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Original Article

# Investigation of Stress Distribution in Teeth with Apical Lesions Restored with Different Post-Materials and Three-Unit Bridges Using Finite Element Analysis

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## Abstract

**Objective** Restoration of root canal-treated teeth presenting with apical lesions requires careful selection of post-materials because their mechanical properties influence stress transfer within dental and supporting structures. This study aimed to evaluate, using finite element analysis, stress distribution patterns in a mandibular premolar with root canal treatment and an apical lesion restored with fiber, cast metal, or zirconia post systems supporting a three-unit bridge under occlusal loading.

**Materials and Methods** Four 3D finite element models were developed: a healthy premolar reference model and three lesioned premolar models restored with fiber, cast metal, or zirconia posts integrated into a three-unit fixed prosthesis. A static occlusal load of 300 N was applied at 45 degrees to the long axis of the tooth on the lingual incline of the buccal cusp. Deformation behavior and equivalent stress (von Mises) distributions were computed across dental tissues, prosthetic components, and surrounding bone structures.

**Results** Occlusal loading generated consistent stress concentration patterns across models, predominantly in the buccal cervical region, the load-application cusp, and the cervical and middle thirds of the root, with intensified stresses at prosthetic connector regions. Posts with higher elastic moduli retained stresses within the post structure and reduced transmission to dentine, whereas fiber posts promoted more homogeneous stress distribution into surrounding dental tissues. These findings indicate that elastic compatibility influences load transfer pathways within structurally compromised abutment teeth.

**Conclusion** Within the limitations of this computational study, higher-modulus post systems localized stresses within the post, whereas lower-modulus fiber posts redistributed stresses to dentine, demonstrating that post-material selection significantly affects biomechanical response in lesioned teeth supporting fixed prostheses.

**Keywords**
- finite element analysis
- post-materials
- stress analysis
- three-unit bridge
- lesioned tooth

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## Introduction

Tooth loss remains prevalent, and fixed prosthodontic rehabilitation is routinely employed to restore function, aesthetics, and tissue stability, ranging from single-tooth replacement to full occlusal reconstruction.[1,2] In the presence of one or more missing teeth, fixed partial dentures cemented on the abutment teeth are called bridge prostheses. To treat missing teeth with fixed partial dentures, the adjacent teeth on both sides of the edentulous area should be able to be used as prosthetic support.[3] The biomechanical suitability of these supporting teeth becomes particularly relevant when pulpal pathology or periapical disease is present, as such conditions frequently necessitate endodontic intervention before their incorporation into fixed prosthetic rehabilitation.

Although it is preferred that the abutment teeth be vital, researchers have reported that it can be used as an abutment for fixed partial dentures in teeth with periapical lesions and root canal treatment (RCT).[4] After RCT of abutment teeth presenting with periapical lesions, radiographically observable bone improvement typically occurs within 6 to 12 months, depending on lesion size.[5] It has been reported in studies that this period sometimes lasts up to 4 years.[6]

Waiting for radiographically complete healing and delaying restorative treatment may cause fractures, caries, and periodontal problems in the teeth, while immediate permanent restoration prevents the risk of microleakage and provides faster healing of periapical lesions. Therefore, it is preferred to perform coronal restoration immediately after adequate RCT.[7,8]

When deciding on the permanent restoration to be made after RCT, the remaining tooth tissue is taken into consideration, and conservative or prosthetic restorations are applied accordingly. Direct or post-supported prosthetic crown applications are preferred in teeth with severe coronal destruction.[9]

The most common failures in post-applied teeth are reported as fractures of the root and many catastrophic fractures in the root requiring extraction.[10] The reason for this may be that the difference between the elastic modulus of dentin and the post-material in post systems creates a source of stress for root structures.[11] It is still unclear which post system best strengthens a restored tooth.[12] Beyond post selection, the definitive coronal restoration also contributes to structural performance, linking radicular reinforcement strategies to prosthodontic material and design considerations. In a study comparing the fracture resistance of fiber and cast posts, it was reported that fiber posts transfer more stress to dentin and resist forces better than cast posts, whereas in cast posts, stresses are retained by the post and transfer less stress to dentin.[11] Despite extensive investigation of post-materials, their biomechanical influence on lesioned abutment teeth supporting multi-unit prostheses remains insufficiently characterized.[12–14]

Post-core restorations combined with definitive crowns enhance structural durability and clinical longevity, with metal-ceramic systems remaining widely used in fixed prosthodontics.[15,16]

Evaluating the biomechanical consequences of such restorative strategies experimentally is challenging; consequently, computational modelling has become a key approach for analyzing stress behavior within complex dental assemblies. Finite element analysis (FEA) is the analysis method that can show materials under ideal conditions by eliminating the human factor.[8] In addition, it plays an important role in determining biomechanical and clinical conditions by offering the possibility of use in different areas of dentistry.[17]

This study advances existing finite element research by integrating post-material selection with the biomechanical effects of a standardized periapical bone defect in an abutment tooth supporting a three-unit fixed prosthesis. Although previous analyses predominantly examined isolated restored teeth or simplified loading conditions, the present models simulate load transfer across prosthetic connectors and adjacent units under oblique occlusal loading. By incorporating apical bone loss, material variability, and multi-unit structural interaction within a unified computational framework, the study clarifies how post stiffness governs stress redistribution across radicular tissues and prosthetic components under clinically representative mechanical conditions.

From a biomechanical perspective, modelling a three-unit bridge introduces connector-mediated load redistribution and inter-abutment interaction that cannot be captured in single-crown simulations. This configuration allows evaluation of force transfer across adjacent units and supporting bone, thereby providing clinically relevant insight into structural behavior under multi-tooth functional loading.

