# Influence of different post design and composition on stress distribution in maxillary central incisor: Finite element analysis

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## ABSTRACT

**Background:** Post design and material has very important effects on dentinal stress distribution since the post placement can create stresses that lead to root fracture.
**Materials and Methods:** In this study we use finite element analysis (FEA) to evaluate stress distribution on endodontically treated maxillary central incisors that have been restored with different prefabricated posts. Six models were generated from the image of anatomical plate: Four metallic posts (ParaPost XH, ParaPost XT, ParaPost XP, and Flexi-Flange) and one fiberglass post (ParaPost Fiber Lux). The sixth model was a control—a sound maxillary central incisor. We used CAD software and exported the models to ANSYS 9.0. All the materials and structures were considered elastic, isotropic, homogeneous, and linear except the fiberglass post which was considered orthotropic. The values for the mechanical properties were obtained by a review of the literature and the model was meshed with 8-node tetrahedral elements. A load of 2N was applied to the lingual surface at an angle of 135°.
**Results:** The stress results were recorded by shear stress and von Mises criteria; it was observed that there was no difference for stress distribution among the titanium posts in the radicular portions and into posts. There was higher stress concentration on the coronary portion with the titanium posts than with the glass fiber post. It seems that the metallic posts' external configuration does not influence the stress distribution.
**Conclusion:** Fiber posts show more homogeneous stress distribution than metallic posts. The post material seems to be more relevant for the stress distribution in endodontically treated teeth than the posts' external configuration.

Received : 06-08-07
Review completed : 25-10-07
Accepted : 04-12-07

DOI: 10.4103/0970-9290.52888

**Key words:** Post composition, post design, stress distribution

Endodontically treated teeth with severe loss of tooth structure require post-and-core restorations for retention purposes.[1] Several post systems have been described in the literature.[2] The cast post-core system is relatively time consuming and involves an intermediate laboratory phase to elaborate the retaining system, which makes the procedure relatively expensive.[3,4] Prefabricated posts do not require this intermediate phase and allow the whole restoration to be performed in one visit, which makes it an easier and less expensive technique.[4]

The post systems include components of different rigidity. Because the more rigid component is able to resist forces without distortion, stress is expected to be transferred to the less rigid substrate.[5] The difference between the elastic modulus of dentine and the post material may be a source of stress for root structures.[5] The use of post systems that have an elastic modulus similar to that of dentine and core result in the creation of a mechanically homogenous unit with better biomechanical performance.[6] Thus, the material of the post and core affect the stress distribution in endodontically treated teeth.[7,8] The effect of post design is also very important for dentinal stress distribution[9] since the placement of a post can create stresses that lead to root fracture.[10]

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The placement of a direct post and core is often necessary to provide a foundation and replace dentine and also to provide the necessary retention for subsequent prosthetic rehabilitation.[11,12] The serrations along the fiber post significantly increases the retention of resin composite core material.[12] However, little is known about the influence of retentive areas on the coronary portion of the post on the stress distribution pattern in the dentin–post complex. It has been difficult to create a valid index of stress distribution at the root structures based solely on experimental and clinical observation.[13] On the other hand, finite element analysis (FEA) has recently become a powerful technique in dental biomechanics.

In this study we use FEA to evaluate stress distribution in an endodontically treated maxillary central incisor that was restored with different prefabricated post systems—one fiberglass post and four titanium posts—with different coronal retentions. The null hypothesis was that post design and composition do not affect the stress distribution.

