Original Article

Apical Third Morphology and Intrusive Force Application: 3D Finite Element Analysis

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Abstract:

Objective: Intrusion as a type of tooth movement is managed by different mechanotherapies during various treatment stages. The morphology of the apical third of the teeth to be intruded plays an important role in the risk of root resorption due to the raise of stresses. The main goal of this study was to compare various types of apical third of the teeth while loaded by an intrusive force.
Materials and Methods: Four 3D Finite element models were designed with all supporting structures. Normal, needle form, short and sharp apices were considered. Intrusive forces of 0.5 N were applied and the VonMises stress along the mesial side of the root was assessed.
Results: A tendency to show increased stresses at the cervical area of the teeth was noticed. The lowest stress was noticed in the blunt apex and the highest findings were shown to be in the needle form apex model.
Conclusion: Normal variation in apical third of the teeth in intrusion can cause an increased stress level and also increased chance of root resorption which should be considered carefully in force applications.

Key Words: Tooth apex; Torsion, Mechanical; Orthodontics; Stress, Mechanical; Finite Element Analysis

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INTRODUCTION

Intrusion of teeth is necessary in different stages of orthodontic treatments. This movement is difficult to achieve not only due to the extensive amounts of bone to be removed but also because of the presence of periodontal ligament (PDL).

Successful orthodontic treatment without considering intrusive tooth movement is not possible in many cases. This kind of tooth movement is believed to be associated with a higher risk of root resorption in adult patients [1,2]. As a response to an orthodontic force, Massler and Malone stated that root resorption occurs in 100 percent of orthodontic patients [3]. Consequent to some orthodontic treatments apical root resorption occurs. No difference has been found to exist between fixed orthodontics techniques [4]. A Relationship between orthodontic treatment and root resorption has been reported by different researchers [5-7]. Mirabella and Artun [8] also considered that abnormal root morphology was a significant risk factor for root resorption.

The limitation of human mind is such that it cannot grasp the behavior of its complex surroundings in one operation [9]. Thus, the process of subdividing all systems into their individual components or ‘elements’ whose behavior is readily understood and then rebuild-

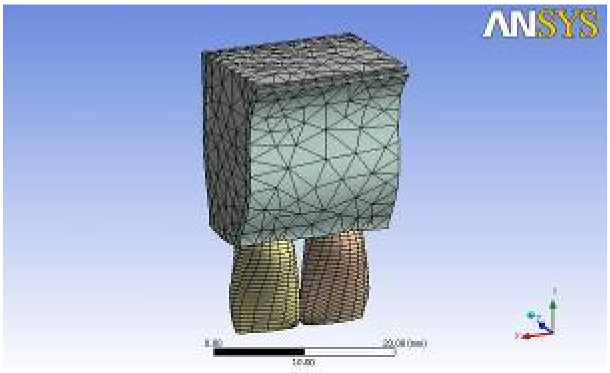

Fig 1. 3D Model after meshing**.**

ing the original system from such components to study its behavior is a natural way in which the engineer and the scientist proceed [9]. This method has proved its efficiencies in many ways [10].

The main goal of this study was to assess the stress state in the apical area of the teeth with normal variation while loaded with an intrusive force.

MATERIALS AND METHODS

Four 3D models of two upper central incisors were designed. Each model contained cortical bone, spongy bone, PDL, and teeth (Fig 1). An average sized tooth was considered for the first model [11]. The second one contained a needle form apical area. The third one had a short and sharp apical area and the last model had a blunt end. PDL was assumed to be 0.25 mm all around the root. SolidWorks 2006 (300 Baker Ave. Concord, MA 01742, USA) was selected for the modeling phase. The next stage was to transfer the models for calculation to the ANSYS Workbench Ver. 11.0 (ANSYS Inc. Soutpointe, 275 Technology drive, Cononsburg PA 15317, USA). Material properties were applied based on recent researches (Table 1). Models were meshed, 32473 nodes and 2877 elements were used in these models (Fig 1). All nodes at the base of the models were restrained so that all rigid body motions were prevented. An intrusive force of 0.5 N at each labial surface of the central incisors was applied. Von Mises stress was evaluated along a path of nodes starting at the cervical area of the mesial side of the upper right central incisor moving towards its apex.

Table 1. Mechanical Properties of the used materials.