Although finite element researches are simulation-based and do not inherently require formal hypothesis testing, the present computational framework was structured using predefined hypotheses to guide model configuration and comparative interpretation. Accordingly, the hypotheses are presented as analytical benchmarks defining expected biomechanical trends rather than experimentally testable clinical outcomes. As a result of a detailed literature review, the lack of studies on the stress distribution in the surrounding bone tissue and teeth caused by the application of different post-materials following RCT in teeth with periapical lesions that will be the basis of bridge prostheses constitutes the aim of the present study. Two hypotheses were proposed for this study: (1) when teeth with periapical lesions, RCT, and restored with different post-materials are supported by bridge prostheses, the stress distribution and sizes will not be different in different parts of the tooth and in the periapical lesion area. (2) According to the post-material used, the stress distribution and sizes on the root and lesion area will not differ in cortical and trabecular bone.

## Materials and Methods

In the study, a mandibular premolar tooth was selected to be used in FEA. The initial CAD data utilized for modeling the human mandible and associated teeth were obtained from publicly available CAD resources developed for 3D

educational initiatives by the University of Dundee's School of Dentistry, located in Dundee, Scotland (Source: https://sketchfab.com/DundeeDental/models). The finalized CAD models employed for FEA in this study were generated and refined using SolidWorks (SolidWorks Corp., Massachusetts, United States), a parametric 3D solid modeling software. The subsequent FEA simulations were performed using ANSYS Workbench (ANSYS, Canonsburg, United States), a widely used finite element method (FEM) software. Detailed and realistic 3D tooth models were incorporated to assess the influence of periapical lesions on stress distribution patterns.

Structural analyses were applied taking into account some general principles: (1) the geometry of the models in the post-core-crown design was simplified so that all components were symmetrical with respect to the vertical mid-axis, (2) the cementum layer covering the root surface very thinly, the root dentin was included as it was, (3) there would be no gap in all components, (4) pre-stresses caused by RCT were ignored, (5) all materials were considered homogeneous, linear and isotropic. The configuration of the sample model used in this study is presented in ►**Fig. 1**.

To examine the effect of different parameters on the mechanical performance of the restoration, a healthy reference model without periapical lesions was created (model 1). Finally, metal porcelain tooth models (models 2–4), which are the abutment teeth in a three-unit bridge prosthesis restored with fiber, cast, zirconia post, were created (►**Fig. 2**). The periapical lesion was modeled as a spherical lesion cavity filled with lesion tissue (idealized) with a diameter of 4 mm at the root apex, based on the morphological characteristics of periapical lesions described in previous histopathological studies, and this geometry was standardized across all models to ensure consistency.[18] A spherical geometry was selected to provide geometric standardization and eliminate directional bias during stress analysis. This simplified representation is commonly adopted in computational modelling to enable controlled comparison between configurations, while acknowledging that actual lesions exhibit irregular morphology that cannot be fully reproduced in idealized simulations.

It was planned to form the post-core, crown, PDL, and gutta-percha in conjunction with the dentin component. During the post preparation, 4 mm of gutta-percha was left in the apical region as determined in the literature,[19] and the distance between the gutta-percha and the apical narrowing point was determined as 0.5 mm. The main components, bone (trabecular and cortical), root, PDL, gutta-percha, post, core, post cement, crown cement, and crown were modeled, respectively. The diameters of trabecular and compact bone were 10 mm and 12 mm, respectively; lengths were determined as 13 mm, 15 mm, and PDL thickness was determined as 0.2 mm. The post was designed in a parallel fashion, tapering toward the tip. The entire root was considered as dentin, ignoring the cementum thickness, and the ferrule amount was determined as 1.5 mm.[20]

Model 2 was designed with a glass fiber post (ParaPost Fiber White, Coltène/Whaledent, Mahwah, United States) with a diameter of 1.5 mm and a length of 15 mm, while a cast metal post made of nickel–chromium alloy (Ni–Cr) was designed for model 3, and a zirconia post was designed for model 4. The thickness of the dual-cure resin cement (Ivoclar Vivadent, Schaan, Liechtenstein) used in cementation was determined to be 50 µm between dentin and post and 30 µm between crown and core.[21]

In model 2, the core restoration was made of composite resin (Para Post Fiber White, Colténe/Whaledent), while in models 3 and 4, the core was designed as a monoblock with post-material. The core structure was formed with a 135-degree chamfer-style step ending at the gingival level, with a 1.5-mm preparation from the vestibule, lingual, and interproximal surfaces of the crown design, and 2 mm from the occlusal. In the crown design, a porcelain crown supported by 0.5-mm-thick metal infrastructure was applied, and a premolar tooth model was created.

## Mesh Modeling

Using the ANSYS Workbench (ANSYS Canonsburg, United States) program interface, the mesh structure was created, and relatively smaller-sized elements were used on the contact surfaces to define the geometries of the structures in the models in the most similar way. The models were created using the curvature approach using tetrahedral elements with a size of 0.5 mm and a growth rate of 1.25 mm. Skewness quantifies the extent to which a geometric shape deviates from an equilateral configuration, serving as a robust criterion for evaluating mesh quality. Within the framework of FEA, skewness values are defined on a scale from 0 to 1, where 0 corresponds to an equilateral (ideal) cell, and 1 signifies a completely degenerate (undesirable) cell. In this investigation, the skewness parameter was employed to evaluate and verify the mesh structure, ensuring its adequacy for producing reliable simulation outcomes. FEMs were created in finite element quality with an average skewness metric value of 0.2, indicating an excellent level of the FEM was obtained. The total number of elements was $1.731.855 \pm 507.768$, and the total number of nodes was $2.562.638 \pm 768.938$, based on the average values obtained from 3 FEA setups.

