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# Stress distribution in endodontically treated single-rooted premolars restored with everstick post and sharonlay: A finite element analysis

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## ABSTRACT

**Background:** The objective of the study is to compare stress distribution in a tooth restored with everstick post and sharonlay by means of three-dimensional finite element analysis (3D-FEA).
**Materials and Methods:** An experimental original study was carried out in which two 3D-FEA models were constructed: (1) tooth restored with everstick post and metal ceramic crown and (2) tooth restored with sharonlay. The material properties were assigned and a force of 100N, 200N, 300N, and 400N was applied to the centric stop of the occlusal surface in centric occlusion at a 45° inclination in a linguolabial direction to the long axis of the tooth. Analysis was run and the stress distribution pattern was studied. As all stress distribution analysis was performed with the Ansys 11.0 software (Inventor AutoCAD 2010; Autodesk) program, the significance of *P* value or tests for statistical analysis was considered.
**Results:** Sharonlay showed more total deformation, larger stress, and strain concentration than that of everstick post.
**Conclusion:** Tooth restored with sharonlay showed greater chances of deformation than everstick post. It also showed maximum strain concentration near the apical portion of the remaining tooth structure and more stress in the cervical third of the postsystem than everstick post.

**Key Words:** Everstick post, finite element analysis, hypermesh, sharonlay

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## INTRODUCTION

Teeth requiring endodontic treatment are weak as they show extensive loss of the tooth structure owing to caries, repetitive restorations, and/or fracture; such teeth are further weakened by endodontic procedures. Endodontically treated teeth (ETT) are hollow cylinders; their strength and bending fracture resistance is proportional to the difference between their outer and inner diameters. The resultant loss of structural integrity necessitates special considerations such as adequate resistance and retention features, which may be collectively termed anchorage. The most accepted method of providing coronal and radicular reinforcement to grossly destructed teeth is the placement of posts in root canals. A post's primary purpose is to retain the final restoration and distribute occlusal stresses along the tooth structure, and multiple factors such as postlength, diameter, remaining dentin thickness, and postadaptation determine its effectiveness.[1]

A desirable quality of posts is its elasticity, which should be similar to dentin to reduce stress

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concentration at the dentin–post interface so that forces are more evenly transferred to the root, and the incidence of root fracture decreases. Glass fiber-reinforced posts have less stiff fibers than carbon fiber posts. They are therefore more flexible than both metal and carbon fiber posts. They have flexural strength more close to the dentin than carbon fiber posts and may be made up of quartz or silica fibers. The E-glass fiber or everstick post is a resin-impregnated unpolymerized glass fiber structure and appears to be superior to the glass and carbon fiber posts in terms of tooth preparation, bonding ability, flexibility, flexural strength, and esthetics.[2]

A new onlay design (sharonlay) with a postextending into the radicular portion of the premolar providing the required reinforcement in a conservative manner and protecting it against both vertical and horizontal forces is proposed herewith. In this design, the onlay component protects the endodontically treated premolar from splitting under compressive loading and the radicular extension serves dual function of retention as well as protection from fracture at the neck due to tensile (horizontal) forces.[3]

The purpose of this study was to compare stress distribution in a tooth restored with everstick post and sharonlay by means of three-dimensional finite element analysis (3D-FEA).

## METHODOLOGY

For carrying out this experimental original study, clearance was taken from the Institutional Ethical Committee.

All the steps in this study were conducted first on extracted mandibular second premolars almost of similar dimensions and were restored with everstick post and sharonlay. Then, taking these samples as reference, 3D models were created for FEA. All models were created with 3D CAD design software, SOLIDWORKS, and all stress distribution analysis was performed with the Inventor AutoCAD 2010; Autodesk program (San Francisco, California, USA).

The models were divided into two groups,

- Group I: Teeth restored with everstick post and metal ceramic crown
- Group II: Teeth restored with sharonlay.

For each group, the layers were then stacked one on top of the other to obtain outlines of the surface contours of the tooth. The periodontal ligament was modeled as a layer 0.3-mm thick around the root surface. Finally, bone was modeled around the tooth.

Postlength inside canal and apical gutta percha were assumed to be 9 mm and 5 mm, respectively. A 100-mm thick layer of the luting agent was modeled on the dentin.

