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Influence of alveolar bone height on stress distribution of endodontically treated teeth with post: A 3D finite element analysis



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ARTICLE INFO

Article history:
Available online 15 July 2015

Keywords:
Alveolar bone height
Titanium post
von Mises stresses

ABSTRACT

Objective: Adequate bone support is an essential factor to avoid undue stress to the tooth. This is especially important, when the tooth is endodontically treated and requires a post. The purpose of the present finite element analysis study was to evaluate the stress distribution in endodontically treated teeth with post with different alveolar bone height.

Method and materials: A 3D model was fabricated using software to represent an endodontically treated mandibular second premolar restored with titanium post and a full ceramic crown restoration and was analyzed using finite element analysis. A load of 300 N at an angle of 60° to the vertical was applied to the triangular ridge of the buccal cusp in a buccolingual plane. The relationship of alveolar bone height at 2 mm and 4 mm was calculated using von Mises stresses.

Results: The finite element analysis showed the maximum stresses of 137.43 Mpa in dentin with alveolar bone height of 4 mm as compared to 105.91 Mpa in the model with alveolar bone height of 2 mm from the CEJ.

Conclusion: Stress was observed more in alveolar bone height level of 4 mm from CEJ than 2 mm alveolar bone height level from CEJ.

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1. Introduction

One of the most common challenges faced by the dentist is the restoration of endodontically treated teeth, more so because of its brittleness as compared to vital teeth.[1–3] The success of endodontically treated teeth is related to the position of the tooth in the dental arch,[4,5] occlusal contact,[6,7] proximal contact,[8] structural loss of tooth,[9–13] and periodontal condition of endodontically treated teeth.[14] The changes that accompany

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http://dx.doi.org/10.1016/j.jpfa.2015.02.004
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the root canal therapy and the thickness of the residual walls and cusps will determine the selection of the restorative materials and procedures for endodontically treated teeth.[15] Important factors of treatment plan to be considered for a severely damaged tooth[16] is the evaluations of important of tooth for occlusion or esthetics, access the remaining tooth structure after removal of all caries and old restorations, canal configuration and to control of plaque and eliminate periodontal infection.

Loosening of teeth and fracture of teeth are one of the most common failures for post and core.[4,5,17–20] Vertical root fracture in endodontically treated teeth with post and core is more in older patients,[21] who usually have reduced alveolar bone height.[22] This results because of improper stress distribution along the roots. Metal posts were commonly used for the past many years, however with increased demands of esthetics, the use of tooth color post and core were introduced in the market and are becoming popular.[23,24]

The purpose of the present in vitro study using finite element analysis was to evaluate the relationship of stress distribution on endodontically treated with post and alveolar bone height. The null hypothesis was that bone height do not affect the stress distribution of endodontically treated teeth.

2. Materials and methods

The study was conducted using a 3D finite element model and were analyzed using finite element analysis (FE). The 3D model was fabricated using commercially available software ANSYS Workbench V13.0 to represent an endodontically treated mandibular second premolar restored with a full ceramic crown restoration. The model was made with a simulated periodontal ligament with alveolar bone. The measurements used in the tooth model were taken as described by wheeler's[25] and model was simulated with the help of an Intel core i7 processor, with 8 GB RAM, 64 bit operating system. The materials used in this study were assumed to be homogenous and isotropic. The modulus of elasticity and poisson's ratio for the elements involved in the study are shown in Table 1.

The models included a porcelain crown, dentin, composite core, alveolar bone, gutta percha filling, titanium alloy post. The geometry of the model was made as shown in the Table 2. Discretization was done by generating mesh containing 982,759 nodes and 656,093 elements for the model of 2 mm alveolar bone height from CEJ and 948,119 nodes and 635,849 elements for the model of 4 mm alveolar bone height from CEJ. The base of the alveolar bone was kept static and a load of 300 N at an angle of 60° to the vertical was applied to the triangular ridge of the buccal cusp in a buccolingual plane. The relationship of alveolar bone height at 2 mm and 4 mm was calculated using von Mises stresses.