	Young's Modulus	Poisson's Ratio
Tooth	20300	0.26
PDL	6.67	0.49
Spongy Bone	13400	0.38
Cortical Bone	34000	0.26

RESULTS

There was a tendency to show stress concentration in the cervical area of teeth while loaded by the intrusive force. Von Mises stress along the cervico-apical path in all models was prepared (Table 2).

The lowest findings were noticed at the blunt tooth model, showing the least amount of changes between the cervical and apical areas. The pressure amounts were 0.0219 MPa at the cervical and 0.0039 MPa at the apical areas.

These findings were almost the same with an increase in the model with short root; 0.0214 MPa and 0.0089 MPa for the cervical and apical areas respectively.

The pattern was almost the same at the normal model except for the rapid increase occurred at the apex; 0.019 MPa for the cervical area and 0.0201 MPa at the apical areas.

The pattern noticed at the normal tooth model

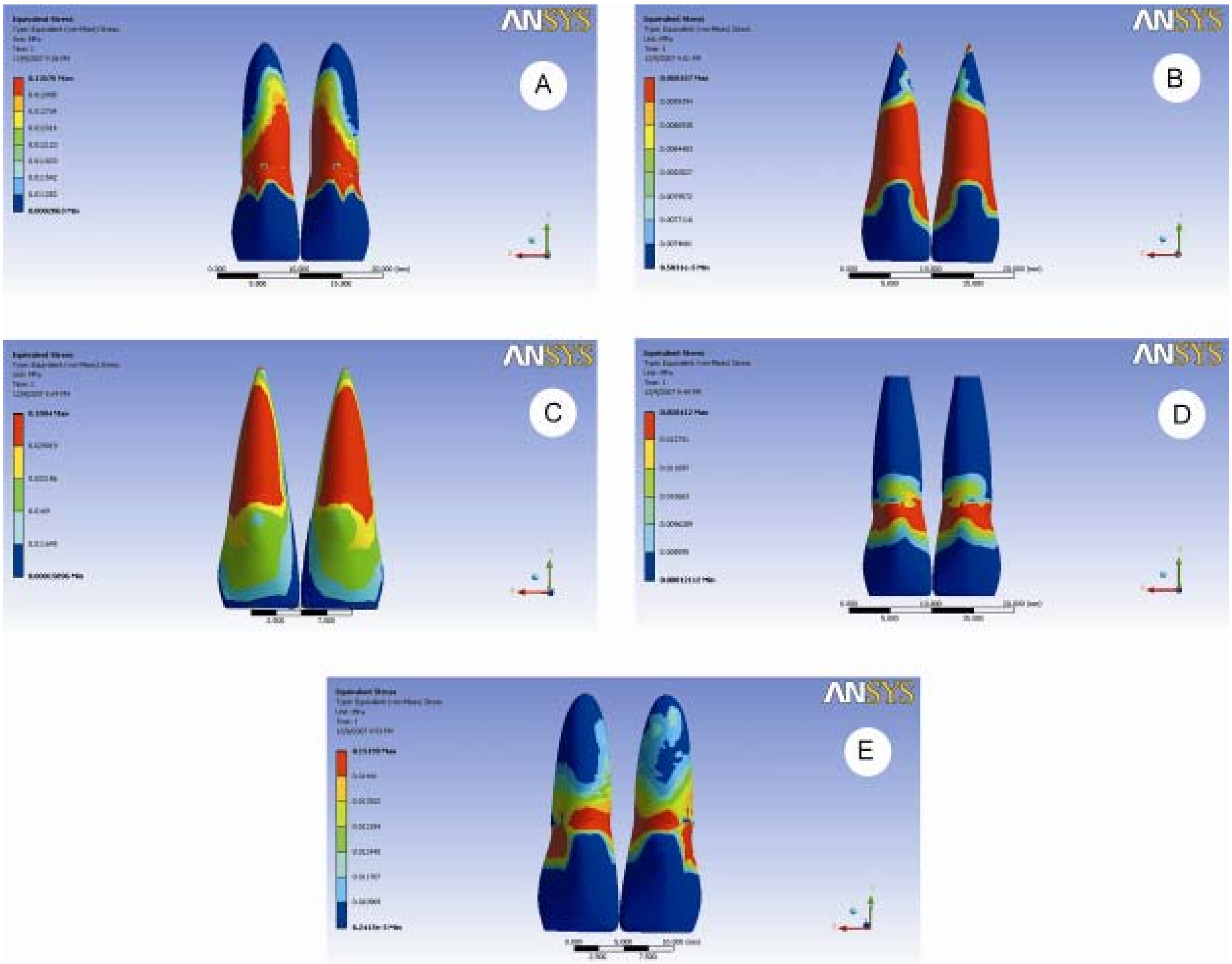

Fig 2. Von Mises stress under intrusive load in (A) Normal teeth (B) Teeth with needle form apex (C) Teeth with short and sharp apex (D) Teeth with blunt apices (E) Teeth with short root.

was repeated at the other one with short root and sharp form of apical area with an increase of about 2.3 times (Fig 2).

The model with needle form apex showed the worst types of findings along the cervico-apical path mentioned for other models. The finding for the cervical area being the same with the normal model at 0.0163 MPa, but increased to about 2.8 times (0.0564 MPa) of that found in the apical area of the normal model.

DISCUSSION

Various stress findings at the apical area produced by intrusive forces applied to 5 different FEM tooth models were assessed.