For Group I, after modeling of everstick post, composite resin core was modeled with metal ceramic crown with a metal thickness of 0.5 mm and a porcelain thickness of 1.5 mm [Figure 1a].

For Group II, a single component restoration, i.e., sharonlay made up of chromium-cobalt alloy was modeled with a porcelain thickness of 1.5 mm on the coronal portion [Figure 2a].

The digital tooth models with post, core, and crown were imported to HyperMesh software (Altair Engineering, Michigan, USA). The models of the surface contours of the tooth were converted into solid models. These models were then meshed using tetrahedral elements with HyperMesh software as a neutral file using the stereolithography format. All materials were assumed to be homogenous, isotropic, and linear elastic. Nodes were assigned and elements were designed for stress analysis. Due to the complicated geometry of the tooth, free meshing technique was adopted. The completed models consisted of 9323 3D tetrahedral elements and 18553 nodes for models in Group I [Figure 1b] and 9012 3D tetrahedral elements and 17,780 nodes for models in Group II [Figure 2b].

A simulated load of 100N, 200N, 300N, and 400N was applied to the centric stop of the occlusal surface in centric occlusion at a 45° inclination in a linguolabial direction to the long axis of the tooth and the stress concentration was analyzed.

## RESULTS

In this study, total deformation, equivalent elastic strain, and equivalent (von Mises) stress at prefabricated metallic post (PFM) crown, sharonlay, everstick post, enamel, dentin, periodontal ligament, gutta percha, and bone were seen and were visualized using shade images. The red zone indicates the highest stress and strain levels, while the dark blue zone indicates the lowest stress and strain levels.

Total deformation was observed at 100N (0.005 mm), 200N (0.01 mm), 300N (0.015 mm),

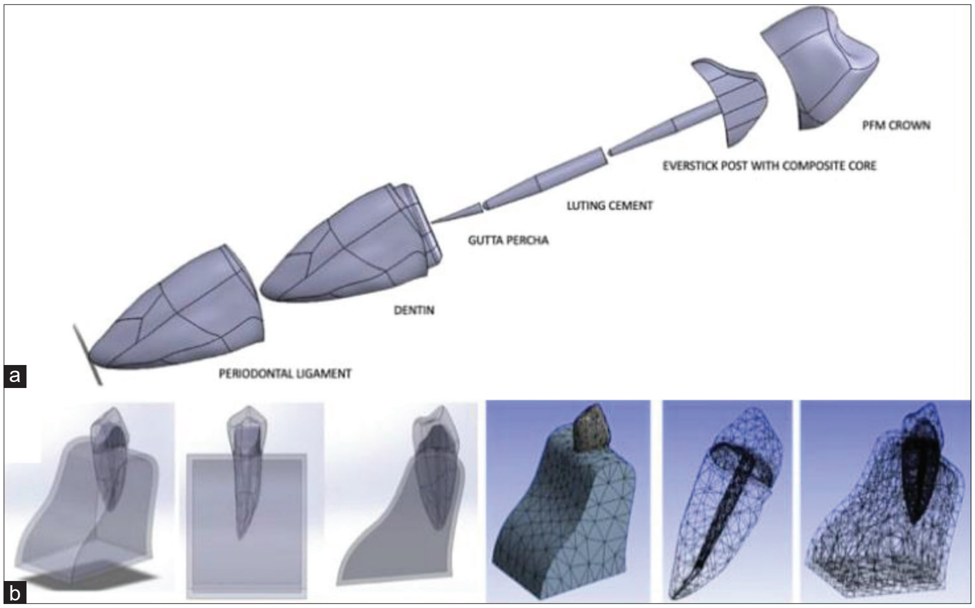


**Figure 1:** (a) Components of constructed model of tooth restored with everstick post and PFM crown, (b) 3D finite element design and meshing of mandibular second premolar restored with everstick post and PFM crown. PFM: Prefabricated metallic post, 3D: Three dimensional.

