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Original Research Article

Effect of various crown-root angles on the resultant stress on the root and periodontal ligament of a maxillary central incisor-A three dimensional finite element study

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ABSTRACT

Objective: To evaluate and compare the resultant stress on the root and PDL of a Maxillary Central Incisor with various crown-root angles. Settings and Sample Population: Finite Element Models of Maxillary Central Incisor were used for simulation of stress on the root and PDL.

Materials and Methods: Three FEM models of a Maxillary Central Incisor with different crown-root angles (170°, 175° and 180°) were constructed and subjected to a force of 2N respectively. The resultant stress generated in the periodontal ligament and root surface were recorded and compared between the models.

Result: The model with the maximum change in crown-root angle (180°) showed the maximum stress in both PDL and root surface. The stress recorded on the root surface was more on the cervical 2/3rd in the palatal region of the tooth as compared to the labial region. Maximum stress in the PDL was seen only in the cervical 3rd of the third model.

Conclusion: With increase in the crown-root angles of a tooth, the stress in the PDL and on the root surface increases.

1. Introduction

The variability in tooth morphology of any tooth is an important factor in achieving an aesthetic, functional and stable Class I incisor and molar relationship after orthodontic treatment.[1]

The most visible teeth during unstrained facial activity are the maxillary central incisors and can be easily distinguished from other teeth.[2] Therefore, the morphology of these teeth has been investigated in different malocclusion groups in different studies.[2]

The axial inclination or crown-root angle of any tooth is one of the most important aspect to be considered. The angle formed by the intersection of the long axes of the crown and root, the crown-root angle, or collum angle which was coined by Anderson in 1930, has been investigated frequently using lateral cephalometric radiographs.[3] In class II, division 2 malocclusion cases, the crowns of these teeth bend lingually, and this abnormal inclination may play a major role in developing a deep over bite in these patients.[4]

The correlation between the crown root angles of the anterior teeth and their reference planes has been of a major importance through years.[5] The labial surface angle and the lingual surface curvature of the maxillary central incisor have been measured on the lateral cephalograms, while the

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labiopalatal thicknesses of these teeth have been measured on study models.[6]

Williams et al (1983) performed a study by tracing the maxillary central incisors of different malocclusion groups on the radiographs. He found that the crown-root angles were different in all the three malocclusions.[7] Therefore, the morphology of the teeth while treating different malocclusions has to be considered. When a consistent force is applied to morphologically different teeth, it will result in different movements with variable stress patterns.[8]

Finite Element Method is accurate and non-invasive and provides detailed results regarding the physiological responses occurring in living tissues, such as the root, periodontal ligament, alveolar bone etc.[9] FEM also has the ability to overcome the disadvantages of other experimental methods, as it controls the study variables and provides a wide quantitative data about variable internal structures of nasomaxillary complex.[10]

Therefore, the purpose of this current study was to evaluatetheEffect of various crown-root angles on the resultant stress on the Root and Periodontal Ligament of a Maxillary Central Incisor using a 3-D Finite Element analysis.

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.

2.2. Methods

A Finite Element Model of a Maxillary Central Incisor (Enamel, Dentin and Pulp), Periodontal Ligament and Alveolar bone were constructed using a three-dimensional computer aided design program.

Each structure of the model (Enamel, dentin, pulp, Periodontal Ligament and Alveolar bone) was meshed using an auto-machine routine in the finite-element analysis program. (Figure 1, Table 1)

Three models were constructed with crown-root angles of 170^o, 175^o and 180^o respectively.

Model I: Maxillary Central Incisor with crown-root angle of 170^o.

Model II: Maxillary Central Incisor with crown-root angle of 175^o.

Model III: Maxillary Central Incisor with crown-root angle of 180^o.

The thickness of the Periodontal Ligament around the tooth was 0.25mm and alveolar bone was 2mm respectively.

After the models were generated, maxillary central incisor brackets at a level of 4.5mm above the incisal edge was constructed on the labial surface.

An orthodontic force of 2N was applied onto the labial surface of the tooth and the resultant stress generated in the PDL and root surface was calculated. (Figure 2)

3. Results

The current study evaluated the resultant stress in the root and PDL of a Maxillary Central Incisor and compared it with the resultant stress in the root and PDL of the same tooth with different crown-root angles.

The results showed the following:

1. AResultant stress seen in the root area. (Figure 3)
2. Resultant stress seen in the Periodontal Ligament: (Figure 4)

The resultant stress in both the roots and Periodontal Ligament of all three models were compared and a following result was obtained. (Table 2)

Table 1: Material properties used in the study.

	Young's modulus	Poisson's ratio
Enamel	8.41×10^4	0.33
Dentin	1.83×10^4	0.30
PDL	6.90×10^{-1}	0.45
Bone	1.37×10^4	0.30

Table 2: Comparison of resultant stress in the root and PDL of all three models.

Stress in MPa	Stress in Root	Stress in PDL
Model I	0.729	0.027
Model II	0.738	0.03
Model III	0.744	0.041

4. Discussion

In this current experimental study, orthodontic forces were applied to three FEM's of maxillary central incisor with various crown-root angles and their stress distribution pattern in the root and periodontal ligament was evaluated. The forces were applied to the labial crown surface at a bracket height of 4.5mm from the incisal edge that is normally used in clinical practice.

In Model I with a crown-root angle of 170 degrees, there was very little stress observed in both the labial and lingual root surface as well as in the periodontal ligament. Such a crown-root angle can be commonly observed in Class II, Division 2 cases where placing the bracket at a normal height of 4.5mm produces minimum stress.