## MATERIALS AND METHODS

FEA was used to perform the stress analysis of the tooth. Two-dimensional (2D) elastic linear analysis was used for simplification purposes. This analysis used anatomy-based geometric structures for the dentin, pulp, feldspathic all-ceramic crown, composite resin core made with microhybrid composite resin (Filtek Z250, 3M ESPE, St. Paul, USA), cortical bone, cancellous bone, periodontal ligament, gutta-percha (Dentsply, Petrópolis, Brazil), and each one of the post systems. In this study, six models were simulated: A control (model C; a sound maxillary central incisor) and five post systems (four titanium post systems and one fiberglass post system). The titanium post systems used were as follows: Model XH (ParaPost XH; Coltène/Whaledent Inc, Cuyahoga Falls, USA); model XT (ParaPost XT; Coltène/Whaledent Inc, Cuyahoga Falls, USA); model XP (ParaPost XP; Coltène/Whaledent Inc, Cuyahoga Falls, USA); and model FF (Flexi-Flange; Essential Dental Systems Inc., S. Hackensack, USA). The lone fiberglass post system was model FL ParaPost (Fiber Lux (Coltène/Whaledent Inc., Cuyahoga Falls, USA). The effect of the design of these systems on the stress distribution in the coronary and radicular portions of an endodontically treated teeth was evaluated.

Six 2D FEA models of a maxillary central incisor were designed for the analysis of stress distribution induced by applied loads. The stress distribution was analysed using ANSYS 9.0 (ANSYS Inc., Houston, USA). These models were generated from a digital image of the anatomical plate and an intact, endodontically treated maxillary central incisor, in CAD software (Mechanical-AutoCAD V6, Autodesk, Spain) in order to obtain the geometry and contour. The data obtained was exported to ANSYS 9.0 using the IGES format [Figure 1a]. Areas corresponding to each structure were plotted [Figure 1b] and then meshed with isoparametric elements of 8-nodes brick with three degrees of freedom per node (plane 183), according to the mechanical properties of each structure and of the materials used [Figure 1c]. The values for the mechnical properties were obtained by means of a literature review and are listed in Table 1.[14-19] The meshing process involves division of the system to be studied into a set of small discrete elements defined by nodes. The number of elements generated varied depending on the different geometries that were meshed, so that the final mesh accurately represented the original geometry. The models had a total of 11,081 elements and 33,534 nodes in model XH; 10,252 elements and 31011 nodes in model XT; 8228 elements and 24,933 nodes in model XP; 10,984 elements and 33,221 nodes in model FF; and 9,229 elements and 28,080 nodes in model FL. All the tooth structures and materials used in the models were considered homogeneous, isotropic, and linearly elastic, except the fiberglass which was considered orthotropic [Table 1], with different material properties for fiberglass in parallel and perpendicular directions. It was assumed that there was ideal adherence between the structures, i.e., the ceramic–cement, cement–core, core–post, post–cement, and cement–dentin interfaces.

**Table 1: Mechanical properties of the dental structures and the materials used**

| Structure | Young's modulus (MPa) | Poisson ratio | References |
|---|---|---|---|
| Dentin | 18600 | 0.31 | 14 |
| Pulp | 2 | 0.45 | 15 |
| Periodontal ligament | 68.9 | 0.45 | 14 |
| Trabecular bone | 1370 | 0.30 | 14 |
| Cortical bone | 13700 | 0.30 | 14 |
| Gutta-percha | 0.69 | 0.45 | 14 |
| Luting resin cement | 5100 | 0.27 | 16 |
| Composite core | 16600 | 0.24 | 17 |
| Feldspathic ceramic | 69000 | 0.30 | 16 |
| Titanium post | 112000 | 0.33 | 18 |
| Glass fiber post | Ex = 37000 | Fxy = 0.27 | 19 |
| | Ey = 9500 | Fyz = 0.27 | |
| | Ez = 9500 | Fx = 0.34 | |
| | Gyz = 3100 | | |
| | Gxy = 3100 | | |
| | Gxz = 3500 | | |

In all cases, a static load of 2N was applied to the palatal surface of the crown at an angle of 135°[20,21] to the tooth's longitudinal axis [Figure 1]. Model displacement of all nodes on the lateral surface and base of the cortical bone were constrained [Figure 1d]. The qualitative stress distribution analyses were recorded by Von Mises [Figure 1e] and shear stress criteria [Figure 1f].

