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Original Research Article

Evaluation of torque expression with varied bracket positions and varying crown-root angles of maxillary central incisor – A 3 dimensional finite element study

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ABSTRACT

Objective: To evaluate the torque expression of right permanent maxillary central incisor with varying bracket positions and to compare the torque expression of the same tooth with different crown-root angulations.
Settings and Sample Population: Finite Element Models of Maxillary Central Incisor were used for simulation of torque expression with various crown-root angles.
Materials and Methods: Three FEM models of a Maxillary Central Incisor with different crown-root angles (170°,175°,180°, and 165°) were constructed with varying bracket heights and subjected to a 30° labial root torque and the resultant torque expressions were evaluated.
Result: The model with the maximum variation in crown-root angle (165°) showed the maximum torque expression at 6mm and minimum at 3mm bracket height while the model with a minimum variation in crown-root angle (180°) showed the minimum torque expression both and 3mm and 6mm bracket height.
Conclusion: With increase in the crown-root angles of a tooth, the torque expression away from the incisal edge increases.

1. Introduction

Brackets are considered as key constituents of fixed orthodontic appliances used to achieve proper tooth position utilizing the SWA technique to effectively express the built-in prescriptions that are separately programmed into different types of bracket systems available in the market.[1] This accuracy depends on ability of the clinician to consistently and accurately identify certain anatomical landmarks and to judge certain angular and linear features of the crown form.[2] The basic premise of the pre-adjusted system is that, precise bracket placement allows the teeth to be positioned with a straight wire into an occlusal contact with excellent tip and torque.[3]

Along with bracket positions, the variability in tooth morphology also affects the aesthetic, functional and stable orthodontic outcome. Therefore, the morphology of permanent maxillary central incisors has been investigated in different malocclusion groups.[4] The assessment of pre-treatment morphology and location is affected by current orthodontic patient record, that generally consists of intraoral and extraoral photographs, periapical, panoramic, cephalometric radiographs, and study models.

The angle formed by the intersection of the long axes of the crown and root, crown-root angle investigated most frequently using lateral cephalometric radiographs, do not provide an assessment of the permanent maxillary incisor

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shape as it cannot be determined from measurement of linear angles or distances.[5] This angle limits the degree to which the roots of these teeth can be torqued lingually when related to the maxillary lingual cortical plate of bone and hence becomes important in orthodontic treatment.

A precise incisor positioning needs an accurate torque expression for a perfect interincisal angle, adequate incisor contacts and sagittal adjustment of the teeth to achieve an ideal occlusion. Mechanically, it refers to the twisting of a structure about its long axis, which results in an angle of twist. Clinically, it represents the buccopalatal inclination of the crown or root, which is an orthodontic adaptation used to describe rotation around an axis. The long axis of the maxillary central incisor root is not always identical to that of the crown, with the crown torqued lingual to the root axis generally.[6] These deviant root angulations confound intrusion and extrusion forces leading the root to encroach on the labial and lingual cortical plate when repositioned.[7] Therefore, the extent of change in the buccolingual inclination of the crowns depends on the wire torque stiffness, bracket design, the wire or slot play, and the mode of ligation.[8]

The FEM proves to be an important instrument in orthodontic research, highlighting several points, such as, stress distribution areas in the periodontal ligament and alveolar bone during tooth movements, direction of the tooth displacement, the ideal position of orthodontic appliances during specific mechanics, etc.[9,10] with the ability to overcome the disadvantages of other experimental methods, as it controls the study variables and provides wide quantitative data about internal structures of nasomaxillary complex.[11]

Therefore, the purpose of this study was to evaluate the torque expression with varied bracket positions and varying crown-root angles of maxillary central incisor using Finite Element Analysis to analyse the most accurate tooth variation and minimum orthodontic force to be applied accordingly.

2. Materials and Methods

2.1. Materials

1. Digitized Pre-Adjusted edgewise appliance.
2. Digitized orthodontic stainless-steel archwires.
3. Digitized stainless-steel ligature wires.
4. Model of a maxillary central incisor with a normal crown-root angle.
5. A computer with Windows 10 Operating System.
6. Altair HyperMesh Software for generating the Finite Element Model.