Each of the structures introduced in the models was given values indicating material properties to describe their physical properties. Poisson's ratio values and elastic modulus were used when introducing material properties to the software. Pulpal values were used as a reference based on previous studies with periapical lesions (►**Table 1**).[4,19–21]

## Loading and Boundary Conditions

In the constructed FEA models, the interfacial relationships between each component were defined within the FEA code to enable accurate analysis. It was assumed that all components were in complete (100%) bonded contact with one another. In each tooth model, the upper and lateral surfaces of the bone model were defined without movement or

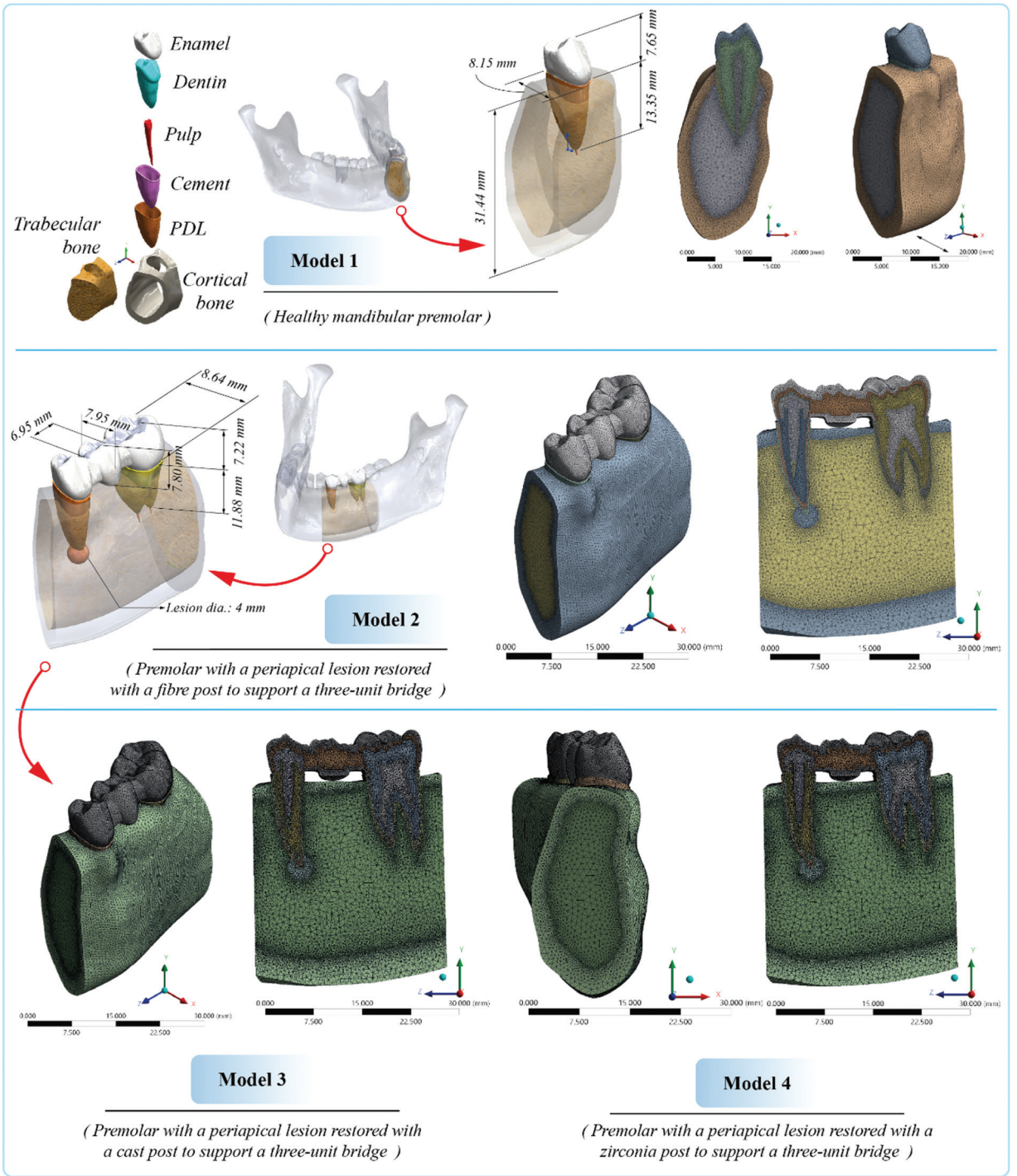



**Fig. 1** Sample model configuration used in the study.

rotation, providing global stability while allowing the tooth and prosthetic components to deform under load. A 300 N static occlusal force was applied at a 45-degree angle to the lingual incline of the buccal cusp, in accordance with validated literature models.[13,14] Furthermore, in this study, gravitational effects were deliberately incorporated into the static structural analysis in ANSYS-not because they significantly influence the primary occlusal stress field, but to allow for a more comprehensive assessment of the deformation behavior across the complete assembly, including bone, tooth, post, periodontal ligament, and crown.

These modelling assumptions were adopted to ensure numerical stability and inter-model comparability in accordance with common practice in dental finite element research. Nevertheless, perfectly bonded interfaces may overestimate structural continuity, isotropic linear-elastic material definitions neglect tissue anisotropy, and static loading cannot represent fatigue or time-dependent

