}	-15 x 10^{-3}	37 x 10^{-3}
2nd premolar cusp end	-20 x 10^{-3}	-13 x 10^{-3}	-15 x 10^{-3}	29 x 10^{-3}
1st molar cusp end	Mesiobuccal cusp: -8x10^{-3}	Mesiobuccal cusp: -15x10^{-3}	Mesiobuccal cusp: -12x10^{-3}	Mesiobuccal cusp end: 21x10^{-3}
	Distobuccal cusp: -4x10^{-3}	Distobuccal cusp: -15x10^{-3}	Distobuccal cusp: -14x10^{-3}	Distobuccal cusp: 21x10^{-3}
	Mesiopalatinal cusp: 8x10^{-3}	Mesiopalatinal cusp: 10x10^{-3}	Mesiopalatinal cusp: 10x10^{-3}	Mesiopalatinal cusp end: 16x10^{-3}
	Disto-palatinal cusp: 3x10^{-3}	Disto-palatinal cusp: 10x10^{-3}	Disto-palatinal cusp: 11x10^{-3}	Disto-palatinal cusp:16x10^{-3}
2nd molar apical	Mesiobuccal cusp: 0.1x10^{-3}	Mesiobuccal cusp: -16x10^{-3}	Mesiobuccal cusp: -15x10^{-3}	Mesiobuccal cusp: 23x10^{-3}
	Distobuccal cusp: 1x10^{-3}	Distobuccal cusp: -17x10^{-3}	Distobuccal cusp: -18x10^{-3}	Distobuccal cusp: 24x10^{-3}
	Mesiopalatinal cusp: -8,726615e-06 *	Mesiopalatinal cusp: 14x10^{-3}	Mesiopalatinal cusp: 16x10^{-3}	Mesiopalatinal cusp: 21x10^{-3}
	Disto-palatinal cusp: 0.9x10^{-3}	Disto-palatinal cusp: 15x10^{-3}	Disto-palatinal cusp: 18x10^{-3}	Disto-palatinal cusp: 23x10^{-3}

Table 3. Displacement amounts at "X", "Y", "Z" axis and total displacement amounts on the apical region.

	"X" axis	**"Y" axis**	**"Z" axis**	**Resultant/Total displacement amounts**
Central apical	-0.8 x 10^{-3}	29x10^{-3}	23 x 10^{-3}	37 x 10^{-3}
Lateral apical	4x 10^{-3}	6x 10^{-3}	31x 10^{-3}	32x 10^{-3}
Canine apical	3x 10^{-3}	-20x 10^{-3}	-15x 10^{-3}	26x 10^{-3}
2nd premolar apical	3x 10^{-3}	-23x 10^{-3}	-16x 10^{-3}	28x 10^{-3}
1st molar apical	Mesiobuccal apical: 0.1x10^{-3}	Mesiobuccal apical: -15x10^{-3}	Mesiobuccal apical: -15x10^{-3}	Mesiobuccal apical: 21x10^{-3}
	Distobuccal apical: 0.2x10^{-3}	Distobuccal apical: 15x10^{-3}	Distobuccal apical: 15x10^{-3}	Distobuccal apical:23x 10^{-3}
	Palatinal apical: 2x10^{-3}	Palatinal apical: -10x10^{-3}	Palatinal apical: -12x10^{-3}	Palatinal apical: 16x10^{-3}
2nd molar apical	Mesiobuccal apical: -0.2x10^{-3}	Mesiobuccal apical: -9x10^{-3}	Mesiobuccal apical: -17x10^{-3}	Mesiobuccal apical: 19x10^{-3}
	Disto-buccal apical: 0,08x10^{-3}	Disto-buccal apical: -9x10^{-3}	Disto-buccal apical: -17x10^{-3}	Distobuccal apical: 20x10^{-3}
	Palatinal apical: 0.3x10^{-3}	Palatinal apical: -6x10^{-3}	Palatinal apical: -18x10^{-3}	Palatinal apical: 19x10^{-3}

The review of the posterior group revealed that crowns of all posterior teeth moved towards palatinal direction except second molars whereas roots moved towards buccal direction (Figure 10). The crown moved approximately 10 times more than apical region in all teeth. The amount of movement in the canine and premolars was similar; however, it was 10 times more than in the molars (Table 2, Table 3) (Movement distance at the incisal edge of the canine tooth=-0.033633mm) (Movement distance at the apical tip=-0.003860 mm).

