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RESEARCH AND EDUCATION

Stress generation in mandibular anterior teeth restored with different types of post-and-core at various levels of ferrule

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Using a ferrule in a tooth preparation scheme can enhance the mechanical integrity of endodontically treated teeth that require the insertion of an intraradicular post to help restore extensive coronal loss.¹ The concept of the ferrule effect suggests that, by preserving or creating an encircling band of dentin, endodontically treated teeth are likely to resist biomechanical complications or failure.² Clinically and biomechanically relevant research data regarding the ferrule effect reveal that its efficiency in ensuring the long-term survival of endodontically treated teeth is related to design parameters such as the ferrule's height,^{3,4} thickness,⁵ and regional integrity.^{6,7} In light of these data, clinical recommendations indicate that the use of a 1.5- to 2-mm-high ferrule, even with 2 or fewer walls, achieves high clinical success by maintaining the fracture resistance of restored teeth⁸⁻¹¹ and that the incorporation of a ferrule with the minimum 1-mm thickness provides advantageous stress redistribution between dentin and restorative elements.¹²⁻¹⁴ However, despite interest in the restoration

ABSTRACT

Statement of problem. Pertinent evidence regarding the mechanical integrity of mandibular anterior teeth restored with a post-and-core is limited.

Purpose. The purpose of this finite element analysis study was to compare the impact of the post type (glass fiber post-and-resin core or cast post-and-core) along with the ferrule effect on the stress fields generated in endodontically treated mandibular lateral incisors and canines.

Material and methods. Three-dimensional models of the segmented mandible were developed. Mandibular incisors and canines with or without a 2-mm circular ferrule and restored with a cast post-and-core or glass fiber post-and-resin core were simulated and subjected to linear elastic static analysis. The principal stress values were calculated. von Mises equivalent stresses were used to evaluate the stress.

Results. Maximum principal stresses in dentin were highest in incisors, with a ferrule. Stress parameters in composite resin core in both incisors and canines were critically close to the tensile failure limit of the core material. Cast post-and-cores cemented in incisors without a ferrule accumulated the highest stresses, exceeding the tensile failure limit of resin-modified glass ionomer cement.

Conclusions. Tooth preparation with a ferrule led to a remarkable rise in stress in the dentin of mandibular incisors but favored the mechanical integrity of the restoration. (J Prosthet Dent 2017;■:■-■)

of endodontically treated teeth, definitive recommendations are still lacking.

Restoration of severely damaged teeth is a challenging undertaking, influenced not only by the presence of a ferrule but also by the remaining sound dentin lateral to the intraradicular post,¹⁵ the type of restored tooth,⁸ and the type of post system.¹⁶ This structure-dependent function of post-restored endodontically treated teeth, with very few studies reported,¹⁷⁻¹⁹ raises

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Clinical Implications

A ferrule has a positive impact on the mechanical stress values of restorative elements, regardless of the post type or tooth group but leads to a considerable rise in stress in the dentin of mandibular incisors. In mandibular anterior teeth without a ferrule, the stress parameters in composite resin core can come dangerously close to the failure limit. A cast post-and-core in mandibular canines without a ferrule provides more favorable stress parameters but causes the critical stress parameters of glass ionomer cement to be exceeded in the incisors.

the question whether the compact anatomy of the tooth type amplifies the irreversible mechanical deterioration of dentin due to pulp removal²⁰ and mechanical,^{21,22} physical,¹⁵ and chemical^{23,24} processing during the endodontic and restorative treatment. The compact anatomy of mandibular incisors creates difficulties with their restoration and may require deviation from existing preparation and restoration guidelines.^{16,25}

Few studies of single rooted teeth restored with different post types have used human mandibular incisors.^{17,18,25,26} Furthermore, the type of post system is a critical parameter influencing the mechanical response of endodontically treated teeth.^{27,28} Current post systems include various materials and designs, with each system possessing advantages and limitations.^{2,5} Despite extensive research, no post system can yet meet the demands for favorable mechanical compatibility.^{1,7,15,29} Cast metal post-and-cores have been the most commonly used and are probably the most studied. They involve less root canal preparation than prefabricated posts, resulting in tissue preservation that is advantageous for the restoration of mandibular incisors.^{20,29,30} Nevertheless, the disadvantages of cast posts include a wedging effect and high modulus of elasticity that could result in root fracture.^{31,32}