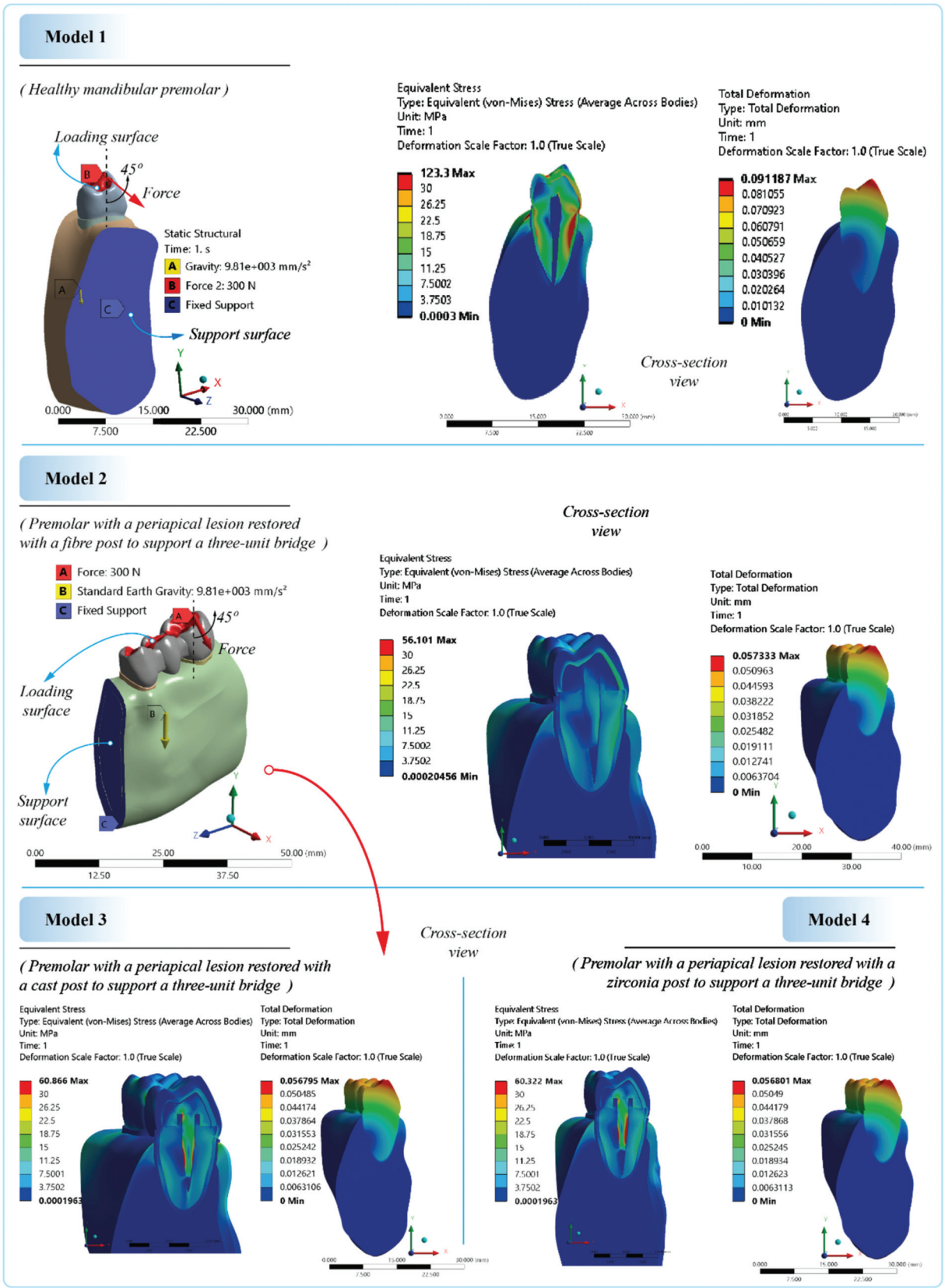



**Fig. 2** FEA models: (model 1) healthy mandibular premolar; (model 2) premolar with a periapical lesion restored with a fiber post to support a three-unit bridge; (model 3) premolar with a periapical lesion restored with a cast post to support a 3-unit bridge; (model 4).

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**Table 1** Material properties[4,19–21]

| Teeth components[a] | Modulus of elasticity (MPa) | Poisson's ratio (–) | Density (kg $m^{-3}$) |
|---|---|---|---|
| Enamel | 84,100 | 0.33 | 2,800 |
| Dentin | 18,600 | 0.31 | 2,200 |
| Cortical bone | 14,000 | 0.323 | 1,400 |
| Cancellous bone | 1,370 | 0.38 | 850 |
| Pulp | 2 | 0.45 | 1,000 |
| Periodontal ligament (PDL) | 68.90 | 0.45 | 1,100 |
| Cement | 8,200 | 0.31 | 2,030 |
| Idealized lesion tissue | 0.69 | 0.45 | 370 |
| Glass fiber-post | 37,000 | 0.27 | 2,500 |
| Zirconia post | 200,000 | 0.31 | 5,500 |
| Ni–Cr post | 204,000 | 0.3 | 7,600 |
| Composite | 12,400 | 0.3 | 2,400 |
| Crown (porcelain) | 68,900 | 0.28 | 2,300 |
| Gutta-percha | 140 | 0.45 | 370 |
| Adhesive resin cement | 7,600 | 0.3 | 2,000 |

[a]FEA definitions—homogenous isotropic linear elastic material model.

behavior; therefore, findings should be interpreted within these methodological constraints.

## Results

The numerical results of deformation and stress derived from the FEA for each component are shown in ►**Table 2**. Looking at the four different models, whose clinical scenarios were created, it was observed that the stresses caused by the application of occlusal load were concentrated on the cervical and middle third of the root in all models, and on the post-material in models 3 and 4. The maximum equivalent stress was formed in the buccal cervical region of the tooth in model 1, in the distal cervical region of the abutment premolars in model 2, in the middle one-third of the post in model 3, and in the buccal cervical and mesial cervical regions of the first molar in model 4. When models 3 and 4 were evaluated among themselves, no difference was observed in terms of localization of tooth components and lesion area stress distributions (►**Fig. 3**). In model 2 (fiber post), the stress was more evenly distributed across the post and surrounding dentin, whereas in models 3 (cast-post) and 4 (zirconia-post), higher stress concentrations were observed within the post itself. This difference is attributed to the variation in elastic moduli of the post-materials, with fiber posts having an elastic modulus closer to that of dentin, thereby promoting more homogeneous stress distribution. The crown regions in all models exhibited similar stress patterns, with maximum equivalent stress concentrated in the occlusal contact areas.

The highest equivalent stress values were observed in the cortical bone for all models, particularly concentrated in the cervico-buccal region where the tooth meets the cortical bone. Models 2 to 4 (lesioned teeth) showed reduced stress

**Table 2** Numerical deformation and stress results obtained from the FEA study by components

| Output | | Components | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|---|---|
| Max. deformation | (mm) | Global (whole model) | 0.091 | 0.057 | 0.056 | 0.056 |
| Max. equivalent stress (von Mises) | (MPa) | Global (whole model) | 123.30 | 56.10 | 60.86 | 60.32 |
| | | M. cortical bone | 117.02 | 37.37 | 37.5 | 37.5 |
| | | M. trabecular (cancellous) bone | 15.40 | 10.73 | 10.19 | 10.19 |
| | | Crown (porcelain/enamel) | 123.30 | 30 | 28.60 | 28.60 |
| | | Post | – | 14 | 60.86 | 59.93 |
| | | Ni–Cr substructure | – | 56.10 | 60.31 | 60.32 |
| | | Lesion | – | 0.02 | 0.01 | 0.01 |