Movements Appeared at "Y" Axis

The displacements in the labiopalatal direction for anterior teeth, and the displacements towards the mesiodistal direction for posterior group teeth are shown on the "Y" axis. Accordingly, (+) direction indicates the palatinal movement and (-) direction indicates the labial movement. In posterior teeth group, (+) direction indicates the distal movement while (-) direction indicates the mesial direction (Figure 12, Figure 13).

The retraction force created by the activation of the T- loop caused a movement in the (+) direction towards palatal direction at the apical tip and incisal edge of the lateral and central teeth (Fig. 13). According to the values obtained, the incisal edge of the lateral tooth moves approximately 10 times more than the apical tip, and as a result of this movement, tipping was observed while the lateral tooth was retracting (the amount of movement at the incisal edge=0.067810 mm) (the amount of movement at the apical tip=0.006857). The tipping in the central tooth, during the retraction movement was much less than the lateral tooth (Movement at the incisal edge=0.058530 mm) (Amount of movement at the apical tip=0.029387 mm) (Figure 12)(Table 2, Table 3).

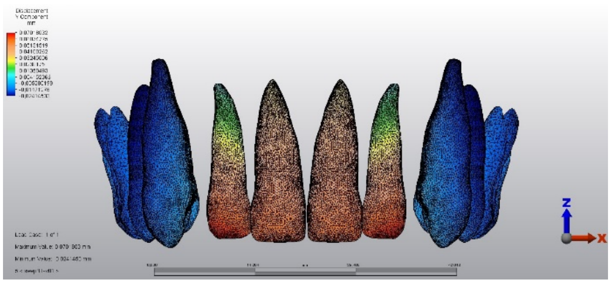

Figure 12. Frontal view of movements occurring in the "Y" axis

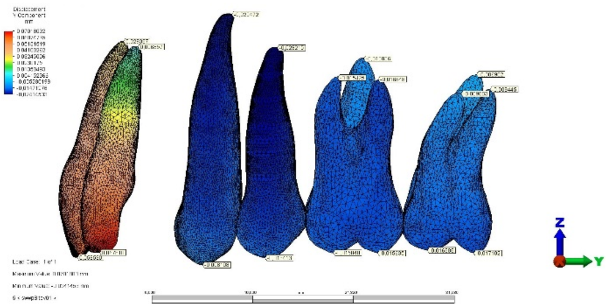

Figure 13. Lateral view of movements occurring in the "Y" axis

When the posterior group teeth were examined, (-) mesial movement occurred in all posterior teeth as a result of the activation of the archwire with asymmetric T-loop. Movement at the apical tip of the canine tooth is approximately 10 times greater than the incisal edge (Mesiodistal tipping) (Amount of movement at the incisal tip=-0.008108 mm) (Amount of movement at the apical tip=-0.020472 mm) The second premolar tooth is closer to parallel presenting a mesialization (Incisal tip=-0.013413 mm) (Apical tip=-0.023215 mm). Mesialization close to the first molar tooth is observed whereas mesiodistal tipping is evident in the second molar teeth. These values are shown in Figure 12.

Movements Appeared at "Z" Axis

Displacements in the inciso/occluso-apical direction for anterior and posterior teeth are shown on the "Z" axis. Accordingly, (+) direction indicates the movement in the apical direction, and (-) direction indicates the movement in the incisal/occlusal direction.

