



Effect of Three-wall Bony Defect along Various Root Surfaces on Position of Center of Resistance: A 3D Finite Element Analysis

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ABSTRACT

Introduction: Increase in adult orthodontic patients has increased the challenges faced by orthodontists, as they often present themselves with a varying degree of dental and periodontal compromise, in which the entire orthodontic treatment planning will revolve around maintenance and augmentation of supporting apparatus. One of the many factors to be considered during treating an adult patient is the height of alveolar bone and its effect on center of resistance (CRes).

Materials and methods: Eight 3D analytical models of upper central incisor were designed using 'Solid Works Office Premium'. The models were subjected to 3 and 6 mm bone loss along all four surfaces, i.e. labial, lingual, mesial and distal. One Newton of retraction force was applied on labial surface of tooth on model number 1, 2, 5 and 6 and 1N of distalization force was applied to model number 3, 4, 7 and 8. The relative location of the CRes to the total root length was taken as 41.8% of total root length from the root apex. The ANSYS software was used to evaluate the change in CRes on all the models.

Results: It was observed that CRes shifted apically from its relative location (41.8% from apex); however, this shift was clinically insignificant. Minimum deflection of CRes, 0.0122 mm, was seen when a distalization force was applied on model with 6 mm bone loss on distal surface, while maximum deflection of 0.0245 mm was seen when retraction force was applied on model with 6 mm bone loss on labial surface.

Conclusion: The resultant displacement in position of center of resistance is negligible; hence, there is no need of changing biomechanics during orthodontic treatment for a tooth with three

wall infrabony defects. However, it is necessary to further study other infrabony defects like two wall or one wall defect, and their effect on position of CRes.

Keywords: Alveolar bone loss, Asymmetric bone loss, Center of resistance, Central incisor finite element study.

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INTRODUCTION

Adults are seeking orthodontic treatment at historic levels, according a survey from the American Association of Orthodontists (AAO). The number of adult patients increased 14% in a 2-year period from 2010 to 2012, to a record high of 1,225,850 patients aged 18 or more.^{1,2} Increase in adult orthodontic patient has increased the challenges faced by orthodontists, as these patients often present themselves with a varying degree of dental and periodontal compromise that may range from marginal, without any significant effect on the prognosis, to severe, in which case the entire orthodontic treatment planning will revolve around maintenance and augmentation of supporting apparatus. One of the many factors to be considered during treating an adult patient is the height of the alveolar bone.

Previous literature provides us the knowledge about change in position of center of resistance (CRes) for varying heights of alveolar bone.^{3,4} All these studies show that as the height of alveolar bone decreases, CRes shifts. This shift needs increase in moment-to-force ratio for translating a tooth.

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All the research conducted in this area has considered equal amount of bone loss on all surfaces of root. None has considered what effect different types of infrabony defects have on position of center of resistance, wherein alveolar bone height is different on different root surfaces. In periodontally compromised patients, bone loss is not always similar on all the sides. According to Goldman and Cohen, there are three types of infrabony defects: one wall, two wall and three wall infrabony defects.⁵ Hence, it is necessary to know the change in CRes for cases with infrabony defects for better application of biomechanics. This study was carried out to evaluate the change in position of CRes for tooth with three wall infrabony defect with following aims and objectives:

- To evaluate the change in position of CRes due to bone loss on labial and lingual surface, when tooth is subjected to 1N of retraction force.
- To evaluate the change in position of CRes due to bone loss on mesial and distal surface, when tooth is subjected to 1N of distalization force.

MATERIALS AND METHODS

Eight 3D analytical models of upper central incisor were designed using ‘Solid Works Office Premium’. Models were designed as per the dimensions and morphology in Wheeler’s dental anatomy, physiology and occlusion text book. Each model consisted of a tooth, periodontal ligament and both cortical and cancellous bone. Variations in the thickness of periodontal ligament (PDL) in different layers of tooth were designed according to Coolidge model (Table 1).⁶ Physical properties of different materials were selected from previous studies (Table 2).⁷⁻⁹

Table 1: Geometry of the PDM widths in the 3D model according to Coolidge⁶

Distance from the alveolar crest (mm)	Distal (mm)	Lingual (mm)	Mesial (mm)	Labial (mm)
13.0	0.25	0.25	0.22	0.25
10.5	0.18	0.22	0.20	0.22
8.0	0.15	0.20	0.17	0.26
6.5	0.14	0.18	0.16	0.18
5.0	0.15	0.20	0.17	0.26
2.5	0.18	0.22	0.20	0.22
0	0.19	0.24	0.21	0.24

Table 2: Mechanical properties for the structural elements

Material	Young’s modulus (N/mm ²)	Poisson’s ratio
Tooth	20300	0.30
PDM	0.667	0.49
Cancellous bone	13700	0.38
Cortical bone	34000	0.26

The models were subjected to 3 and 6 mm bone loss along all four surfaces (Figs 1 to 4) as follows:

- Model 1: 3 mm bone loss on labial surface (Fig. 1)
- Model 2: 3 mm bone loss on lingual surface (Fig. 1)
- Model 3: 3 mm bone loss on mesial surface (Fig. 2)
- Model 4: 3 mm bone loss on distal surface (Fig. 2)
- Model 5: 6 mm bone loss on labial surface (Fig. 3)
- Model 6: 6 mm bone loss on lingual surface (Fig. 3)
- Model 7: 6 mm bone loss on mesial surface (Fig. 4)
- Model 8: 6 mm bone loss on distal surface (Fig. 4)

A 1N of retraction force was applied on labial surface of tooth on model number 1, 2, 5 and 6 with point of force application centered mesiodistally (this was presumed to be the location of the brackets). The force applied was tipping in nature and perpendicular to long axis of the tooth. Similarly, 1N of distalization force was applied to model number 3, 4, 7 and 8. The relative location of the CRes to the total root length was taken as 41.8% of total root length from the root apex. The ANSYS software was used to evaluate the change in CRes on all the models.

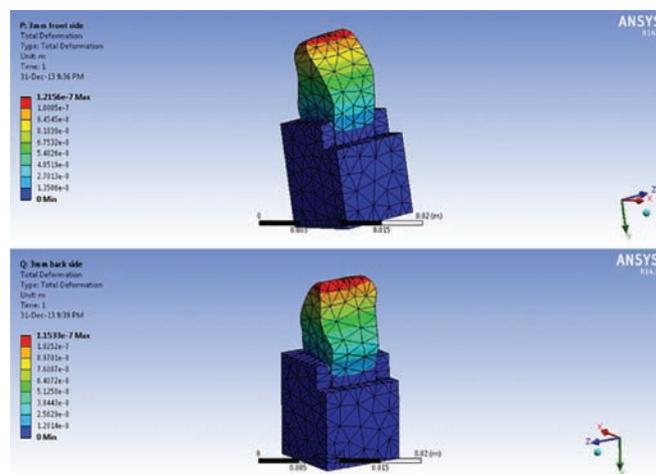


Fig. 1: Tooth model with 3 mm bone loss on labial and lingual surfaces

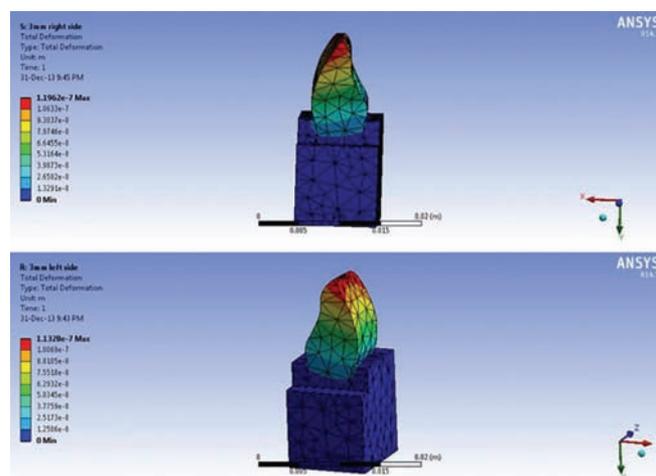


Fig. 2: Tooth model with 3 mm bone loss on mesial and distal surfaces

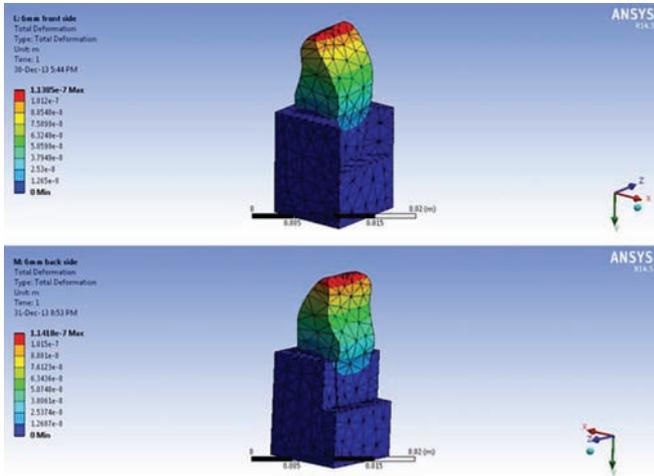


Fig. 3: Tooth model with 6 mm bone loss on labial and lingual surfaces

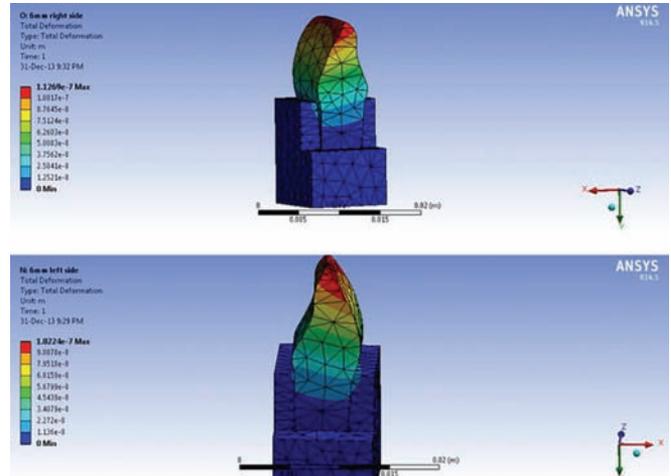


Fig. 4: Tooth model with 6 mm bone loss on mesial and distal surfaces

RESULTS AND OBSERVATIONS

On evaluation, it was observed that CRes shifted apically from its relative location (41.8% from apex). The resultant displacement of CRes is mentioned in Table 3.

Minimum deflection of CRes, 0.0122 mm, was seen when a distalization force was applied on model with 6 mm bone loss on distal surface; while maximum deflection of 0.0245 mm was seen when retraction force was applied on model with 6 mm bone loss on labial surface.

DISCUSSION

Clinical studies report a slight loss of periodontal attachment in adults during treatment with fixed orthodontic appliances. It is necessary for us to know what effect loss of periodontal attachment has on biomechanics so as to achieve tipping, bodily or root movement. Change in CRes requires change in moment-to-force (M/F) ratio to achieve same amount of bodily movement for a given

tooth. Bantleon states that 3 mm of alveolar bone loss causes 20% of M/F ratio increment to maintain bodily movement, while Geramy found that 17.35% of M/F ratio increment was required for same amount of bone loss.^{3,10} Tanne et al studied the effect of alveolar bone loss on the M/F ratio for bodily movement of a maxillary central incisor with 13.0 mm root length, with the use of a 3D finite element model.⁴ According to their results, the M/F ratio increased from 10.7 (no bone loss) to 12.3, 13.9, and 15.0 for 2.5, 5.0, and 6.5 mm alveolar bone loss, respectively. Jagdev et al studied the amount of tooth displacement and stress distribution with varying degree of alveolar bone loss.¹¹ They concluded that stresses progressively increased in magnitude with decrease in alveolar bone height; also, it was observed in their study that there was overall increase in the amount of tooth displacement with decrease in alveolar bone height.