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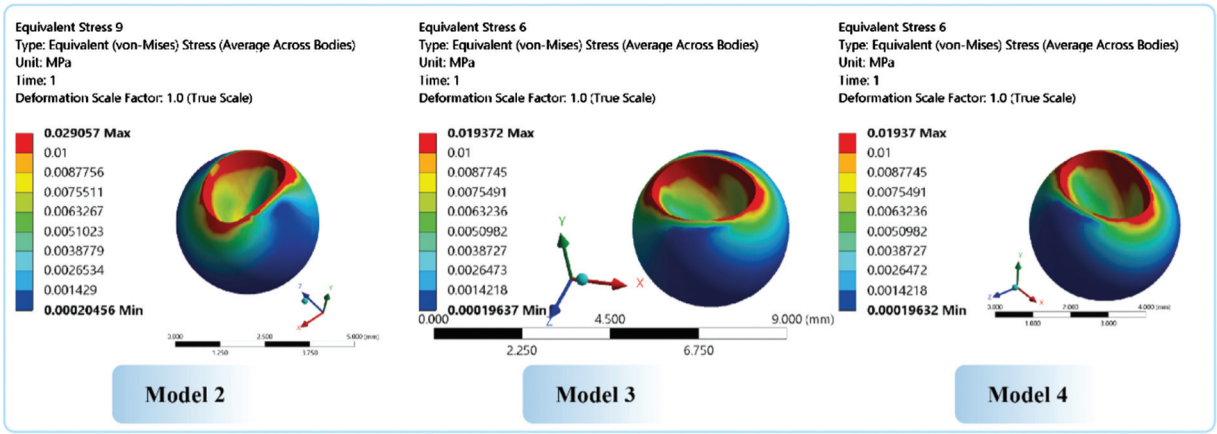



**Fig. 3** Stress distributions within the lesion region for models 2 to 4.

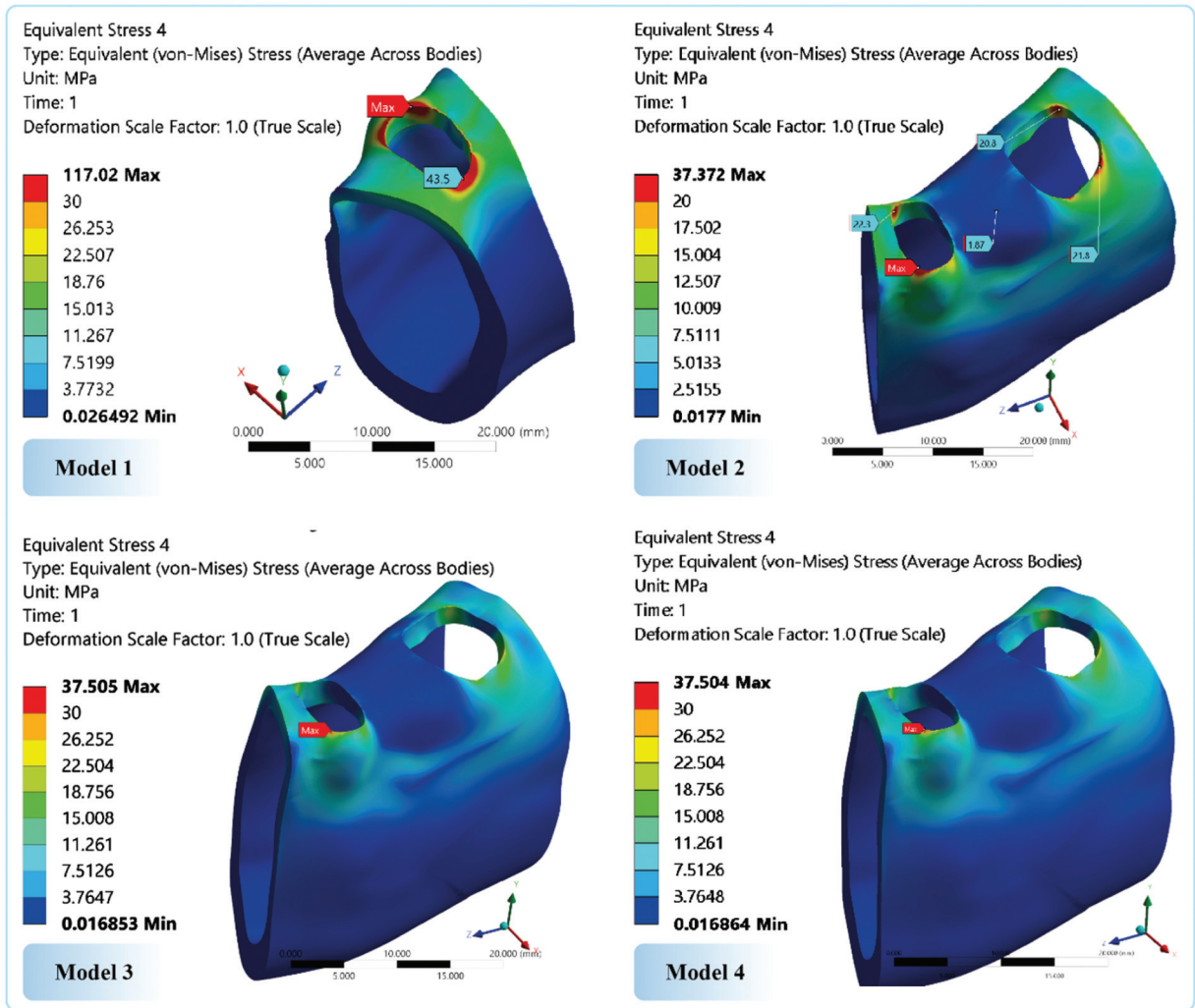



**Fig. 4** Stress distribution in the cortical bone across all models.

values due to the altered load distribution resulting from the lesion. Stress values in the trabecular bone were lower compared with the cortical bone across all models (►**Fig. 4**). Among the lesioned models, model 2 (fiber post) demonstrated slightly higher stress values in the trabecular bone compared with models 3 and 4 (cast and zirconia posts) (►**Fig. 3**). Model 2 exhibited slightly higher stress values in trabecular bone than models 3 and 4, reflecting differences in stress localization associated with variation in elastic moduli of the post-materials.