Table 1 – Mechanical properties.

Material	Modulus of elasticity	Poisson's ratio
Enamel[24]	84.1	.33
Dentin[24]	18.6	.31
Pulp[24]	.00207	.45
PDL[24]	.0689	.45
Cancellous[24]	1.37	.3
Gutta percha[24]	.292	.45
Porcelain[24]	86.2	.19
Titanium alloy[26]	103.4	.3
Panavia F[24]	18.3	.30

Table 2 – Material geometry.

Material	Dimension
Porcelain crown	2 mm
Alveolar bone height	2 mm from the CEJ and 4 mm from the CEJ
Gutta percha filling	5 mm
Cement thickness	At coronal: .75 mm At middle: .4 mm At 5 mm from the apex: .1 mm
Post diameter	At coronal: 1.3 mm At middle: 1.15 mm At 5 mm from the apex 1 mm
Ferrule height	2 mm
Periodontal ligament	.18–.25 mm

3. Result

The finite element analysis showed the stress distribution in all the structures as shown in Fig. 1 and Fig. 2.

As shown in Table 3, the maximum stresses in dentin were observed in the titanium alloy post in alveolar bone height of 4 mm as compared to alveolar bone height of 2 mm from the CEJ.

4. Discussion

The finite element analysis has been used for stress analysis by various investigators.[27–32] Previously, other methods have been used to analyse stress concentration in the tooth structures like the photo-elastic studies.[33] The advantage of FE analysis is that the experimental condition can be kept identical in all the models, which is not possible in experimental human study. In the present study, the FE analysis showed changes in the stress distribution between the two models at 2 mm and 4 mm alveolar bone height from CEJ.

In this study a load of 300N was applied although a higher load may be observed in the clinical conditions. The maximum load in the present study was observed in the dentine and the minimum load was seen in the cement.

The major finding, in this study is that the bone height was a significant factor in the stress distribution. The stress in the dentin, post and the cement was much higher in the model with the alveolar bone height of 4 mm from CEJ compared to bone support of 2 mm alveolar bone height from the CEJ. This shows that the height of the bone plays an important factor in tooth stability. Studies[34] found that endodontically treated teeth with advanced periodontal condition tend to fracture more frequently. Moreover, it was observed that higher alveolar bone height supports stronger forces until root fracture.[35]

The internal canal architecture of the tooth may be modified because of severe carious involvement and during root canal instrumentation resulting in greater canal diameter.