2.2. Method

A CBCT scan of the right permanent maxillary central incisor with crown-root angle of 175° was used to construct a geometric model in this study using Altair HyperMesh Software. Three similar models were constructed with different crown-root angles (170°, 180°, and 165°) using the Altair HyperMesh Software (Figure 1) (Table 1)

A 17° angulation was incorporated onto the bracket for complete expression of torque onto the tooth model. The bracket was then positioned at three different heights; for each CRA they were termed as A for 3 mm bracket height from incisal edge, B for 4.5 mm, and C for 6 mm (Figure 2).

The geometric model was converted into a Finite Element Model using the Altair HyperMesh Software. The material properties of the structures involved in the study, the teeth, PDL, alveolar bone and stainless-steel material (bracket and archwire) have been designed experimentally and they are the average values reported in the literature (Table 2).

A 30° labial root torque was applied on the archwire at different bracket heights to reflect an active clinical situation (Figure 3) and the torque expression on each tooth with different crown-root angles and different bracket heights were simulated and studied.

The study design and sample size were not relevant as this was a Finite Element Study.

3. Results

The current study evaluated the torque expression with varied bracket positions and varying crown-root angles of maxillary central incisor using Finite Element Analysis. The torque expressions of all the models were evaluated. (Figures 4, 5, 6 and 7).

Table 1: Models with different crown-root angles.

Models	Crown- Root Angles (in degrees)
Model 1	175
Model 2	170
Model 3	180
Model 4	165

Table 2: Material Properties of various structures used in the study.

Components	Young's Modulus (MPa)	Poisson's Ratio (μ)
Teeth	20300	0.30
PDL	0.667	0.49
Bone	13700	0.38
Stainless steel	190000	0.265

4. Discussion

Using PEA brackets, the position of a bracket on the crown determines the tooth's final tip, torque, height, and rotation. If the bracket is not placed correctly or the tooth morphology does not correspond with that for which the bracket was

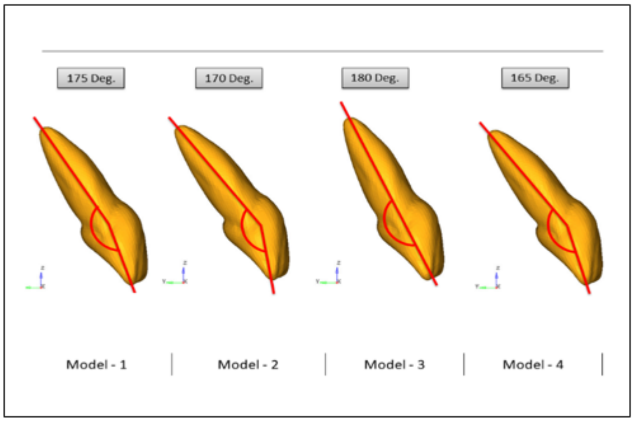

Fig. 1: Construction of four geometric models.

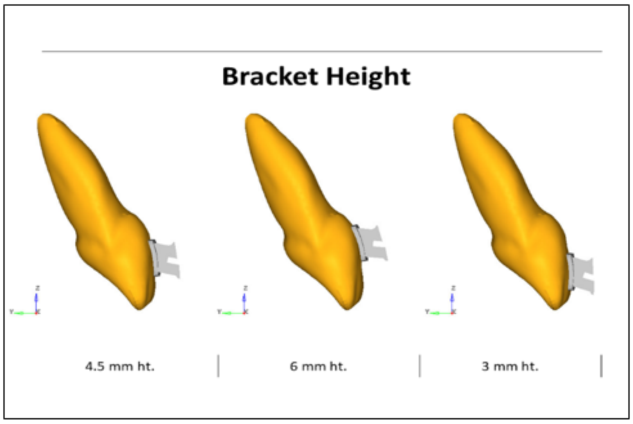

Fig. 2: Brackets positioned at different heights from theincisal edge.