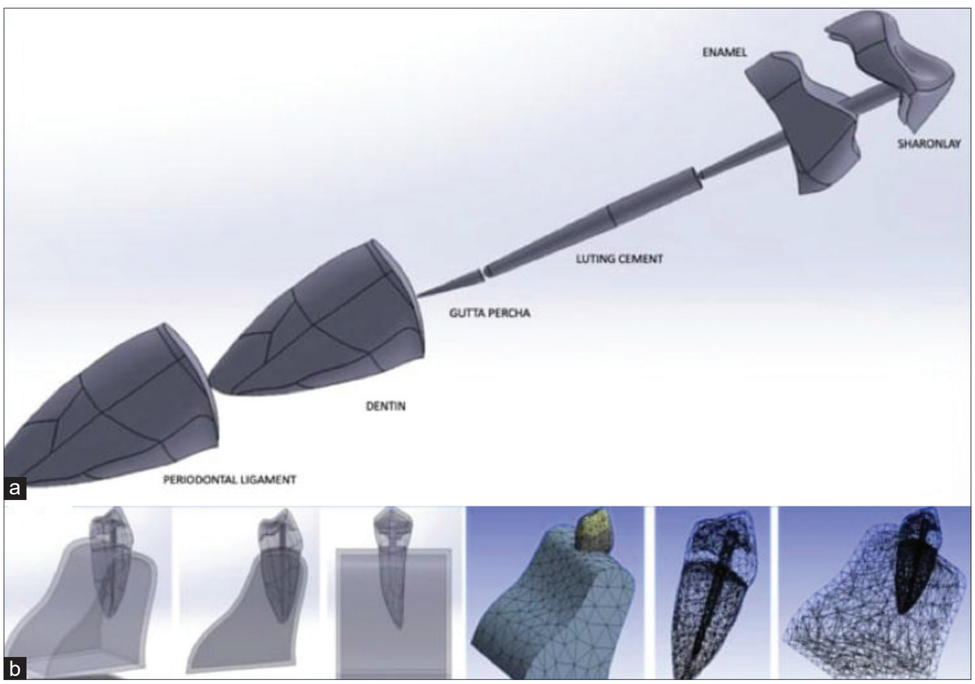


**Figure 2:** (a) Components of constructed model of tooth restored with sharonlay, (b) 3D finite element design and meshing of mandibular second premolar restored with sharonlay. 3D: Three dimensional.

and 400N (0.020 mm) for everstick post and at 100N (0.005 mm), 200N (0.010 mm), 300N (0.020), and 400N (0.030 mm) for sharonlay was observed on lingual cusp in both the groups [Figures 3-10].

Maximum stress (21.51MPa at 100N, 43.02MPa at 200N, 64.5MPa at 300N, and 86.05MPa at 400N) in everstick post was observed on the lingual aspect of the tooth structure whereas in sharonlay, the maximum stress (69.3MPa at 100N, 138.7MPa at 200N, 208.14MPa at 300N, and 277.5MPa at 400N) was seen to concentrate more in the cervical third of the post [Figures 3-10].

While maximum strain, 0.007 mm/mm at 100N, 0.014 mm/mm at 200N, 0.021 mm/mm at 300N,

