Anterior teeth torque and posterior anchorage need in anterior retraction: 3D analysis using finite element method

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Abstract

Aim: Anchorage management is a challenging problem while retracting anterior segment in orthodontic treatments. The purpose of this study is to evaluate the effect of anterior teeth labiolingual inclination on the amount of anchorage loss and distance of anterior retraction.

Methods and Materials: Six 3D computer models of an upper anterior segment were designed in SolidWorks 2006 (SolidWorks, Concord, Massachusetts, USA).The models contained supporting structure, upper central and lateral incisors, their PDLs, the brackets and an anterior retraction arch wire with two vertical open loops. The models were the same except for the torque of anterior teeth which were 0, 5, 10, 15, 22, and 35 degrees consequently. ANSYS Workbench Version 12.1 (ANSYS Inc., Southpointe, Canonsburg, PA, USA) was selected for the analysis. At each analysis, the end points of the arch wire were displaced distally simulating the anterior retraction arch wire activation. The displacement produced in the labio-mesio-incisal point angle and the mesializing force applied to the terminal molar was assessed.

Results: Torque degree of 0 to 22 exerting almost equal force on anchorage unit during retraction while 35 degrees of torque causing more reciprocal force. Ten degrees of anterior torque resulted in maximum displacement of anterior segment.

Conclusions: To have maximum anchorage and faster anterior teeth movement during retraction degree of torque suggested to be about average and neither too protruded nor uprighted.

Keywords: Anterior tooth torque, Anterior retraction, Posterior anchorage

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An orthodontic treatment is not completed unless favorable teeth movements are completed in an acceptable consequence to provide a normal occlusion. According to Proffit et al.1, physiologic and orthodontic tooth movements are accounted for in treatments.

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The applied force system triggers a physiological change of the surrounding attachment apparatus. The net result is an inflammatory process and tooth movement.

Anchorage is the resistance to an unwanted tooth movement. [1,2] Anchorage preparation is one of the most important parts of an orthodontic treatment in patients who need space closure mechano-therapy. Successful outcome is usually related to the planned anchorage method. Depending on the amount and direction of desired tooth movement, anchorage preparation is classified into minimum, moderate, and maximum.[3] Anchorage loss is an unwanted reaction during tooth movement that could compromise treatment goals ie. proper anterior-posterior dental relationships and favorable

amount of anterior teeth retraction, therefore; many ways are considered to prevent or reduce this problem such as intra-oral and extra-oral adjunctive appliances, using multiple teeth in anchorage system, retraction type and ….. [4]
Factors such as malocclusion, type and the extent of tooth movement (bodily/tipping), root angulation and length, crowding, overjet, extraction site, alveolar bone contour, skeletal pattern and … [4] are believed to affect anchorage.
In cases of severe bimaxillary dentoalveolar protrusion, anchorage preservation is crucial. During anterior segment retraction, the force acting on the anterior teeth would generate a reciprocal force on the posterior teeth with the same magnitude but in an opposite direction5 The effect of anterior teeth torque while retracting them in bodily manner is not clearly discussed in literature.
The finite element method (FEM) can reconstruct the size and shape of a model similar to the actual structure. The FEM allows evaluation of the stress distributions and 3-dimensional (3D) displacements in various systems with an irregular geometry and nonhomogeneous physical properties.[6] This modeling technique lends itself to interpretation of clinical changes and helps the clinician establish information which cannot be done in-vivo. Further, this technique is a non-invasive means of studying dento-skeletal structures and thus helps investigate the soft tissue and skeletal responses to mechanical forces.[7,8]
The main aim of this study was to evaluate the anchorage demands for retracting anterior teeth with different labio-lingual inclination with bodily tooth movement and the other was to determine the amount of anterior tooth retraction and its relationship with their torque. To the author's knowledge this is the first time that the effect of anterior teeth torque on anchorage during bodily retraction is evaluated by the FEM.

Materials and Methods

Six 3D computer models of an upper anterior segment were designed in Solid Works 2006 (Solid Works, Concord, Massachusetts, USA). The teeth were modeled according to Ash's dental anatomy. The models contained supporting structure, upper central and lateral incisors, their PDLs, the brackets and an anterior retraction arch wire with two vertical open loops. The models were the same except for the torque of anterior teeth. The torque was 0, 5, 10, 15, 22, and 35 degrees consequently. The 3D models were designed to be as realistic as possible, without using any symmetry in modeling. The models were transferred to the ANSYS Workbench Version 12.1 (Ansys Inc., Southpointe, Canonsburg, PA, USA). Boundary conditions restricted displacements of the nodes at the base of the models to prevent rigid body motion. The manner of restriction was based on the anatomy of the maxilla. Mechanical properties (Table 1) were then applied and the models were meshed with 52470 nodes and 16659 elements. (Figure 1a ,1b)
The center point of the bracket slot was 3.93 mm gingival to the incisal edge. At each analysis, the end points of the arch wire were displaced distally 1 mm simulating the anterior retraction arch wire activation. The displacement produced in the labio-mesio-incisal point angle and the mesializing force applied to the terminal molar was assessed.