Higher stress findings which were noticed at the labial side of the teeth than lingual ones could be explained by the crown labial torque produced by the force application. The first point to be mentioned is the importance of different shapes of root at their cervical two-thirds in expression of stresses at the root apex. The more convergent the root wall, the less stresses will be expressed at the apex.

For the normal model, no significant stress concentration was observed at the root apex while under intrusive force (Fig 3).

Two models had a short root, one with a normal shape apex and the other one with a sharp apical area. Comparing these two models showed that the root length by itself cannot

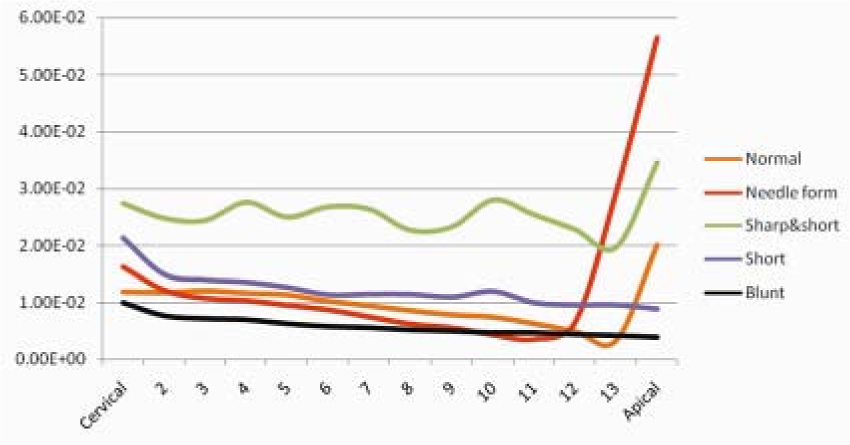

Fig 3. Von Mises stress (MPa) of root along a cervico-apical path.

cause any stress increase along the root or apex. The model with a sharp apex showed an increased stress along the middle part of the root which can explain the enhanced tendency of root resorption in theses roots and is in accordance with the findings of Taithongchai et al [6] and Thungudomporn and Freer [12].

The blunt shaped root model showed no significant stress concentration at the root. The stress level was lower than that of normal at the apex which can be explained by the increased area at the apex that decreases the stress. Again it should be mentioned that general root shape can alter these findings according to its angle of convergence in the cervical third of the root. These findings are against that of Levander and Malmgren [13] and Thongudomporn and Freer [12] who reported that blunt-shape roots frequently showed root resorption compared with normal ones.

The needle form root apex, in intrusion, showed the highest stress concentration at its apex which is in accordance with the findings of Sameshima and Sinclair [14] and Thongu-

Table 2. Von Mises stress (MPa) along the cervico-apical path.