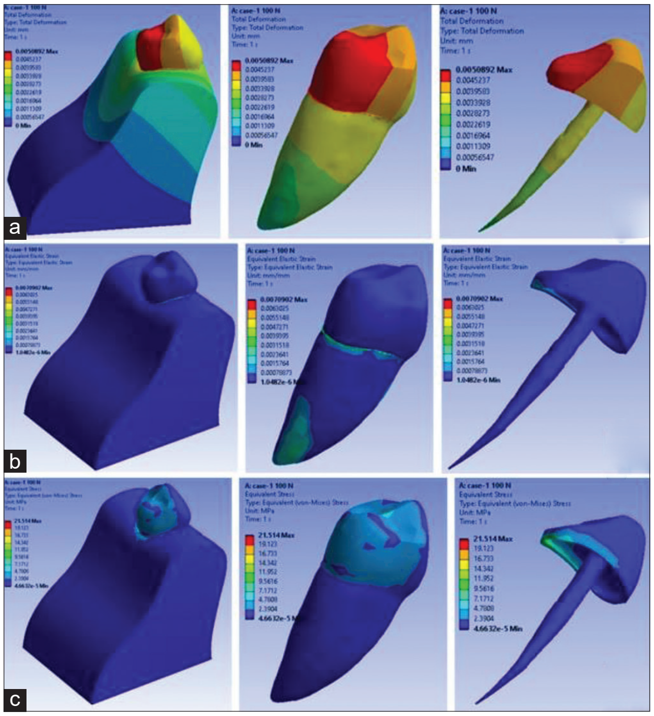


**Figure 3:** (a) Total deformation at a load of 100N; (b) Equivalent elastic strain when 100N was applied; (c) equivalent von Mises stress concentration when 100N force is applied on tooth restored with everstick post with PFM crown. PFM: Prefabricated metallic post.

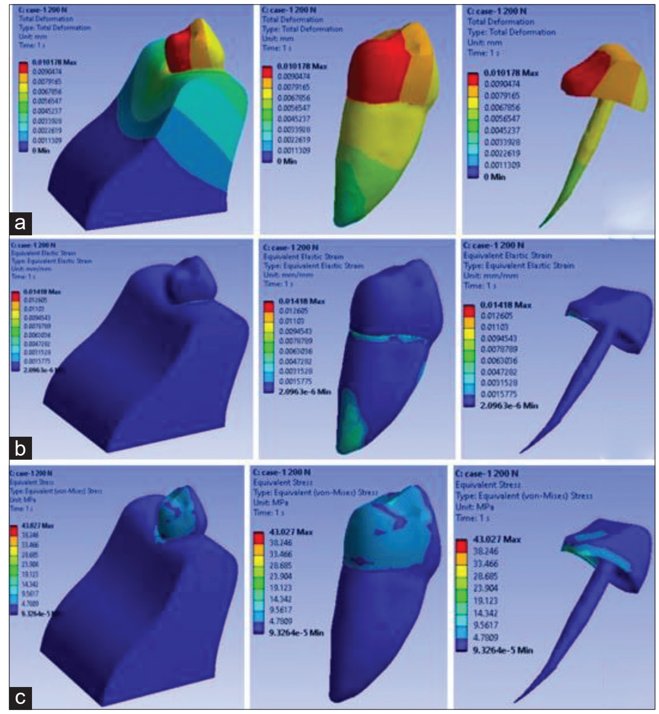


**Figure 5:** (a) Total deformation at a load of 200N; (b) Equivalent elastic strain when 200N was applied; (c) equivalent von Misses stress concentration when 200N force is applied on tooth restored with everstick post with PFM crown. PFM: Prefabricated metallic post.

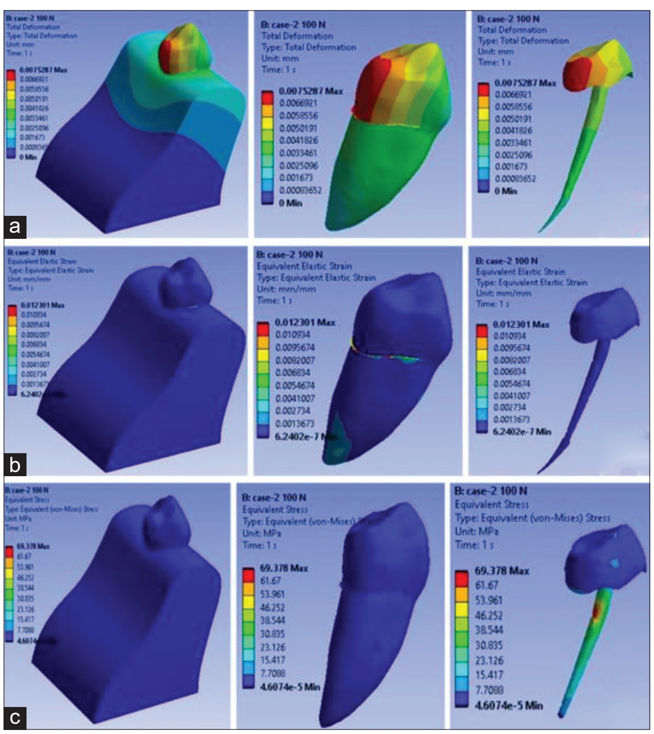


**Figure 4:** (a) Total deformation at a load of 100N; (b) Equivalent elastic strain when 100N was applied; (c) equivalent von Misses stress concentration when 100N force is applied on tooth restored with sharonlay.