A glass fiber post with composite resin core (FP) has been reported to distribute the load across the dentin evenly and reduce the possibility of root fracture.³³⁻³⁵ However, the additional removal of root dentin during post space preparation could lead to thinning of the root walls in the mandibular incisors.²⁵ Moreover, an irregular cement layer thickness has been reported for prefabricated post techniques,¹⁶ and such reduced adhesive properties of the cement could result in initial detachment of luting interfaces²⁷ and post debonding.³⁶

Finite element analysis (FEA) is based on the assumption of simplified mechanical properties of materials and tissues and has been used to estimate

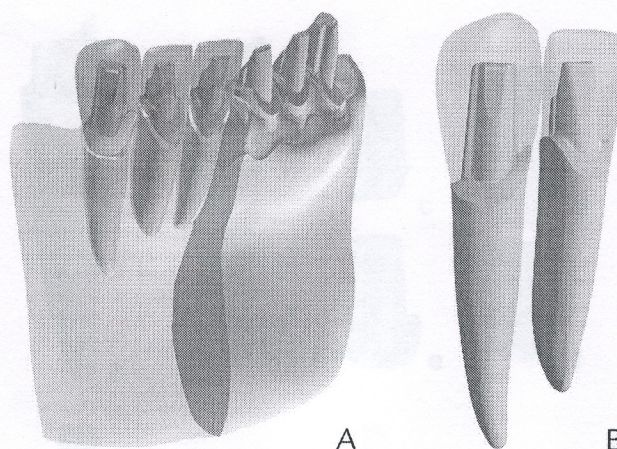


Figure 1. A, Design of anterior segment of dentate human mandible. B, Design of vital crown, restored mandible lateral incisor, and canine.

3-dimensional (3D) stress distributions at any point in a multicomponent model, such as a restored endodontically treated tooth.³⁷ Therefore, the purpose of this study was to investigate the presence of a ferrule and the stress field generated in endodontically treated mandibular anterior teeth when restored with 2 post-and-core systems. The null hypothesis tested was that the mechanical response of mandibular incisors and canines would be similar when restored with cast or FP with different ferrule heights.

MATERIAL AND METHODS

Ten 3D models of the anterior dentate human mandible were developed by using computed tomography scans (Mimics; Materialise NV). Institutional Review Board approval was obtained from the Committee of Bioethics at Bogomolets National Medical University prior to initiating this study. The computed tomography scans were introduced and modified with 3D computer-aided design (SolidWorks 2006; SolidWorks Corp) and reverse engineering environments (Geomagic Studio; Geomagic Inc) (Figs. 1-4).

The models of the mandibular lateral incisor and mandibular canine were considered either vital or endodontically treated. They were restored by using gold cast post-and-core (CP) or FP (Fig. 2). Each tooth model represented a single clinical case. The fiber post was designed to have parallel sides (1.1 mm in diameter) with an alternating taper in the apical third and rounded head. The CP design corresponded to the averaged geometry of the preparation for individual posts.³⁸ It had a taper of 0.07 mm starting from 0.3 mm at the apical end. All posts extended to approximately two-thirds of the root canal length, preserving 5 mm of apical gutta percha. The tooth preparation scheme of post-restored models included a 2-mm ferrule (F+) and a 0-mm ferrule (F-). Resin-modified glass ionomer cement (RMGI) was modeled