Tooth layer		Normal	Needle form	Sharp & short	Short	Blunt
Incisal	**1**	0.0119	0.0163	0.0274	0.0214	0.01
	2	0.0118	0.0122	0.0248	0.015	0.0077
	3	0.0121	0.0108	0.0244	0.014	0.0072
	4	0.0117	0.0104	0.0276	0.0136	0.007
	5	0.0114	0.0096	0.025	0.0127	0.0063
Cervical	**6**	0.0103	0.0088	0.0268	0.0114	0.0058
	7	0.0095	0.00756	0.0264	0.0115	0.0056
	8	0.00865	0.00629	0.0227	0.0115	0.0052
	9	0.0079	0.00563	0.0233	0.011	0.005
	10	0.0075	0.00439	0.028	0.012	0.0047
	11	0.00634	0.00363	0.0254	0.01	0.0047
	12	0.005	0.00662	0.0228	0.0096	0.0044
	13	0.0034	0.0294	0.0197	0.0096	0.0042
Apical	**14**	0.0201	0.0564	0.0345	0.0089	0.0039

domporn and Freer [12] who reported, in their radiographic studies, that teeth with a needle form root apex showed more root resorption.

Based on the contemporary knowledge of orthodontics which believes in a relation between apical stress and root resorption, it was tried to compare the root forms to evaluate the chance for root resorption.

Al-Qawasmi et al [15] stated that genetic predisposition influenced external root resorption. Studies like this confirm the role of other factors that is away from the force level and stress and should be assessed separately. Studies to assess the root resorption and different environmental and non-environmental causes are really needed to interpret the numeric findings of *in vitro* studies.

CONCLUSION

This study made it clear that deviations in the apical area can cause different stress concentrations and promote the chance of root resorption, though the force magnitude has not been assessed to show its importance.

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REFERENCES

1-Thilander B. Indication for orthodontic treatment in adults. In: Thilander B, Ronning O, editors. Introduction to orthodontics. Stockholm: Thandlakarforlaget, 1985. p. 237.

2-Lu LH, Lee K, Imoto S, Kyomen S, Tanne K. Histological and histochemical quantification of root resorption incident to the application of intrusive force to rat molars. Eur J Orthod 1999 Feb; 21(1):57-63.

3-Massler M, Malone AJ. Root resorption in human permanent teeth. A roentgenographic study. Am J Orthod 1954;40(8):619-33.

4-Beck BW, Harris EF. Apical root resorption in orthodontically treated subjects: analysis of Edgewise and light wire mechanics. Am J Orthod Dentofacial Orthop 1994;105(4):350-61.

5-Spurrier SW, Hall SH, Joondeph DR, Shapiro PA, Reidel RA. A comparison of apical root resorption during orthodontic treatment in endodontically treated and vital teeth. Am J Orthod Dentofacial Orthop 1990;97(2):130-4.

6-Taitongchai R, Sookkorn K, Killiany DM. Facial and dentoalveolar structure and the prediction of apical root shortening. Am J Orthod Dentofacial Orthop 1996;110(3):296-302.

7-Costopoulos G, Nanda R. An evaluation of root resorption incident to orthodontic intrusion. Am J Orthod Dentofacial Orthop 1996;109(5):543-8.

8-Mirabella AD, Artun J. Risk factor for apical root resorption of maxiallry anterior teeth in adult orthodontic patients. Am J Orthod Dentofacial Orthop 1995;108(1):48-55.

9-Zienkiewicks OC, Taylor RL. The finite element method. Vol 1. 4th ed. London: McGraw Hill Book Co, 1989.

10-Geramy A. The same amount of CRes displacement in various orthodontic tooth movements while the applied force is remained constant: 3D analysis using finite element method. J Dent Shiraz Univ Med Sci 2002;3:59-65.

11-Ash MM, Dental anatomy, physiology and occlusion, 6th ed. Philadelphia: WB Saunders; 1984.

12-Tongudomporn U, Freer TJ. Anomalous dental morphology and root resorption during orthodontic treatment: A pilot study. Aust Orthod J 1998; 15(3):162-7.

13-Levander E, Malmgren O. Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. Eur J Orthod 1988; 10(1):30-8.

14-Sameshima GT, Sinclair PM. Prediciting and preventing root resorption: part I. Diagnostic factors. Am J Orthod Dentofacial Orthop 2001; 119(5):505-10.

15-Al-Qawasmi RA, Hartsfield JK Jr, Everett ET, Flury L, Liu L, Foroud TM et al. Genetic predisposition to external apical root resorption. Am J Orthod Dentofacial Orthop 2003;123(3):242-52.