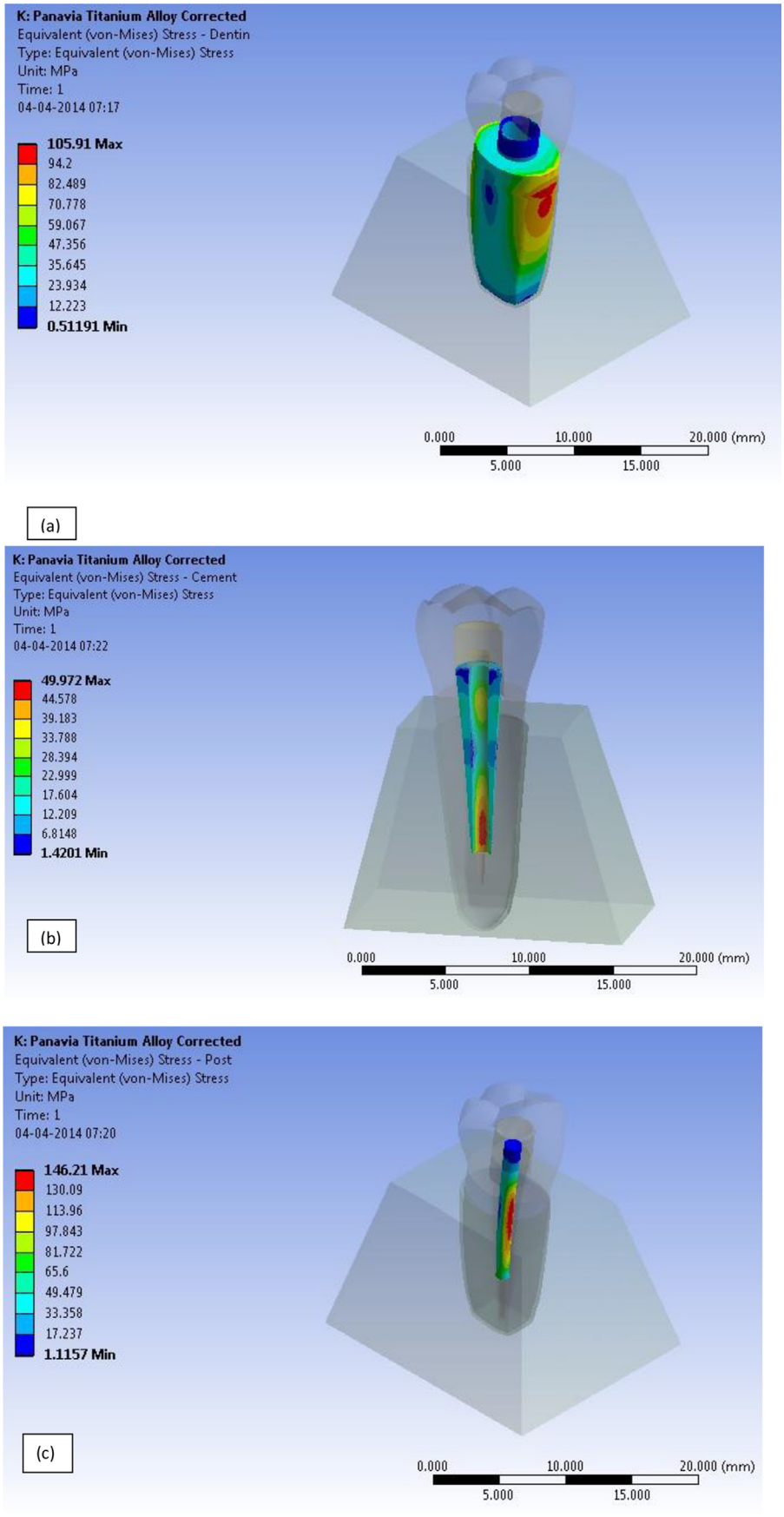


Fig. 1 – Stress distribution in (a) dentin (b) cement (c) post with alveolar bone height of 2 mm from CEJ.