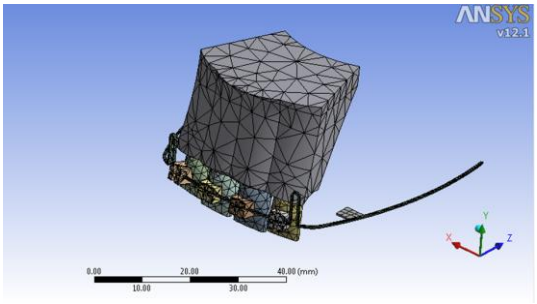

Figure 1a: Meshed 3D model

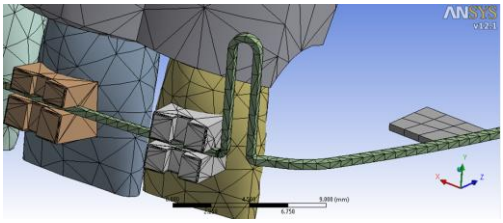

Figure 1b: closer view of the 3D model showing the loop, arch wire, lateral incisor bracket, and simulated canine bracket.

Results

The relationship between mesial movement of the anchored (posterior) teeth and the torque of the anterior teeth during retraction is shown in figure 2. When torque of tooth was 0 degree, reciprocal force applying to anchorage was 1.72 N. As the crown torque of the anterior teeth increased to 22 degrees, anchorage demand remained mostly the same but after that with raising torque degree to 35, mesializing force to the anchorage unit increased to 1.83 N.

The amount of anterior segment retraction was increasing from 0.18mm to 1.69mm when anterior teeth torque increased from 0 to 10 degree. At the level of anterior teeth torque degree between10 to 22, anterior segment movement decreased about 0.18 mm and finally higher levels of anterior teeth torque the size of displacement seemed to be unchanged. (Figure 3)