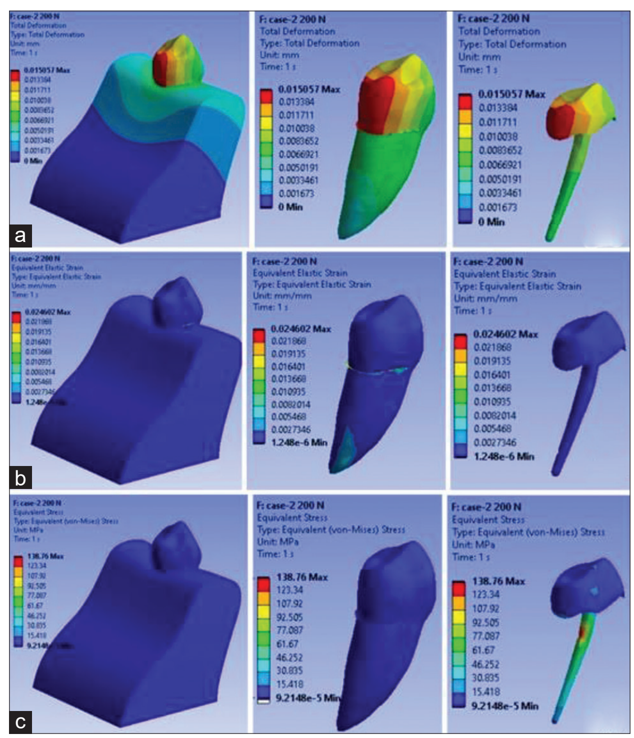


**Figure 6:** (a) Total deformation at a load of 200N; (b) equivalent elastic strain when 200N was applied; (c) equivalent von Misses stress concentration when 200N force is applied on tooth restored with sharonlay.

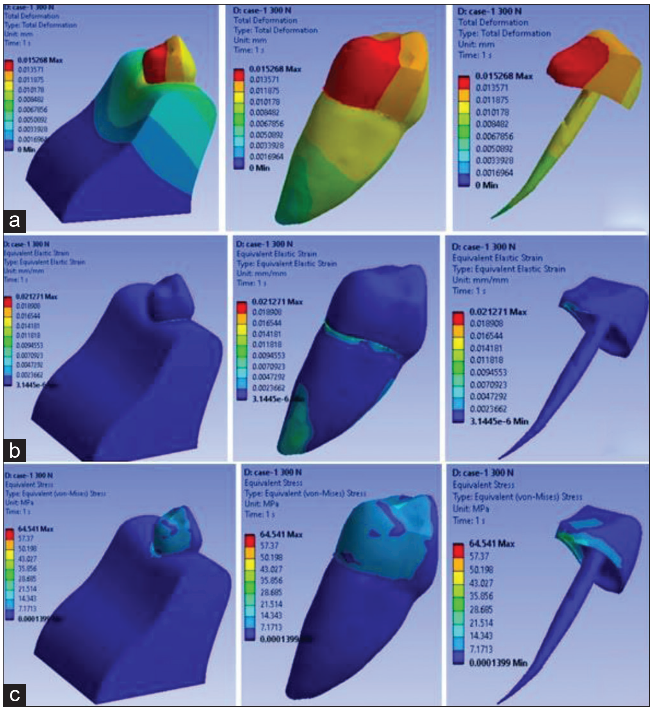


**Figure 7:** (a) Total deformation at a load of 300N; (b) Equivalent elastic strain when 300N was applied; (c) equivalent von Misses stress concentration when 300N force is applied on tooth restored with everstick post with PFM crown. PFM: Prefabricated metallic post.