In Figures 14 and 15, vertical displacements of teeth on the "Z" axis were examined. In the anterior region corresponding to the shorter leg of the asymmetrical T-loop (+) resulted in intrusion; however, the posterior region corresponding to the longer leg resulted in extrusion movement. The maximum amount of movement in the vertical direction at the incisal edges was detected in the lateral tooth (0.021024 mm), it was followed by the incisal edge of the central tooth (Figure 14). The movement distance in the posterior group occlusal regions was in the opposite towards incisors and less. (The movement distance of the incisal edge of the canine tooth=- 0,015040 mm) (The movement distance of the incisal edge of the canine tooth =-0.015985 mm).

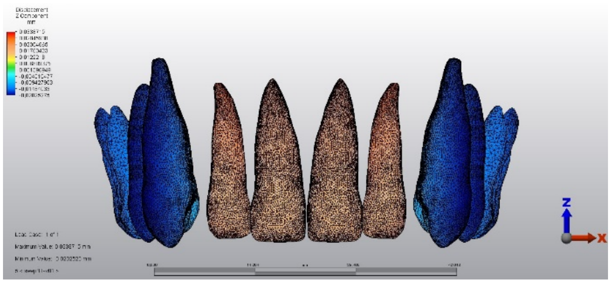

Figure 14. Frontal view of movements occurring in the "Z" axis

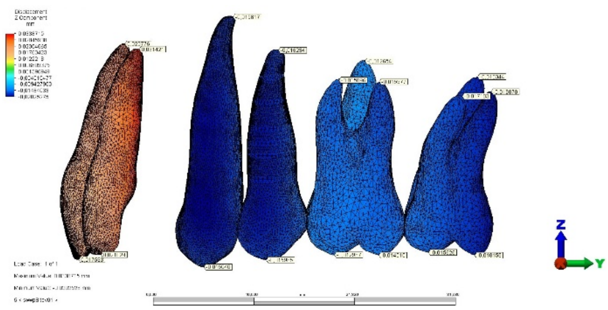

Figure 15. Lateral view of movements occurring in the "Z" axis

When root tips were examined, the apical tip of the lateral tooth moved towards the positive direction more than the apical tip of the central tooth (Lateral tooth apical tip=0.031421 mm) (Central tooth apical tip=0.023776 mm). The amount of root tip movement of the teeth in the posterior region was negative and similar to each other (Canine root tip = 0.015817 mm) (First molar mesiobuccal root tip = 0.015096 mm). The amount of extrusion at the apical ends of the posterior teeth was 2-3 times less than the amount of intrusion of the apical ends of the anterior teeth when compared to incisors (Table 3).

The Examination of Total/ Resultant Displacement of the Teeth

The displacement amounts which was the resultant of the displacements in the "X", "Y", "Z" axes of the teeth were examined in Figure 16. The most significant displacement was observed at the incisal edges of the lateral teeth (0.071131 mm). A displacement of 1/2 to 1/3 of the amount of movement of the incisors was observed in the incisal of the canine teeth and subsequent posterior teeth (The incisal edge of the canine tooth =0.0377 mm) (The incisal edge of the second premolar tooth=0.029102 mm) (Figure 16). Although the displacement distances on the apical region were more on anterior teeth, they were similar (Table 3).

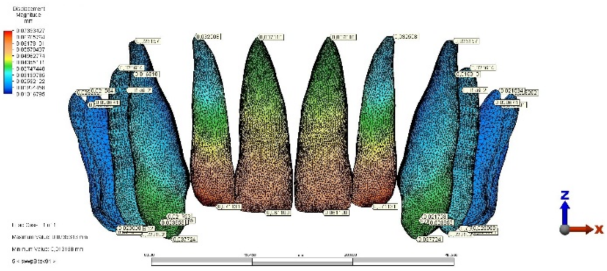

Fig. 16. Frontal view of the motion simulation that will occur in the teeth when the extraction gaps are closed as a result of the asymmetric T-loop activation

When the resultant displacement simulation was superimposed, an apparent intrusion and excessive tipping movement occured in incisors, while minimal displacements were observed in posterior teeth (Figure 17).