## RESULTS

Stress distribution analysis using von Mises and shear stress criteria showed critical zones with great stress concentration. These results are represented in [Figure 2] for von Mises analysis and in [Figure 3] for shear stress analysis. The figures utilize a false-color nonlinear scale for stress. From the von Mises stresses it is clear that there is no difference for stress distribution among the titanium posts in the radicular portions and into posts. When the stress distribution on the coronary portion among the posts was evaluated it could be seen that the stress concentration was associated, especially, to post material. The titanium posts presented higher stress concentration on the coronary portion than the fiber posts. Moreover, compared to fiberglass posts, the titanium posts showed lower stress concentration at the middle third of

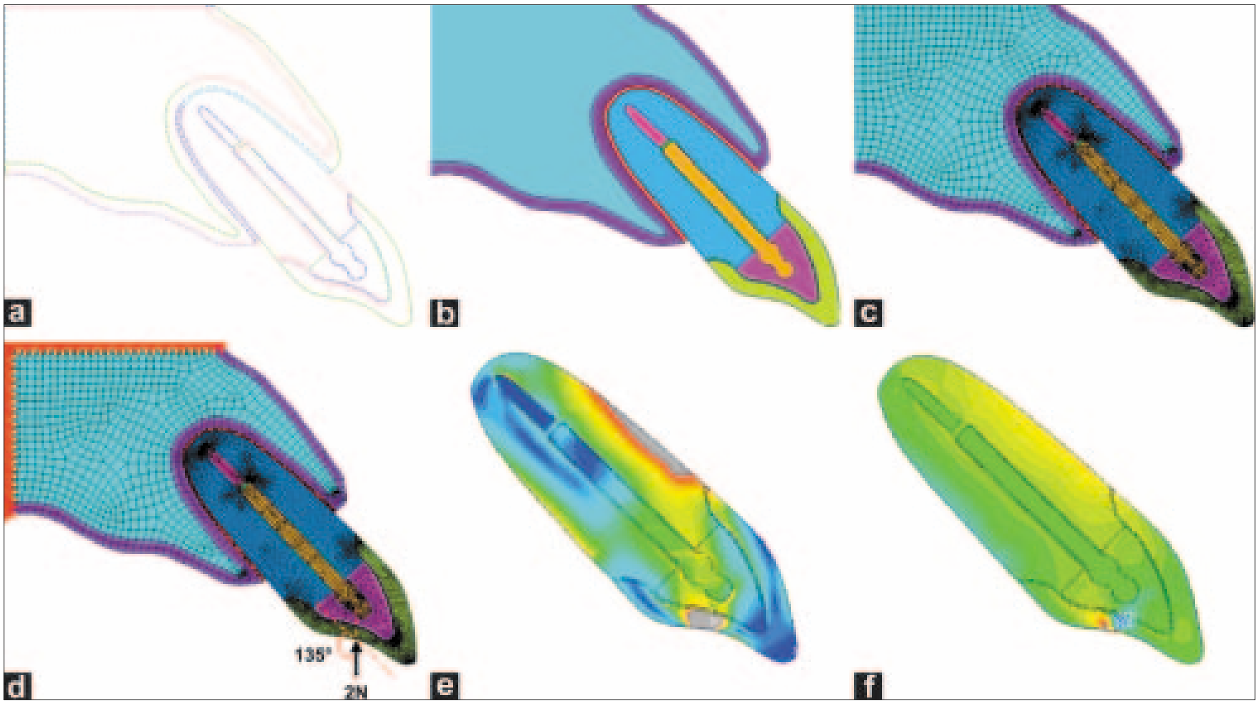


**Figure 1:** (a) Contours generated; (b) areas plotted for each structure and materials; (c) mesh of each structure; (d) model displacement restriction and load application; (e) stress distribution by von Mises criteria; (f) stress distribution by shear stress criteria