Considering the models with periapical lesions (models 2–4), the highest stress value was seen in model 2, but when the models were compared within themselves, no difference was found between the values, and low stress distributions were observed. In all models, as it descends from the cervical region of the tooth toward the apex, a decrease in the stresses occurring in the alveolar bone and tooth root was observed. It was observed that the maximum equivalent stress values at the lesion region were similar to the models with bridge post-materials (abutments) (models 2–4).

## Discussion

The study showed differences in the stress distribution regions between the models using post-materials with different elastic moduli on the abutment teeth. The lowest stress distribution was observed in model 4. The stress value of model 3 was similar to that of model 4. Consequently, the first hypothesis was rejected. Models 2 to 4 exhibited similar stress values in the cortical bone, while in the trabecular bone, all three models demonstrated comparably lower stress levels. These findings support the rejection of the second hypothesis.

Periapical lesions develop when necrotic pulp tissue moves to the periapical region, triggering an immune response. RCT is among the recommended treatments,[17] which may take up to 4 years in some cases.[22] Therefore, if the tooth with a periapical lesion is to be used as a support for the prosthesis to be made, it is recommended to start the restoration after at least 1-year follow-up to reduce the risk of complications before the treatment.[23] However, teeth with significant material loss may be prone to fractures or microleakage, which can adversely affect periapical healing.[24] In a retrospective study by Mindiola et al,[25] the absence of definitive coronal restoration within 90 days following RCT was identified as the principal factor associated with subsequent tooth extraction. Another retrospective study[26] reported that teeth with crowns placed more than 4 months after RCT were three times more likely to be extracted than those with crowns placed within 4 months. For this reason, a solid coronal restoration is recommended immediately after the completion of RCT in lesioned teeth, even if follow-up is required for placement of more complicated restorations such as crown bridges.[27]

In some cases, full crown restorations can be used in teeth that have lost coronal tooth structure due to RCT.[28] The crown can sometimes be made directly on the remaining coronal structure,[28] while in other instances, post-core restorations are applied to provide retention for restorations in teeth with significant material loss.[29] In studies evaluating the fracture resistance and failure rate of teeth with advanced coronal tissue loss and different restorations, it was reported that post-retained restorations showed improved mechanical resistance and limited failure compared with teeth restored without post.[30,31] Post-core restorations followed by crown placement enhance overall structure durability and facilitate easier repair in case of fractures.[15]

The optimal post system for strengthening restored teeth remains uncertain.[12] Some authors recommend posts with high modulus of elasticity (e.g., cast post, zirconia post),[32] while others advocate for posts with elastic moduli similar to dentin (e.g., fiber post).[33] The literature presents various studies and perspectives on the selection of restorative materials, with in vivo studies unable to control numerous variables and in vitro studies using static loading possibly not fully representing real-world conditions. Dynamic loading appears to offer more accurate simulation, although many studies apply unrealistically high loads to assess fracture. Consequently, many studies on post-restored teeth rely on FEA.[13,14]

In FEA studies performed on teeth with fiber posts, Seo et al[34] and Shetty et al[35] reported that the highest stress concentration in the alveolar bone occurred in the cervico-buccal region of the tooth in groups with fiber posts, while Nokar et al[36] reported that higher stress values were observed in the fiber posts, cervical and middle third of the root, in the medial cervical and middle third of the root. It was observed that it was concentrated in the buccal region of the cervical region, where the fiber post and the tooth root meet.

In a study comparing cast metal and fiber posts,[37] it was reported that the stresses occurring in the post region were higher in the cast post, while the fiber post model transmitted the stresses less to the post-structure and distributed them more to the surrounding dental tissues. In a similar study,[38] maximum stress occurred in the cervico-buccal region of the tooth, with higher stress observed in cast posts compared with fiber posts in the post region. In this study, comparing fiber and cast posts (models 2 and 3), a similar stress concentration was found in the cervico-buccal region of the post-abutment tooth, with higher stress distribution in the post region for cast posts compared with fiber posts. The current study findings align with those of both studies.[37,38] This observation is consistent with previous studies indicating that posts with higher elastic moduli localize stress within the post structure and reduce transmission to surrounding tissues.

While comparisons with previous studies provide contextual support, direct equivalence is limited by differences in modelling assumptions, boundary conditions, and prosthetic configurations. Therefore, the present findings should be interpreted cautiously, recognizing that simplified geometry, bonded contacts, and static loading constrain clinical extrapolation and emphasize trend comparison rather than absolute prediction.

Zirconia posts with elastic moduli similar to cast posts were found to transmit less stress to the dentin layer compared with fiber posts.[39,40] In a similar study,[40] increased stress values were observed in the middle and apical thirds of zirconia posts, with more homogeneous stress distribution observed in glass fiber posts. Additionally, increased stress distribution was noted in models using glass fiber posts compared with those using zirconia posts. Under chewing force, the fiber post model showed increased stress distribution in dentin, whereas the zirconia post model

exhibited increased stress values in the middle and apical thirds compared with the fiber post model.

In an FEA study examining stress distribution of different post systems (fiber, cast, zirconia posts) in radicular dentin,[36] fiber posts resulted in higher stresses in the middle and cervical parts of the root and dentin compared with other posts. Across all models, two regions of stress concentration were identified: the cervical part of the root and the cervical and middle thirds, where the cortical bone ends on the root. These findings are consistent with those reported by Yang et al.[41] In addition, in this study, in all models with fiber post, cast post, and zirconia post, the stresses were concentrated in the cervico-buccal part of the root and in the cervical and middle thirds of the cortical bone and bone junction. Stresses in the cervical part of the cortical bone were similar in the cast and zirconia post models, but less in the fiber post model.