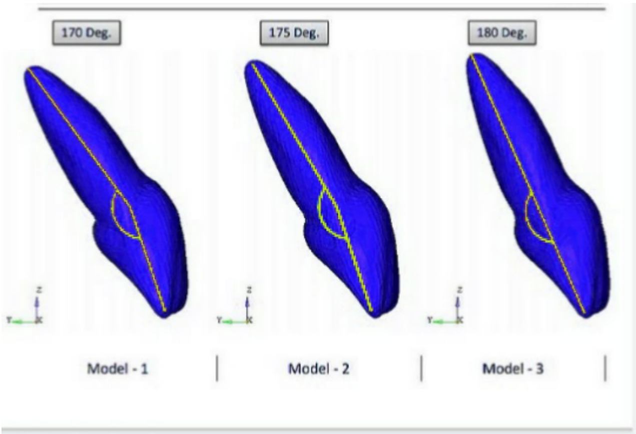

Fig. 1: Maxillary Central Incisor with different crown-root angles.

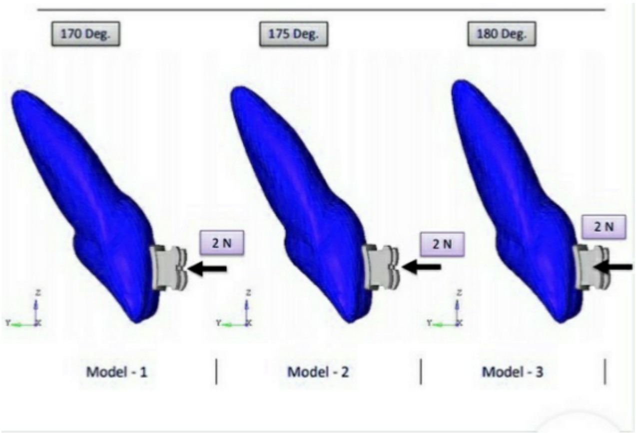

Fig. 2: Brackets constructed and force applied on the models.

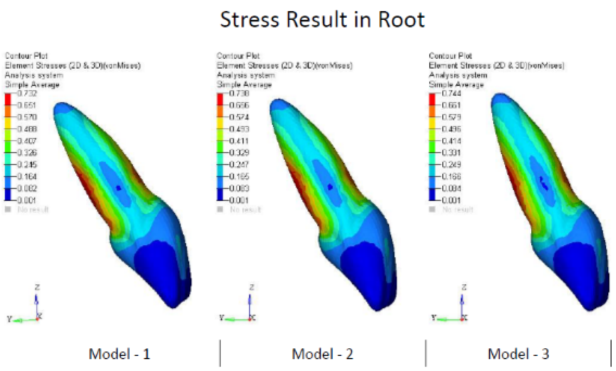

Fig. 3: The resultant stress in the root area.

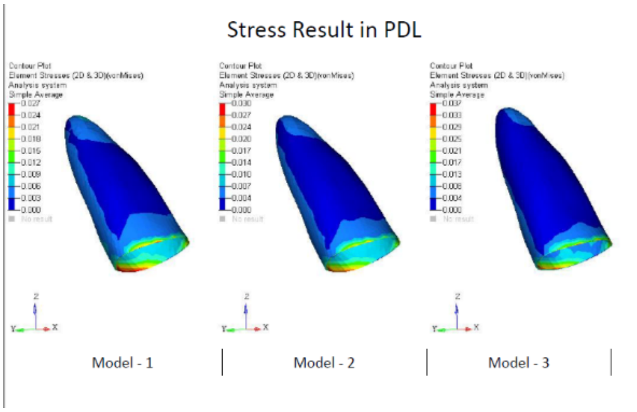

Fig. 4: The resultant stress in the PDL.

In Model II with a crown-root angle of 175 degrees, the stress in both the root surface and periodontal ligament increased as compared to model I. Stress was observed more on the lingual surface of the root as compared to labial surface. Such crown-root angles can be observed commonly in Class I cases.

In Model III with a crown-root angle of 180 degrees, the stress evaluated in both the root surface and periodontal ligament was more as compared to Model I and Model II. More stress was observed in the lingual surface as compared to the labial surface of the root. Such crown-root angles are commonly observed in Class II, Division I or Class III cases where the central incisors tend to be more proclined.

When all three models were compared, model III showed the highest amount of stress generated in both the root surface and periodontal ligament which shows that with an increase in the crown-root angle, the stress in the root surface and the periodontal ligament increases.

Finite Element Analysis was chosen for this study since it provides adequate information of stress and tension occurring in the living tissues which is difficult to be evaluated by any other experimental technique The results obtained by this method enables the evaluation of stress distribution produced by forces within the periodontal ligament and the bone, thereby defining the areas of stress and the location where tooth movement occurs.

5. Conclusion

Three fundamental points can be concluded from this study:

1. When a force of 2N was applied on all the three models at the same point, the maximum stress calculated was in Model 3, with the maximum crown root angle (180°).
2. The maximum stress of 0.744 MPa was recorded in the cervical 2/3rd on the palatal surface of Model 3 as compared to the labial surface.

3. The maximum stress of 0.037 MPa was recorded in the cervical 1/3rd of Model 3 which the maximum as compared to the other two models.
4. With increase in the crown-root angle, the stress produced at the cervical 3rd increases indicating the risk of root resorption or dehiscence.

6. Source of Funding

None.

7. Conflict of Interest

None.

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