Until now, all the researchers have focused on even or circumferential type of bone loss for evaluation of change in position of center of resistance. In this study, asymmetrical bone loss (three wall bony defect) was studied to evaluate the change in position of the CRes. Orthodontic treatment requires buccolingual as well as mesiodistal tooth movement. Hence, in this study effect of bone loss on position of CRes during mesiodistal tooth movement was also taken into consideration. The present study shows that when there is attachment loss on only one tooth surface, i.e. labial, lingual, mesial or distal, the CRes shifts apically. However, the amount of deflection, even when the bone loss was 6 mm, is clinically insignificant, i.e. in situations where bone loss is present only on one surface of tooth and other surfaces are intact, there is no need to change biomechanics.

Limitation of this study is same as for any finite element study. The other two bony defects also need to be studied to see the effect of asymmetric bone loss on

Table 3: Resultant apical displacement of CRes from relative its relative position (41.8% from root apex) in eight tooth models

Tooth model	Resultant displacement (mm)
Tooth model with 3 mm bone loss on labial surface	0.016
Tooth model with 3 mm bone loss on lingual surface	0.014
Tooth model with 3 mm bone loss on mesial surface	0.015
Tooth model with 3 mm bone loss on distal surface	0.018
Tooth model with 6 mm bone loss on labial surface	0.024
Tooth model with 6 mm bone loss on lingual surface	0.015
Tooth model with 6 mm bone loss on mesial surface	0.018
Tooth model with 6 mm bone loss on distal surface	0.012



change in position of CRes. With advent of 3D finite element models, the 3D location of CRes is possible. Vicilli et al showed that the 3D axes of resistance, or their 2D projection intersections, should be used to plan movement of an arbitrary tooth.¹² Clinical approximations to a small 3D 'center of resistance volume' might be adequate in nearly symmetric periodontal ligament cases. Dathe et al concluded from their study that the center of resistance should be replaced by a newer and wider mathematical concept, the 'center of elasticity', together with a limiting parameter, the 'radius of resistance'.¹³

CONCLUSION

It was concluded from the results of the present study that there is negligible deflection of CRes when alveolar bone loss is only on one surface of tooth. Maximum deflection of 0.0245 mm was seen when retraction force was applied on model with 6 mm bone loss on labial surface which is clinically insignificant.

CLINICAL IMPLICATIONS

Since the resultant displacement in position of center of resistance is negligible, there is no need of changing biomechanics during orthodontic treatment for a tooth with three wall infrabony defects. However, it is necessary to further study other infrabony defects like two-wall or one wall defect, and their effect on position of CRes, as this article covers only three-wall infrabony defect.

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