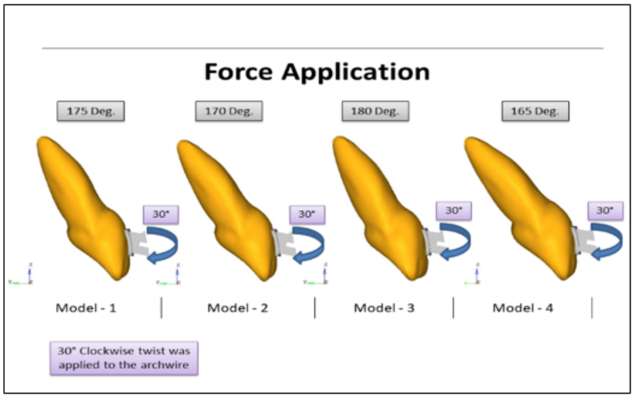

Fig. 3: Labial root torque applied onto the brackets.

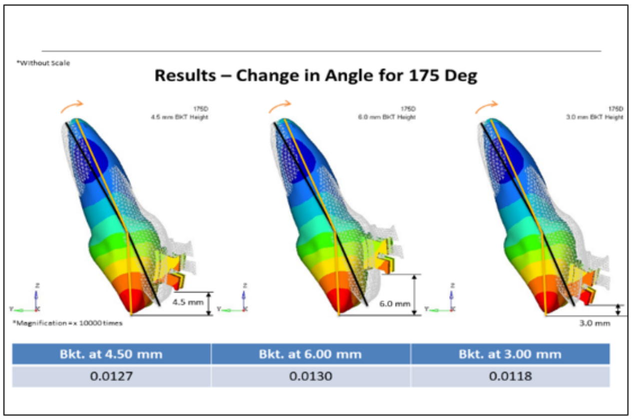

Fig. 4: Torque expression on model 1.

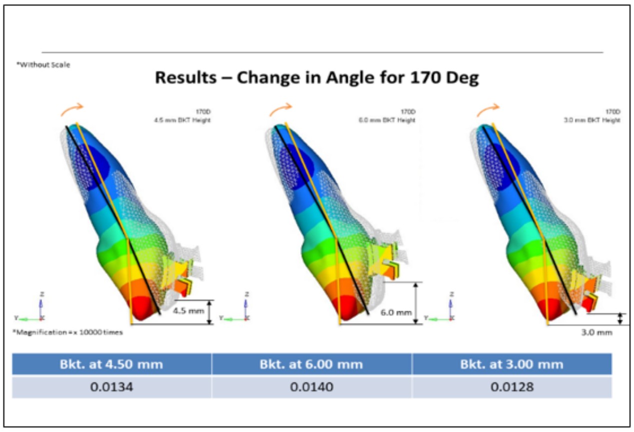

Fig. 5: Torque expression on model 2.

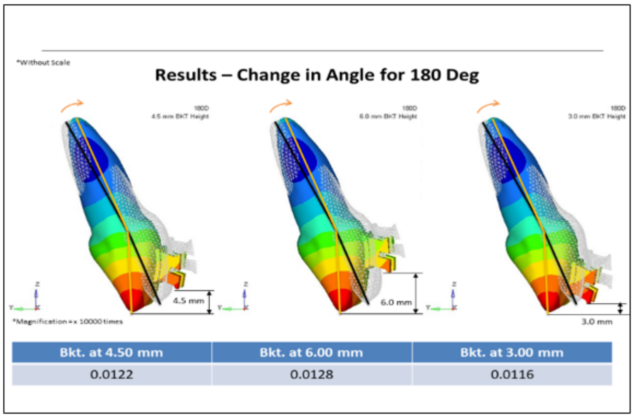

Fig. 6: Torque expression on model 3.