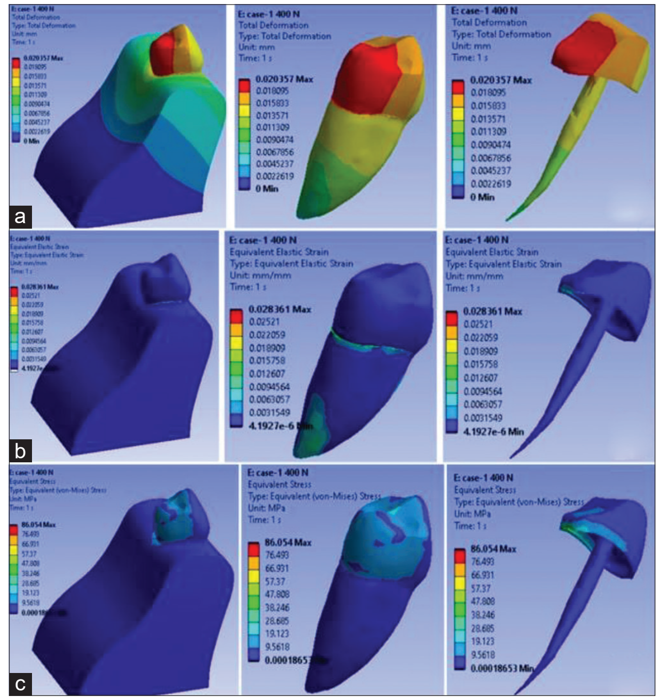


**Figure 9:** (a) Total deformation at a load of 400N; (b) Equivalent elastic strain when 400N was applied; (c) equivalent von Misses stress concentration when 400N force is applied on tooth restored with everstick post with PFM crown. PFM: Prefabricated metallic post.

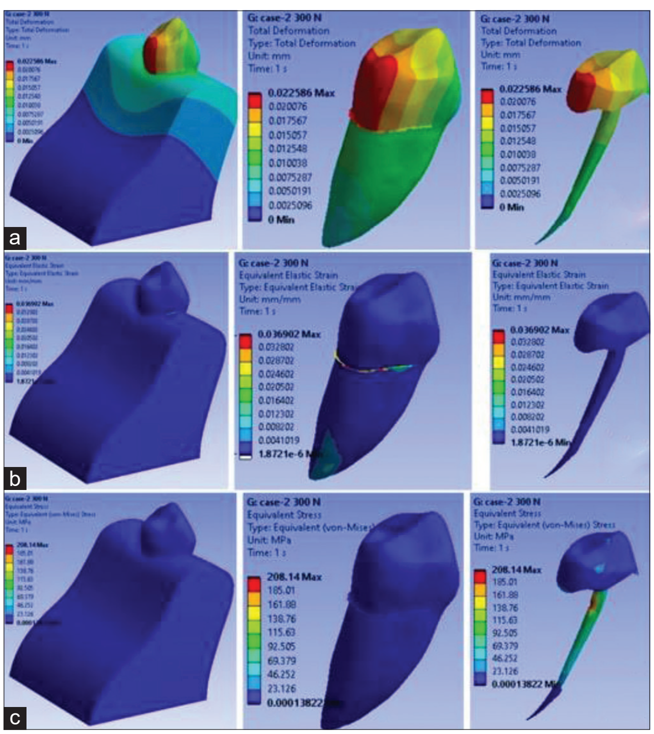


**Figure 8:** (a) Total deformation at a load of 300N; (b) equivalent elastic strain when 300N was applied; (c) equivalent von Misses stress concentration when 300N force is applied on tooth restored with sharonlay.