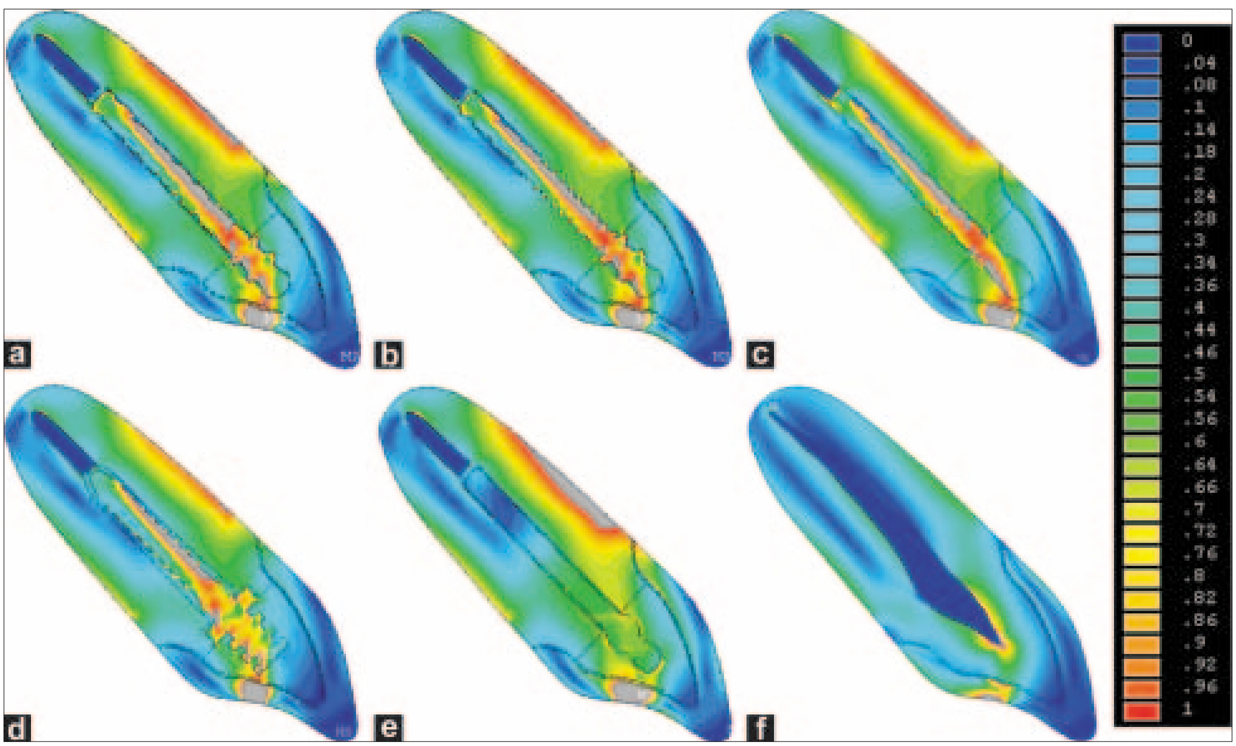


**Figure 2:** Stress distribution by von Mises criteria on maxillary central incisor models: (a) model XH; (b) model XT; (c) model XP; (d) model FF; (e) model FL; (f) model C

buccal surface of the radicular dentin. With the FL model the stress distribution pattern was more homogeneous than with the titanium posts.