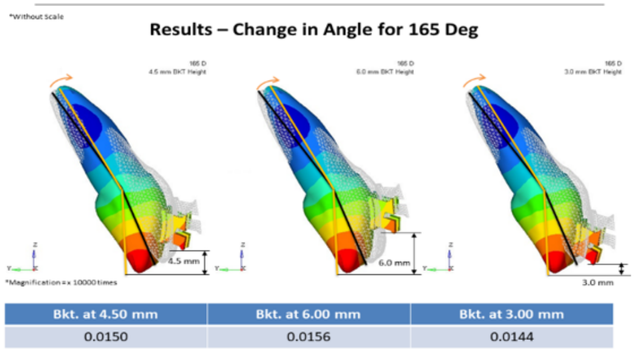

Fig. 7: Torque expression on model 4.

developed, the force will not be applied on the centre of clinical crown and the final tooth position will not be optimal. To obtain their optimal final inclination and torque, a prescribed bracket height has been proposed and these advised heights are different for each type of bracket. This is possible only if the bracket positions are accurate and CRA to be standardized. [10]

Maxillary central incisor was chosen for this study since they are the most visible teeth during unstrained facial activity and are of great concern to the patient. [4] The FEM enables us to answer complex biomechanical questions in the field of orthodontics via simulation; although many measurements cannot be taken in vivo, they can nevertheless contribute useful information to clinical investigations. [11]

The bracket heights were kept at a constant height of a difference of 1.5 mm from each other. A difference in the crown-root angles were considered in the study clinically relating to the shape of maxillary central incisors in different malocclusions (Class II Division 1, Class II Division 2, and Class III).

For all the models, the torque expression increased along with the bracket height from the incisal edge, with minimum torque expression at the 3 mm bracket height followed by 4.5 mm and a maximum torque expression was seen at 6 mm height. The difference in the torque expressed at each bracket height was also simulated to be 6° from each other, and was constant irrespective of the CRA.

This was in accord with the results by van Loenen and Kong et al, [12,13] that stated that as the bracket positions changed to a higher position from the incisal edge, the torque expression consistently increased and minimum root movement was seen at the highest bracket height of 6 mm.

The increase in torque expression was attributed to:

1. Due to the curvature of the labial surface of the crown at the gingival area, the archwire was engaged completely into the bracket for maximum expression of torque which led to minimum movement of the root.
2. As stated in previous studies, the nearer the bracket placed to the centre of resistance of a tooth, the less is the root movement in the opposite direction also called as torque loss.

Therefore, during orthodontic treatment, this is an important consideration while moving the teeth or torquing them to maintain aesthetics and for long term retention. Crown-root angulation of maxillary central incisors may limit the degree to which the roots of these teeth can be torqued palataly. In severe cases, the root may inadvertently encroach on palatal cortical plates, causing unwanted root resorption and dehiscence. [14,15]

A limitation of current study is that there may be a variability in the results during in the clinical situation as tooth movement is a biologic process and tissue resistance cannot be eliminated while predicting the amount and type of tooth movement.

Hence, to increase the validity of this study, clinical studies can be carried out. Another limitation of this study is that, the stresses generated both at the apex of the root and at the bracket level were not evaluated. Therefore, further studies can be performed to check which bracket height caused the maximum and minimum stresses at the apex which could also be related clinically while treating such malocclusions. Also, the differences in torque expressions only in the vertical dimension were assessed and only one type of torque prescription was chosen for this study. Therefore, further studies can be carried out using multiple bracket prescriptions and variability in torque expressions after a change in horizontal positions of brackets.

5. Conclusion

The following conclusions can be drawn from the current study:

1. A significant change in the bracket position on a tooth with different crown-root angles produces a considerable amount of labial root torque which can be useful while treating different malocclusions clinically.
2. As the bracket position is moved away from the centre of resistance, more torque loss is observed.
3. The presence of a difference in morphologies of a same tooth play an important role in torque variation expressed at different bracket heights from the incisal edges.
4. Torque expression increases with increase in the crown- root angle of a specific tooth
5. Thus, when positioning a bracket, the individual variations in crown morphology and the vertical height of the bracket position should be assessed. If large deviations are present, the use of indirect bonding systems or custom-made brackets should be considered or should be combined with wire bending during orthodontic treatment to place the maxillary anterior teeth in optimal positions and to obtain the desired labiolingual inclinations and aesthetics.

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7. Conflicts of Interest

None to declare.

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