In the present study, no prior FEA researches were identified that specifically evaluates the stress distribution within the tooth and surrounding tissues when teeth affected by periapical lesions, and restored using various post-materials, are employed as post systems for bridge prostheses. Accordingly, the present analysis was informed by the findings of previous studies that employed comparable methodologies, wherein tooth models incorporating periapical lesions were simulated to assess structural behavior under similar loading conditions.

In studies investigating the stress distribution in teeth with periapical lesions, Belli et al[13] simulated premolar tooth models with endodontic-periodontal (EP) lesions, 1- and 2-mm lesion diameters, and their elastic modulus was restored with different post-materials. In another study of the researchers,[14] the stresses at the root end increased with the size of the lesion, and when the material in the channel has a high elastic module in the channel, it was reported that the stress does not transmit the tension to the bone due to the bone defect in the periapical region. In another study[42] that examined the effect of tooth movement, and thus force on the periapical region, on the healing of periapical lesions after RCT, some teeth were subjected to orthodontic movement and therefore force, while others did not apply for orthodontic movement purposes. In the histomorphological analyses performed at the end of the study, it was observed that orthodontic movement delayed the periapical healing process but did not prevent the healing.

In the present study, it was observed that stresses accumulated on the cast and zirconia post-materials were less transmitted to the radicular dentin. Conversely, in the model with a fiber post, the small amount of stress generated in the post-material was distributed to the root dentin. The current study shows similar results to both studies by Belli et al.[13,14] However, unlike Belli et al's studies, the 135-degree angled force applied to the premolar tooth, which serves as the bridge abutment, was applied to the entire masticatory area, not individually, and bone loss was not simulated.

Additionally, Belli et al[13] stated that posts with a high modulus of elasticity might be preferred because they have a positive effect on wound healing, as they transmit less stress to the surrounding periodontal tissues during the healing of the lesion. In the present study, it was observed that post-materials with high and low elastic modulus produced stress values of 0.01 and 0.02 MPa at the lesion site, respectively, in premolar teeth with 2-mm-diameter lesions. The fact that posts with a high modulus of elasticity had lower stress values at the lesion site suggested that the results of Belli et al[13] might be correct.

In the study by Durmuş and Oyar,[43] Belli et al[13,14] reported that post-materials with a high modulus of elasticity (cast post, zirconia post) cause lower stress in weakened roots (~6%) and at the tooth/post interface (~12%), but higher stress in the post itself (~5 times higher). On the other hand, post-materials with a low modulus of elasticity (fiber post) cause higher stress in weakened roots (~11% to 17%) and at the post/tooth interface (~17.5%). At the same time, it has been noted that overly flexible fiber posts can lead to bacterial infiltration and gaps at the core/tooth and post/tooth interfaces if post flexion is not controlled.

In the current study, stress distributions formed by post-materials with different modulus of elasticity align with the findings of Durmuş and Oyar.[43] Additionally, the use of fiber posts in lesioned teeth may lead to the redevelopment of the lesion due to bacterial infiltration caused by uncontrollable post-flexion.

In the study by Petcu et al,[44] forces of 100 N and 300 N were applied to teeth with periapical lesions, revealing that the risk of deformation increased with higher force levels. Maximum stresses were concentrated in the cervical region of the tooth, with the highest deformation observed at the incisal part of the crown, decreasing toward the apical part. Consequently, the study reported no destructive effects on the tooth. The present study similarly found maximum stresses concentrated in the cervical region of the tooth, with deformation decreasing from the buccal cusp apex toward the apical area.

FEA studies[45,46] examining the effect of connector width on stress distribution in fixed partial prostheses report that maximum stress occurs in the connector region, decreasing as connector thickness increases. When simulating teeth with periapical lesions using bridge prostheses, we observed lower stress on the abutment first premolar teeth compared with the single-crown tooth model, with stresses concentrated in the binding regions. This lower stress in teeth restored with bridge prostheses is attributed to stress distribution across the binding regions.

In a study by Verma et al[47] investigating stress distribution in bone in fixed partial dentures with different abutment types using FEA, maximum equivalent stress values were 99.62 MPa when both post systems were natural teeth, 116.20 MPa when one abutment was restored with post-core, and 136.90 MPa when both teeth were restored with post-core systems. Differences in stress values were explained by the high modulus of elasticity of the stainless-steel post used, leading to stress concentration within the post. The study suggested that the modulus of elasticity of the post-core material should closely match that of the tooth to evenly distribute forces in the crown and root dentin. In the current study, examining bridge prostheses restored

with posts of varying modulus of elasticity, the maximum equivalent stresses value was 56.101 MPa in the model using post-material with low modulus of elasticity (Model 2), while values were 60.866 and 60.322 MPa in models using high modulus of elasticity materials (models 3 and 4), respectively, consistent with findings by Verma et al.[47]

Bacchi et al[48] in studies on implant-supported fixed prosthetic restorations, found that the use of materials like gold, silver-palladium, titanium, zirconia, and CR-Co resulted in decreased stress on the implant bone with increasing material hardness.[48] Conversely, Meric et al[49] concluded that higher modulus materials increase bone stress. In the present study, Ni–Cr was used as the infrastructure material with varying post-materials. The current study findings align partially with both Bacchi et al[48] and Meric et al,[49] highlighting the complexity of material selection in prosthetic restorations.

In the study by Sertel et al,[50] stress distribution of different substructure materials in tooth-implant-supported fixed prostheses was examined using FEA. Two 3-unit fixed dental prosthesis (FDP) models were constructed: one tooth–implant-supported model, including tooth 34 and an implant at position 36, and one fully implant-supported model. Vertical and 45-degree angled forces were applied to these models. The study found that stress values under both vertical and oblique forces were higher in cortical bone compared with trabecular bone. This was attributed to the higher modulus of elasticity of cortical bone, which initially absorbs the force applied to the model. In the present study, we also observed that maximum equivalent stress was higher in cortical bone than in trabecular bone across all models, consistent with the findings of Sertel et al.[50]

In addition to studies[13,14,43,51] suggesting that using materials with low elastic modulus in bridge prostheses reduces stress, the current study results are in agreement with FEA studies that indicate low elastic modulus materials in teeth with periapical lesions can reduce stress transmission to the lesion area and surrounding bone tissue.