On analysis by shear stress criteria it was observed that the titanium post systems presented similar behavior among themselves, with stress concentration on the buccal surface

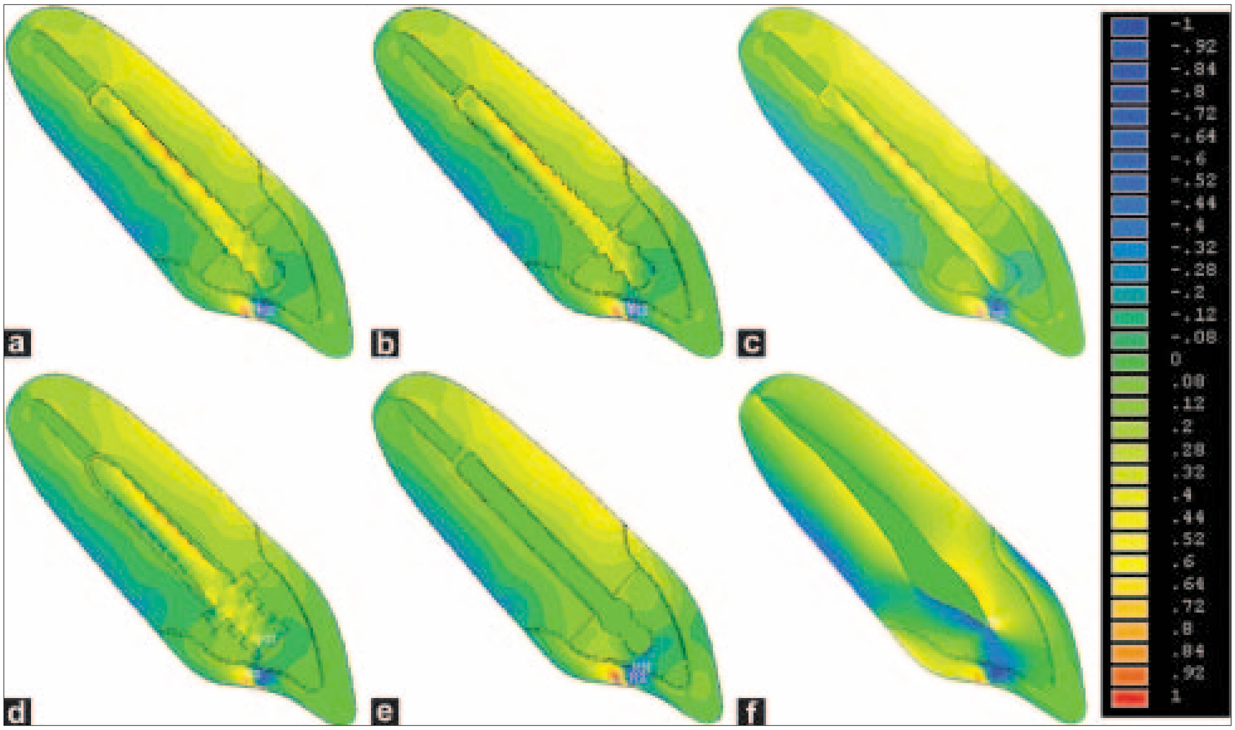


**Figure 3:** Stress distribution by shear stress criteria on maxillary central incisor models: (a) model XH; (b) model XT; (c) model XP; (d) model FF; (e) model FL; (f) model C

of the post. The fiberglass post system showed no stress concentration in the post.

## DISCUSSION

The null hypothesis—i.e., that post design and composition do not affect the stress distribution—was rejected. The stress distribution on endodontically treated maxillary central incisors restored with different prefabricated post systems—glass fiber post and metallic titanium posts—were affected only by the post material. The coronal configuration of the all-titanium posts did not result in different stress distribution into core material and into the dentin portion near the core material.