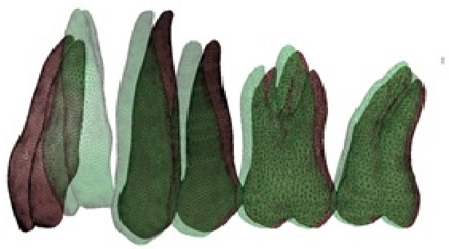

Figure 17. Overlay image of the resultant motion simulation. Brown colors indicate the position at the beginning of the movement whereas green colors indicate the positions of the teeth at the end of the movement.

The incisor angles were evaluated in an imaginary reference plane imitating the maxillary plane, the angle between the upper incisors and the horizontal plane was 102˚ at the beginning of the movement (Norm= 104˚ +-6.2˚) and decreased to 85˚; and tipping by 17˚ appeared at the end of the movement. These values are shown in Figure 18.

A torque of 30˚ was applied to the incisors to provide a nearly parallel retraction of the 4 incisors in order to compensate the excessive tipping movement (Figure 19).

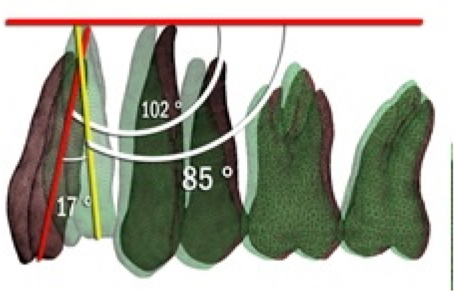

Figure 18. Change in the incisor angles as a result of the movement in the teeth. The brown color shows the tooth positions at the beginning of the movement; the green color shows the tooth positions after the movement.

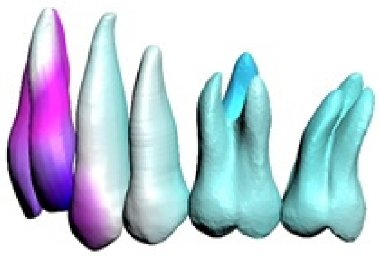

Figure 19. Tooth movement simulation using a 30˚ torqued archwire.

DISCUSSION

Proper positioning of the upper incisors is important for function, stability and aesthetics. Therefore, retraction of the upper incisors is one of the critical steps for a successful orthodontic treatment. The movement of the incisors depends on the tissue response of the biomechanics applied. The analysis of the force system and its effects is important for the optimum tissue response.[29]

There is a limited number of studies reported the effects of the asymmetric T-loop design in deepbite cases and there is not any study examining the movements created by this design in the teeth and supporting tissues.[16] The aim of our study is to examine and evaluate the instant tooth movement that occur during the simultaneous retraction and intrusion of incisors of the continuous asymmetric T-loop arch wire through 3D finite element analysis, which is intended to be used in deep bite cases.

Hilgers[15] said that the effects of the arch wire containing the asymmetrical T-loop are equal in both extraction and not extraction cases. In this study, these movements were investigated on the maxilla model with the premolar teeth extracted in order to increase the amount of activation of the wire during the use of the technique.

Finite element analysis (FEM) which is used in the solution of complex analytical systems in engineering may be applied to all kinds of objects and complex structures in dentistry[30] by not limiting the number of materials used, obtaining displacements sensitively, controlling the experimental model and changing the boundary conditions. This analysis method was preferred in our study because of its advantages such as reflecting mechanical and physical properties very well. [31, 32]

The characteristics of the force applied by these mechanics should also be taken into account while deciding on the mechanics to be applied for intrusion. TMA wires have lower modulus of elasticity (load-deflection ratio) than stainless steel wires and do not require helix bending, apply approximately 50% lower force than stainless steel wires in similar activations, shapeability properties are superior to nickel titanium wires and intermittent force application has such advantages.[33] In our study, .016x .022 inch TMA wire was used depending on 2 reasons; it was aimed to use the same properties specified in Hilgers' article and to keep the intrusion force low for the incisors to not cause any root resorption. TMA(β titanium) wires are more elastic than steel wires by 40%. It’s spring back values are higher than other wires and the working range is also wide. The absence of nickel makes this wire corrosion resistant and ensures biocompatibility.[34]