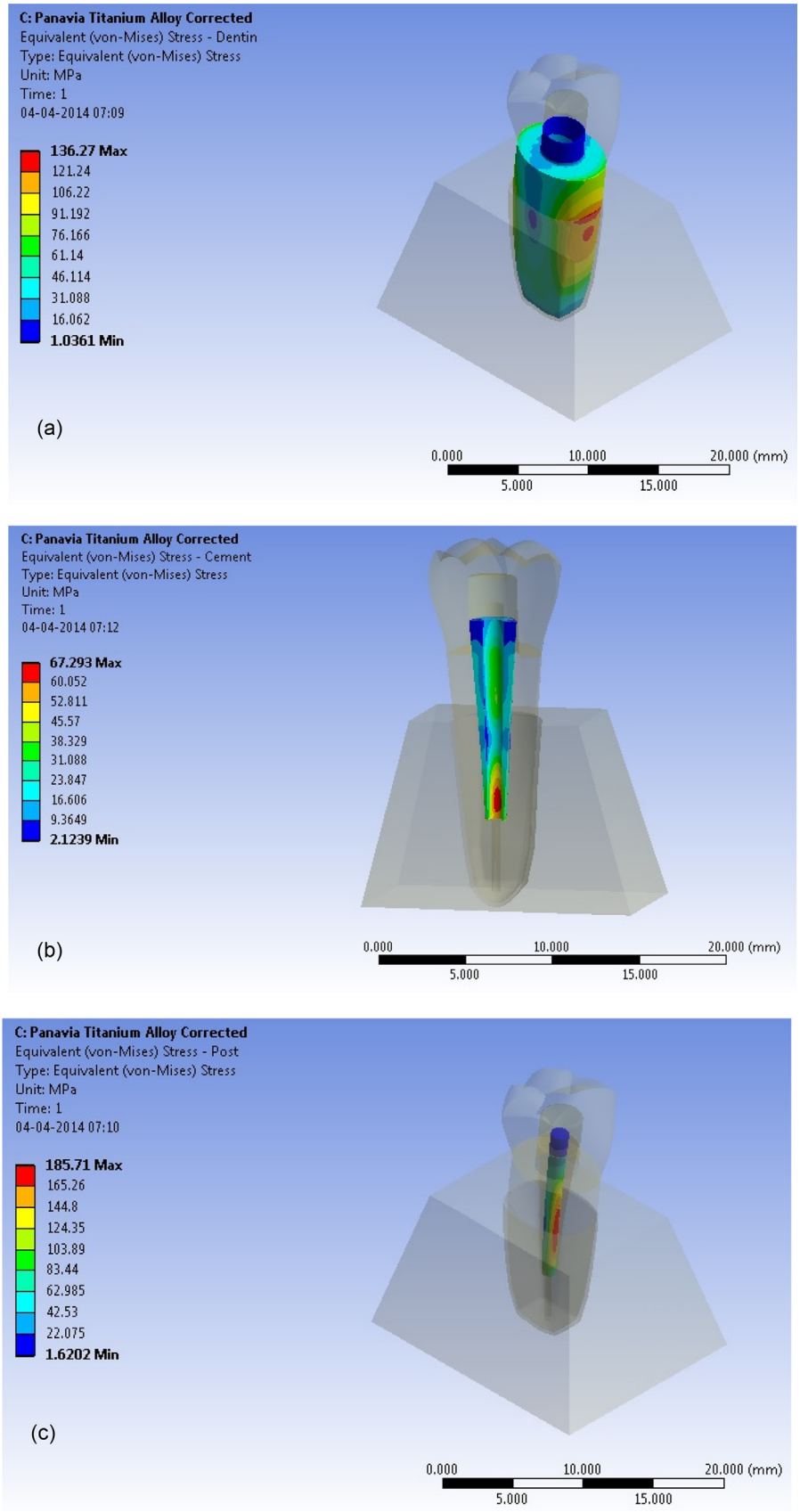


Fig. 2 – Stress distribution in (a) dentin (b) cement (c) post with alveolar bone height of 4 mm from CEJ.

Table 3 – Amount of stresses on titanium post, cement and dentin measured in Mpa.

Bone height	Stresses in Mpa		
	Dentin	Post	Cement
2 mm	105.91	146.21	49.97
4 mm	137.43	185.71	67.29

Therefore, it is important that the selection of the cementing medium for the post be carefully evaluated. It has been observed that the modulus of elasticity of the cement layer is more important to the stress concentration of root filled teeth than the thickness of the cement layer.[36] Moreover, cements with elastic modulus similar to dentin could reinforce weakened root and reduced stress in dentin.[24] Therefore, in this study Panavia F (Kuraray America,Inc.) was chosen for post cementation which has a modulus of elasticity of 18.3 which was almost similar to the dentin (Table 1).

5. Conclusion

Within the limits of the present FE analysis study, it is observed that –

1. Stress distribution in dentin, cement and post was related to bone height level.
2. Stress was observed more in dentin, cement and post with alveolar bone height level of 4 mm from CEJ as compared to 2 mm alveolar bone height level from CEJ.

Conflicts of interest

All authors have none to declare.

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