From a clinical standpoint, these biomechanical differences are relevant because stress localization patterns may influence the structural durability of abutment teeth supporting fixed prostheses. Material selection should therefore be considered not only in terms of numerical stress magnitude but also regarding load redistribution capacity, particularly in compromised periapical support conditions.

Clinically, these findings suggest that post stiffness influences where stresses are preferentially localized in a lesioned abutment supporting a fixed partial denture. Higher-modulus posts tended to retain stresses within the post structure, whereas lower-modulus posts promoted stress distribution toward dentine. Accordingly, post-selection may be considered alongside remaining radicular integrity and the biomechanical demands imposed by bridge connectors.

Retrospective studies on teeth restored with cast post-core systems for single crowns and bridges have shown varying survival rates. A 5-year retrospective study[52] reported a survival of 13.9 years for teeth restored with cast post-core single crowns or bridges, while a 10-year study[53] found no statistically significant difference in clinical success between groups. A retrospective study[54] reported that 12 years for fiber-reinforced composite resin posts, 11.8 years for cast metal posts, and 10.2 years for prefabricated metal posts. And a 10-year study[55] found that the survival rate of teeth restored with prefabricated posts was 84.6%, and the survival rate of teeth restored with cast metal posts and cores was 82.6%.

In FEA of dental structures, maximum principal stress is frequently employed to assess tensile stresses and predict crack initiation, particularly in brittle materials. However, the present study utilized von Mises equivalent stress as the primary evaluative metric. This choice was driven by the consideration that equivalent stress yields a scalar quantity representing the overall intensity of the stress state, encompassing both tensile and compressive components. It has been extensively applied in dental FEA to assess structural integrity under complex loading conditions.[56,57] While maximum principal stress remains a valuable indicator for predicting fracture risk in dental hard tissues, the FEA models developed in this study incorporated a multi-material assembly comprising not only the tooth structure but also the periodontal ligament, cortical and trabecular bone, various post-materials, luting cements, and a three-unit bridge framework. This composite system was subjected to both occlusal and lateral loading conditions, resulting in a complex stress state. Under such circumstances, equivalent stress offers a comprehensive scalar measure by integrating both shear and normal stresses, thereby facilitating meaningful comparative analysis across heterogeneous materials with differing mechanical behaviors (e.g., ductile versus brittle). The use of equivalent stress in this context is further supported by recent multi-component dental FEA studies. For instance, Wan et al[56] and Pereira et al[57] employed equivalent stress to investigate stress distributions in restored molars and premolars under varying occlusal loading scenarios. Consequently, the methodological choice in the present study is consistent with current best practices in the field and enables direct comparison with contemporary biomechanical analyses reported in the literature.

In this study, a healthy single tooth model was selected as the control to provide a clear baseline for stress distribution in the tooth and surrounding bone. This approach allows for meaningful comparison of how post-materials and periapical lesions alter biomechanics relative to natural conditions. Using a three-unit bridge on a structurally compromised tooth without a post would not represent a true baseline and could introduce confounding variables. Furthermore, in clinical practice, such compromised teeth are rarely used to support bridges without reinforcement. Therefore, the healthy tooth model remains the most appropriate control for the objectives of this study.

The analysis relies on idealized contact definitions and loading protocols. All interfaces were modeled as perfectly bonded, which may overestimate structural continuity compared with clinical conditions where micro-gaps, debonding, or slip can occur. In addition, the applied load was static and oblique, and therefore does not capture fatigue

accumulation or time-dependent interfacial degradation during function.

One major limitation of the present study is the inability to precisely replicate FEA and intraoral conditions, including thermal changes and static/dynamic forces during oral function. FEA studies standardize teeth in idealized structures, whereas anatomical variations among individuals are significant. Additionally, clinical lesions manifest in diverse sizes and structures, whereas the present study models assume homogeneity. Interpretation of numerical data from FEA may not fully correlate with clinical outcomes. Future research could benefit from long-term clinical studies assessing teeth with RCT, lesions, and bridge prostheses using different post-materials and including in vivo studies and improved FEA with variable lesion sizes. Another limitation is the lack of in vitro fracture strength testing for various post-materials analyzed by FEA.

## Conclusion

Within the limitations of this computational study, the following conclusions can be drawn:

1. No numerically significant differences were observed in the force distribution within the periapical lesion region among abutment premolar tooth models restored with different post-materials.
2. Fiber posts may be considered suitable for restoration in teeth with well-preserved radicular structures, as their elastic modulus closely approximates that of natural dentine, potentially promoting more favorable stress distribution.
3. It may be anticipated that cast metal or zirconia posts are more appropriate for use in teeth presenting with apical lesions, as these materials appear to transmit lower stress levels to the surrounding periodontal tissues.

These conclusions should be interpreted within the inherent constraints of finite element modelling, including idealized contact definitions, isotropic material assumptions, and static loading conditions. Accordingly, the outcomes represent comparative biomechanical trends rather than definitive predictors of clinical performance.

## Highlights

- Finite element analysis was used to evaluate the biomechanical behavior of post-restored premolars with periapical lesions serving as abutments for a three-unit fixed dental prosthesis.
- High-modulus posts (cast metal, zirconia) concentrated stresses within the post structure and transmitted lower stress to radicular dentin and periapical tissues compared with fiber posts.
- Fiber posts, due to their dentin-like elasticity, produced more homogeneous stress distribution but transferred higher stress levels to surrounding dentin.
- Stress magnitudes within the lesion region remained low and showed no clinically relevant differences among post types.
- Across all models, maximum stresses localized in the cervical root and cortical bone, while bridge prosthesis loading redistributed stresses toward connector regions.
- Findings suggest that fiber posts may be suitable for structurally intact roots, whereas cast or zirconia posts may be preferable in teeth with apical lesions due to reduced stress transmission to periodontal structures.

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Conflict of Interest
None declared.

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