Oral rehabilitation is inherently difficult, and the functional and parafunctional forces within the mouth result in extremely complex structural responses by the oral tissues. Determination of the resulting stresses can be accomplished only with appropriate stress analysis techniques and with sufficient information of the characteristics of the oral tissues and restorative materials.[5] This study may be useful in the clinical setting for selecting the ideal design and material for a post system so as to provide the maximum possible longevity, since a higher von Mises stress value is a strong indication of a greater possibility of failure.[5]

Experiments have shown that fiberglass posts give better biomechanical performance, with greater fracture loads and with a mode of failure allowing for repair, because the root is not affected by the fracture.[6] Barjau-Escribano *et al.*[6] found that the stress concentration pattern predicted different biomechanical performances for stainless steel and fiberglass posts. The stress distribution pattern reported by them was similar to that which was observed in this study, with fiberglass posts showing more homogeneous stress distribution than titanium posts. Figure 2 shows that compared to teeth restored with titanium posts there is higher stress concentration on the buccal surface of the middle third of the radicular tooth restored with the fiberglass post. This is due to the capacity of fiberglass posts to transfer stress to the dentin. The homogeneous stress distribution pattern seen with fiberglass posts may be similar to that seen in teeth restored with feldspathic crown and can be explained by the fact that the modulus of elasticity of the fiberglass post, which fills the pulp space, and that of the dentin is similar.

According to Barjau-Escribano *et al.*,[6] and as observed in this study, titanium posts concentrate stress close to the post–cement interface, promoting weakness of the restored tooth. Akkayan and Gulmez[22] observed that the fractures occurring with the use of fiberglass and quartz post systems could be repaired, whereas this was not true of the fractures occurring with zirconium and titanium post systems. The stress concentration of titanium posts was due to the difference in the stiffness between the post and its surrounding material (core, cement, and dentin).[10,22] Thus, fiberglass posts can be considered a very good choice for post-endodontic restoration because of three main attributes: It gives good biomechanical performance because post, core, cement, and dentin constitute a homogeneous ensemble; it provides excellent aesthetics, which makes it suitable for restoration in the anterior region; and it shows good adhesion to cement agents.[10]

Some authors consider the design of the post to be an important factor influencing the radicular stress distribution in endodontically treated teeth restored with post systems.[4,10,15] In this study, a difference in stress distribution between the models of teeth restored with different coronary and radicular configurations of titanium posts was not observed. Additional investigations, including comparison with tissue morphologic condition, strain gauge data, or *in vitro* tests, are necessary to further validate our findings. Clinical studies also are needed to show the relative longevity and success rates of different post systems.

This study applied the FEA to better simulate a restored endodontically treated tooth and to describe the stresses created during loading. A major advantage of FEA is its ability to solve complex biomechanical problems for which other methods of study are too cumbersome.[15] However, in the FEA, assumptions related to the material properties of simulated structures (such as isotropy, homogeneity, and linear elasticity) are not usually absolute representations of the structure. Therefore, FEA must ideally be used as an initial step and as an aid for planning further laboratory tests and clinical studies; this will reduce the inaccuracies inherent in FEA. Moreover, according to Pegoretti *et al.*,[23] although the limitations related to the assumption that the stress distributions are identical in all vertical sections parallel to the selected two-dimensional model (plane strain assumption), results based on 2D models have been widely used for modeling the clinical reality. Also, these authors considered that 3D models are definitely more accurate in describing the actual states of stress but, at the same time, much more complicated to realize and they do require a much extensive computing time to be resolved. We used 2D elastic analysis for its simplicity. The small differences observed in the numerical results between the 2D and 3D analyses do not disqulify the use of appropriate 2D models for investigating key aspects of the biomechanics of dental restorations in a single tooth unit.[24]

## CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions could be drawn:

1. The design of the metallic posts does not significantly influence the biomechanical performance of the complex tooth restoration.
2. A fiberglass post shows more homogeneous stress distribution when compared to a metallic titanium post.
3. The post material seems to be a more relevant factor on the stress distribution of endodontically treated teeth restored with post than the post's external configuration.

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**How to cite this article:** Silva NR, Castro CG, Santos-Filho PCF, Silva GR, Campos RE, Soares PV, *et al*. Influence of different post design and composition on stress distribution in maxillary central incisor: Finite element analysis. Indian J Dent Res 2009;20:153-8.

**Source of Support:** Nil, **Conflict of Interest:** None declared.