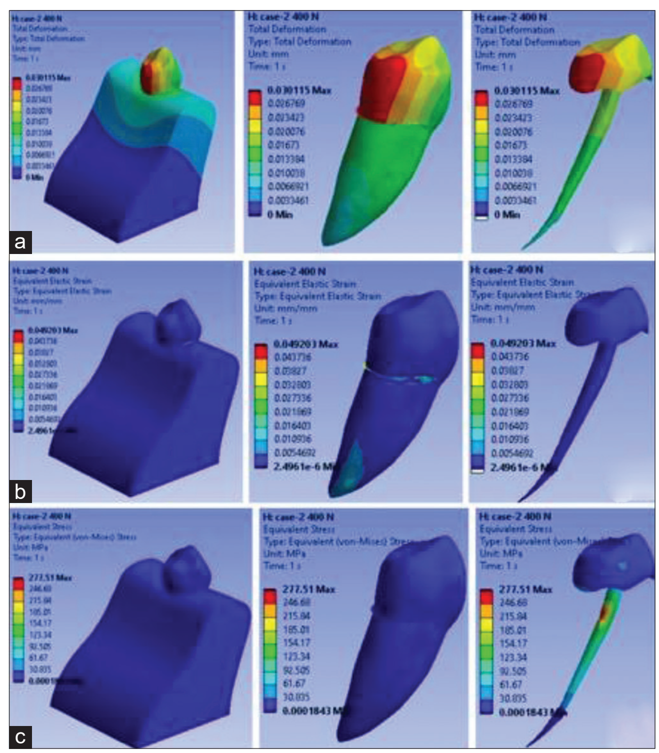


**Figure 10:** (a) Total deformation at a load of 400N; (b) equivalent elastic strain when 400N was applied; (c) equivalent von Misses stress concentration when 400N force is applied on tooth restored with sharonlay.

and 0.028 mm/mm at 400N for everstick post and 0.012 mm/mm at 100N, 0.02 mm/mm at 200N, 0.036 mm/mm at 300N, and 0.049 mm/mm at 400N for sharonlay were observed to be concentrated on the apical portion of the remaining radicular tooth structure with increasing load [Figures 3-10].

## DISCUSSION

The finite element method (FEM) was first developed in 1943 by Alexander Hrennikoff and Richard Courant to solve complex elasticity and structural analysis problems in civil and aeronautical engineering. Davy *et al*. applied FEM to the study of post and core restorations. FEA is an accurate numerical method in stress analysis and has been applied to dental biomechanics.[4]

Young's modulus of elasticity and Poisson's ratio of the modeled material are specified for each element. A system of simultaneous equations is generated and solved to yield predictable stress distributions in each element throughout a structure. The variables may be manipulated with computer precision, which eliminates variation resulting from sampling error. FEM analysis repeated any number of times will yield identical results 100% of the time. Thus, it is certain that the results are always caused by manipulation of the variables and not by chance. For this reason, conventional inferential statistical analysis is not normally included in FEA.[5]

Using FEA, the stress generated can be analyzed accurately by assessing the stress concentration areas. In addition, FEA is a noninvasive method, less time-consuming, no extensive instrumentation is required. It is very easy to simulate any biological condition in preoperative, intra-operative, and postoperative stages for more accurate and reliable results and even possible to vary the properties to different elements and within an element according to the polynomial applied.[6] Because of these advantages, this method has been used to investigate the mechanical behavior of ETT subjected to different techniques and restorative materials.[7-9] At this point, a few limitations need to be addressed regarding the present study. The structures and materials used in this study were considered to be linearly elastic, homogeneous, and isotropic. This meant that the computational simulation was not absolutely same as that of natural tooth structure and supporting tissues. The elastic modulus and Poisson's ratio values applied for the structures and materials in this study were used as thus determined from a study published earlier[2] [Table 1].

Stresses are produced as a result of mastication forces imposed on a structure. The distribution or pattern of these stresses is the result of the angle of the load and the geometry of the object. In addition, notches or imperfections which present within the material may cause localized increase in the magnitude of the stresses, known as stress concentrations. These stress concentrations can contribute to the failure of the material through crack formation and an increased likelihood of fatigue failure.[10]

One of the advantages of everstick post is that it can be used in areas of esthetic consideration, i.e., in the anterior region where widely teeth with single canal are seen. Moreover, sharonlay is most commonly given in premolars with a single canal. Therefore, to replicate the outcomes and to evaluate the stress generated, mandibular premolars were taken in this study.