The force acting in the "X" axis creates a rotational moment in the "Y" axis. The mesiodistal tipping of the incisors is controlled by this moment/force ratio.[35]

It was observed in this study that the crown of the posterior teeth, especially the canine and the second premolar, were tilted to the palatal side (Figure 10). It is recommended to use devices such as transpalatal arch, quad helix, etc.in order to prevent the narrowing of the arc.[36] However, such instruments were not included in our study to ensure the compatibility with the literature.[15]

The T-loop arch wire used in our study was placed close to the lateral tooth with an interbracket distance of 42 mm, as stated in the study of Chen et al.[35] and the loop was activated in the sagittal direction of 2 mm. The study findings of Chen et al. are similar with our study, that palatal tipping of the posterior tooth crowns occurs as a result of this activation.[35]

Accordingly, the mesiodistal force acting on the incisors should increase in order to reduce the tipping motion in the “Y” axis. Chen et al.[35] stated that the mesiodistal force acting on the incisors in the “X” axis is insufficient and a greater amount of force is needed in the Fx direction for the nearly parallel retraction of the incisors. In order to increase the force in the X axis, the loop position was changed to be close to the lateral or canine tooth. Furthermore, the movements that would occur in 1 and 2 mm loop activation were examined; however, no significant difference was observed.[35]

The moment at the “X” axis which is formed by the Fy force acting on the incisors in the labiopalatinal direction creates a movement opposite to the tilting movement of the incisors in the palatal direction. The positive values of Mx/Fy moment that will occur during this movement is a factor preventing palatal incisor tipping. Chen et al.[35] reported that the Mx/Fy ratio formed in the buccolingual direction is mostly positive; however, since these values are lower, it is insufficient to provide translation of the incisors in the labiopalatinal direction. Accordingly, a larger amount of Mx moment must be created for the translation movement to occur.[35]

A(-) mesial movement occurred in all posterior teeth to close the extraction gap as a result of the activation of the continuous asymmetric T-loop arch wire. However, it was observed that the roots bended mesially and the crowns distally, especially in the canine tooth (Figure.12, Figure13). This effect decreased towards molar teeth. This may be considered that the Spee curve was given to the posterior region had an effect as well as the negative moment resulting from the intrusion force.[4] Furthermore, it is considered that the reason for the less mesial displacement of the incisal edge of the canine when compared to the posterior group teeth was the higher tipping movement due to close location to the loop and the severe mesial movement in the root camouflaged the movement at the incisal tip. Burstone[4] stated that the best control of the reactive unit in the posterior region during incisor intrusion may be achieved by reducing the amount of force. When an intrusion force is applied with a continuous base-arc type system, vertical forces and moments occur.[4] The rotational tendency of the wire in the posterior region causes the distal movement of the molar crown and the mesial movement of the root. The force is kept lower in order to prevent this; much teeth as possible are included in the buccal segment.[4]

The use of a transpalatal arch connecting the anchorage of two opposing segments will increase the anchoring potential.[4, 5, 37] In addition, it will prevent anterior movement of the molar roots along with the usage of a short arm high-pull headgear passed above the resistance of molar center.[4,37]

Chen et al.[35] reported that the moment (Mx) in the "X" axis forces the canine tooth to distal rotation after the activation of the T-loop, and this moment reduces the effect of the posterior segment mesializing force (Fy) formed in the "Y" axis. The opposite of the same effect is also applicable for incisor teeth. Therefore, the forces and moments occurring in the "X" and "Y" axes affect each other.