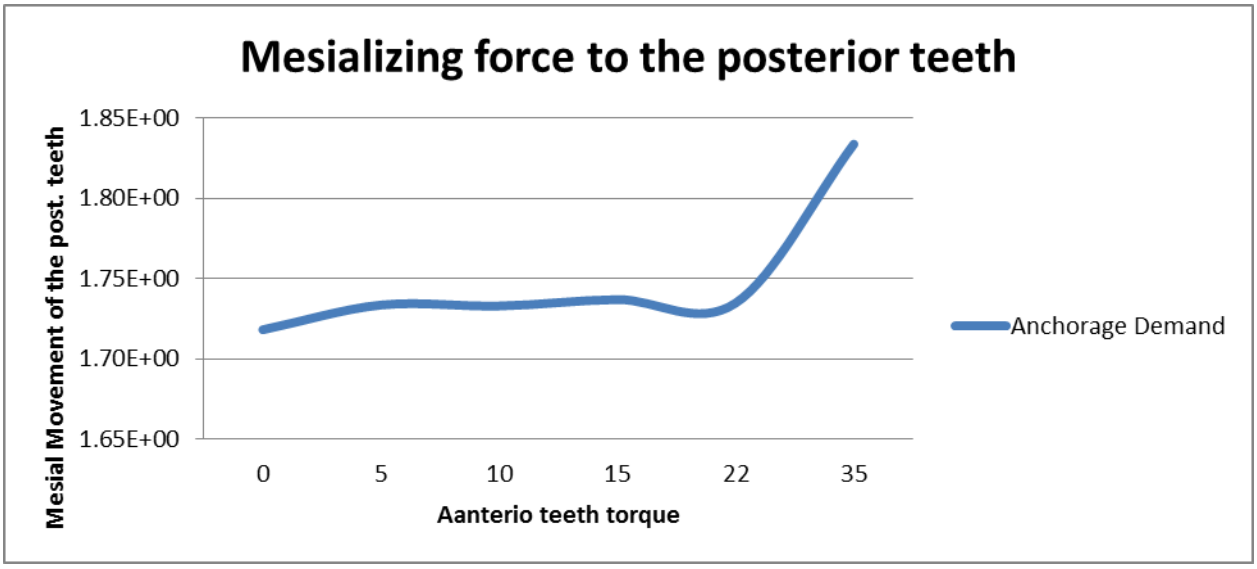

Figure2. The applied force to the posterior teeth

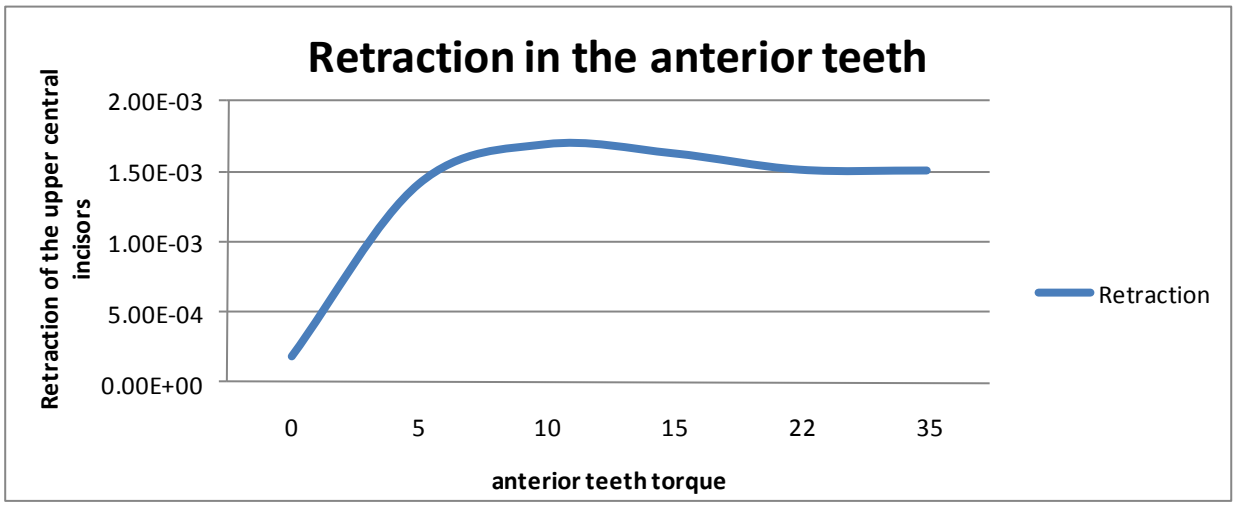

Figure3: Retraction of the upper central incisors under the same amount of arch wire activation with different anterior teeth torque

Discussion

Tooth movement is a basic phenomenon in orthodontic treatments. Different studies have tried to analyze the factors affecting movement. Biochemical mediators which are related to tooth movement velocity have been studied earlier.

This study tried to analyze the anterior teeth retraction and its relation with the teeth torque. There are several cases that need retraction of the anterior segment teeth while torque is higher than favorable range. In its form, this is a challenging point in our practice. Expert practitioners use to let the incisors decrease this torque by controlled tipping, while being retracted. The borderline to decide changing the tooth movement type needs a clinical judgment. (Based on the experience and practitioner)

Two clinical strategies towards completing this movement and reaching the goal are as follows:

Using a round arch wire in the first phase of the retraction continued by a rectangular one with proper torque (in standard edgewise technique) or making use of built-in torque in the bracket bases. (in straight wire technique) Change of wire cross-section is at the time of reaching proper torque in the anterior teeth which is produced by tipping teeth in the first phase. This is judged by the clinician at chair side.

Using plain rectangular wire at first, letting anterior teeth torque change using the play between the wire and bracket slot. Torque is added to the anterior wire segment after reaching an acceptable torque in the anterior teeth (in standard edgewise technique) or the wire size is increased to a full sized one in straight wire technique to stop the tipping movement and start the bodily one.

When loaded by a class II elastic, an increased resistance is felt to exist in the anterior teeth to the bodily retraction when palatal root torques is higher than normal. It can be considered somehow the same as the resistance shown in a tipped back molar to be displaced mesially by a class II mechanic. This resistance is considered favorable in Tweed technique and all who followed him. The protrusive upper incisors afford a most potent toe-hold or stationary anchorage, and this condition, if present, must be overcome before these teeth are being moved by inter-maxillary elastics; otherwise undesirable anterior movement of the mandibular teeth is very likely to occur.9 Occasionally, the upper incisor crowns, in addition to being very protrusive, have open contacts or spaces between them and Tweed suggested that closing these open contacts will reduce the degree of protrusion, also less displacement of the molar anchors will occur.9

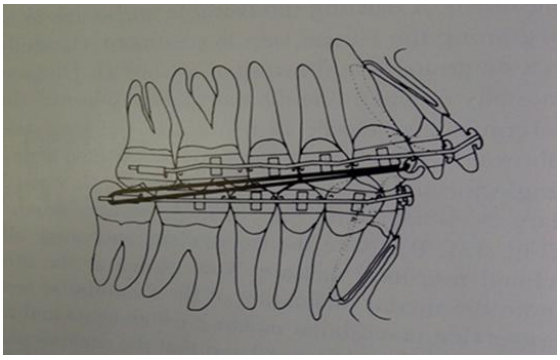

Figure 4. Class II mechanic inter-maxillary elastics

Conclusion

Based on the results of this study, the anchorage needed to retract the anterior teeth is directly depended on the torque of the anterior teeth. Correction of the anterior teeth torque before retraction, as a phase of elimination of their resistance, is strongly recommended.

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