The greatest natural forces exerted against teeth and implants during mastication can range from 42N to 1245N. The average magnitude of force is greater in the molar region (200lb), less in canine area (100lb), and least in the anterior incisor region (25–35lb). These average bite forces increase with parafunctions to magnitude that may approach 1000lb. Therefore, in our study, load till 400N was applied considering that our study is on premolars.[11]

Everstick post is a flexible, resin-impregnated, uncured glass fiber post which has an interpenetrating polymer network resin matrix that can be cured to

**Table 1: Mechanical properties of materials in finite element analysis model (units for Young's modulus measured in GPa)**

| Materials | Young's modulus (GPa) | Poisson's ratio |
|---|---|---|
| Enamel | 84.1 | 0.33 |
| Dentin | 18.6 | 0.31 |
| PDL | $68.9\times10^{-3}$ | 0.45 |
| Cortical bone | 13.7 | 0.30 |
| Spongy bone | 1.37 | 0.30 |
| Gutta percha | $0.96\times10^{-3}$ | 0.45 |
| Metal | 203.6 | 0.30 |
| Everstick post | 13–16 | 0.28 |
| Porcelain | 69 | 0.28 |
| Composite resin | 8.3 | 0.28 |
| Cement layer (GIC) | 18.6 | 0.28 |

GIC: Glass ionomer cement; PDL: Periodontal ligament the anatomic shape of the canal. The specialty of this technique is that resin-impregnated unpolymerized glass fiber post very well adapts to the morphology of the root canal and attains high flexural strength after light curing. The glass fibers can be reactivated even after polymerization, leading to the desired shape of the core. In addition, it provides maximum support to the crown structure by filling the root canal space completely with fibers. After curing these fiber-reinforced posts, they exhibit high tensile strength and elastic modulus which is similar to the elasticity of dentin, thereby causing less root fracture. This allows the stress of occlusion to be evenly distributed throughout the root structure.[12]

Sharonlay is a design consisting of an onlay with postextending into the radicular portion of the tooth, casted into a single component giving the advantages of the onlay and radicular postextension is indicated to enhance retention as the post in a multirooted molar does not enhance resistance. Single-component restorations have a greater surface area for dissipation of stresses, thereby taking more load before fracturing compared to two-unit components.[3]

In our study, sharonlay showed more total deformation, larger stress, and strain concentration than that of everstick. Everstick post showed better results as the elastic modulus is similar to that of dentin, the stress concentration was seen to be dissipated more at the level of cervix in the tooth structure, suggesting that the elastic modulus influences maximum stress development in the remaining radicular tooth structure rather than accumulating within the post system.

Whereas, in case of sharonlay, it was seen that the stress was more concentrated around the cervical third of the post. This could be because the elastic modulus of metal is more than that of radicular dentin, thus reducing the strain on dentin but resulting in more stress concentration within the postsystem, potentially leading to fracture.

Many other studies have demonstrated favorable outcomes with everstick post with compared to other types of postsystem. One such study was done by Sinha *et al*. In their study, they showed that the highest mean fracture resistance (819.91 N) was demonstrated by the everstick which was higher compared to other glass fiber posts.[13]

Doshi *et al*. also concluded in their study that the E-glass fiber post had a significantly higher fracture resistance than the glass fiber or carbon fiber posts, which may be attributed to its minimal preparation of postspace, lower modulus of elasticity, and the unique technique of placement and bonding. There was no catastrophic failure in this group.[1]

Another study conducted by Khurana *et al*., in which everstick post showed significantly high resistance to fracture when compared with the other fiber-reinforced composite (FRC) post (Ribbond) and thus can be a promising alternative to the conventional postcore systems and other FRC postsystems.[14]

In our study, sharonlay showed more total deformation, stress, and strain concentration when compared to everstick post but in a study conducted by Sharath Chandra *et al*., it showed that sharonlay gives higher fracture resistance to a premolar as compared to (a) metal onlay with prefabricated metal post and (b) metal onlay over endodontically treated tooth.[15] However, more studies need to be conducted to elevate the outcomes when an endodontically tooth is restored with sharonlay.

## CONCLUSION

Within the limitations of this study, it has been concluded that:

1. Total deformation was seen more in sharonlay than compared to everstick post with increasing load
2. Strain was observed to be concentrated more in the apical portion of the remaining tooth structure in sharonlay than everstick post
3. The maximum stress development was present in sharonlay than that of everstick post. The location of maximum stress development in sharonlay was seen to be concentrated in the cervical third of the postsystem whereas in everstick post, the stress was concentrated more on the lingual wall at the cervical region and was dissipated to the remaining tooth structure. Hence, chances of vertical root fractures are more in tooth restored with sharonlay than in tooth restored with everstick post with PFM crown.

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### Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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