The quantity of force that .016x.022 inch TMA asymmetrical T loop arch wire would apply to the incisors during the intrusion movement was measured with a force gauge from the mesial side of the lateral bracket (Figure 9). Accordingly, an average of 75 g force (approximately 18,5 g for each incisor) acted on the incisors with the asymmetrical T-loop arch wire. The optimal amount of force to be applied in the intrusion movement is controversial. Many researchers including Reitan, Burstone,[4] Bench, Gugino and Hilgers[38] Ricketts,[39] Liu and Herschleb,[40] Nicolai, Kesling,[41] Siatkowski,[42] Karanth and Shetty[43] mentioned about optimal intrusive forces. Burstone[4] addressed that it is appropriate to use the lowest possible force for incisor intrusion. If the force magnitude is large, the risk of root resorption would increase as opposed to the amount of intrusion.[44] Moreover, the posterior teeth would be extruded reciprocally and the tilting motion would be distally on the crown and mesially on the root. Burstone[4] stated that a force of 25 g for the upper incisors may be appropriate for intrusion; and if co-intrusion of 4 incisors is desired, a force of approximately 100 g (approximately 25 g per tooth) should be applied from the midline with a 30 mm long segmental arch. Nanda[5] indicated that intrusion force of 15 gr for the upper central incisor, 10 gr for the upper lateral incisor, 25 gr for the upper canine, 50-60 gr for the upper 4 incisors may be sufficient.

A standard T-loop, when positioned close to the anterior tooth and activated, the M/F ratio will be higher at the anterior part and creates an extrusion movement while the M/F ratio will be lower and an intrusion movement occures in the posterior tooth.[45,46] The step caused an increase in M/F ratio at the premolar bracket end, and a decrease in the canine bracket end.[16] With an asymmetric T-loop, the greatest vertical movement at the incisal edges was observed in the lateral tooth close to the loop (0.021024 mm), followed by the incisal tip of the central tooth. The amount of movement in the occlusal regions of the posterior teeth was opposite to the incisors and less(The amount of movement of the incisal tip of the canine=- 0.015040 mm) (Table 2). Burstone[4] stated that the light forces (40-60 gr) acting on the posterior segment during the intrusion of the incisors may be easily controlled by the occlusal forces originating from the muscles; however, if extrusion is not desired, the amount of force should not exceed these limits or he suggested the use of high-pull headgear. The intrusion quantity in the anterior group teeth is higher than the amount of extrusion in the posterior teeth group due to the higher anchorage of the posterior teeth group.

When the resultant displacement of the teeth was examined, the greatest displacement was observed at the distal incisal edge of the lateral tooth (0.071131 mm). This may be due to the fact that the posterior region anchorage is greater than the anterior region and the mesializing forces created by the increased Spee twist on the posterior tooth roots. The displacement was observed at the rate of 1/2 to 1/3 of the amount of movement of the incisors at the cusp tip of the canines and the following posterior teeth. This displacement amount decreased from canine towards molars (Figure.16) Higher displacement amount on the lateral and canine teeth, which were the closest to the loop bend was an expected finding (Table 2). Shorter root length and thinner structure of the lateral tooth is also a factor that facilitates the movement.

Individual variations are not taken into account in finite element analysis evaluations and our results cannot predict long-term tooth movement, since finite element models may only describe an initial movement system. The force system and individual biological responses may change as tooth movement progresses in the clinic. A prospective, comparative, and controlled clinical trial that evaluates the results found here could confirm the findings of this study.

CONCLUSION

1) Intrusion and retraction may be performed simultaneously in the incisal area with continuous asymmetric T-loop archwire; however, some extrusion takes place in the posterior region during movements.
2) Three-dimensional force and moment systems occur in the asymmetric T-loop system. The forces and moments occurred at different axis, effect each other and prevent formation of pure translation movement.
3) Excessive palatal tipping appears on incisor crowns after retraction with asymmetrical continuous T-loop arch wire. The torque should applied to the anterior region of the archwire to prevent this. It is considered that this interaction may be eliminated with brackets to be produced specifically for four incisors in patients with deep bite and retrusive incisors.
4) Although the anterior and posterior segments are connected to each other with eight ligatures, more tipping occurs in the teeth close to the T-loop twist.
5) Asymmetrical continuous T-loop arch wire causes palatal tipping on the crowns of posterior segment teeth, it would be beneficial to use additional anchoring mechanics such as transpalatal arch, Nance device in order to eliminate this effect.

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