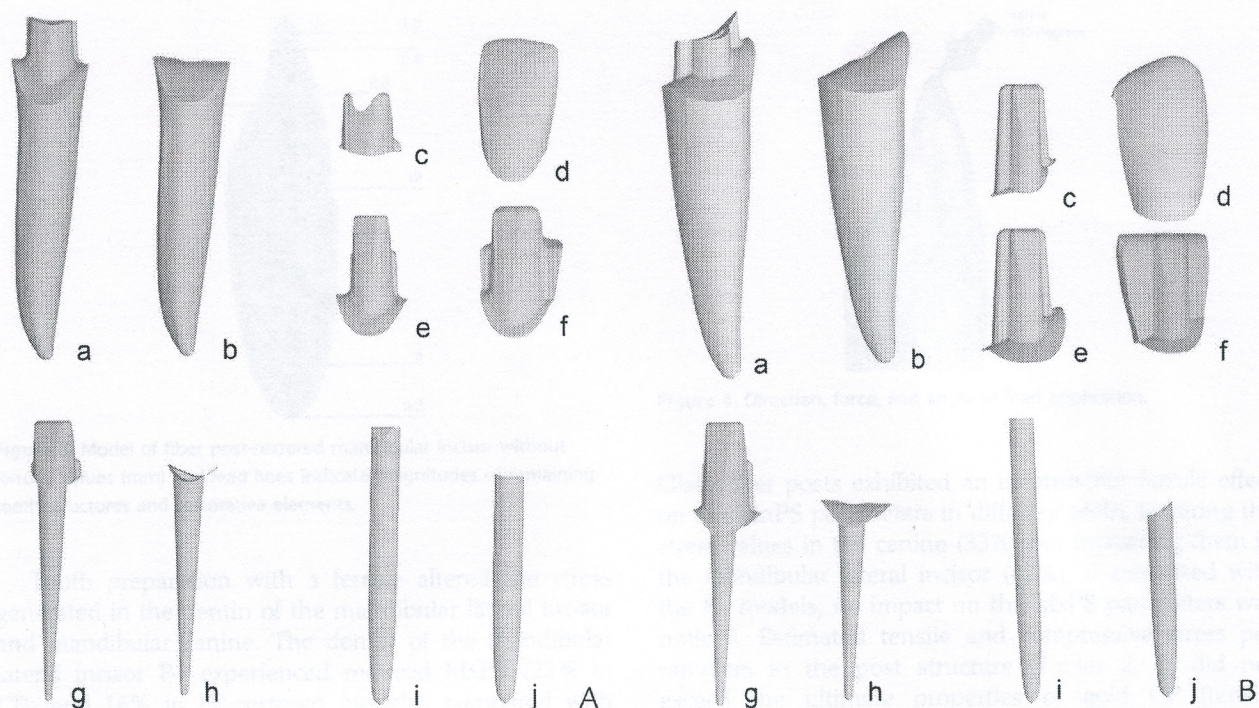


Figure 2. A, Design of ferruled and non-ferruled mandibular incisors, restored with cast post-and-core or glass fiber reinforced post with composite resin core; (a,b) dentin of ferruled and non-ferruled mandible incisor; (c) composite resin core; (d) crown porcelain; (e) resin-modified glass ionomer cement around crown; (f) crown metal framework; (g) cast post-and-core; (h) resin-modified glass ionomer cement around cast post-and-core; (i) glass fiber reinforced post; (j) composite cement around glass fiber reinforced post. B, Design of ferruled and non-ferruled mandibular canines; (a,b) dentin of ferruled and non-ferruled mandible canine; (c) composite resin core; (d) crown porcelain; (e) resin-modified glass ionomer cement around crown; (f) crown metal framework; (g) cast post-and-core; (h) resin-modified glass ionomer cement around cast post-and-core; (i) glass fiber reinforced post; (j) composite cement around glass fiber reinforced post.

as a luting agent for CP and crowns, whereas FP cementation was modeled as composite resin cement. In all cases, the cement thickness was 0.03 mm. A metal-ceramic (MC) single crown served as a definitive restoration in all models. All structures were designed to adhere to classical geometries (Fig. 3).³⁸

All models were entered into the FEA environment (Algor; Algor Inc). Models were transformed into solids and meshed with 8-node brick/tetrahedral elements. The average number of nodes in the mesh of the mandibular lateral incisor models was 58 701 with 137 324 elements, whereas it was 127 352 nodes and 247 720 elements in the mesh of the mandibular canine models. The mechanical properties of tissues and materials (Young modulus,³⁹⁻⁴⁷ shear modulus,⁴³ and Poisson ratio^{7,13,22,40,42,43,48,49}) were considered homogeneous and isotropic, except for the orthotropic parameters of FP (Table 1). The orthotropic elastic properties used were derived from the Halpin-Tsai equations for fiber-reinforced composite resin materials for transverse and axial load directions.⁴³

A linear elastic static structural analysis was performed under 140-N oblique loading, angled at 135 degrees from the vertical tooth axis and applied to the

incisal edge (Fig. 4). Fixed displacements and rotations in all directions were applied at nodes on the cameo surface of the selected sections (mandible symphysis and inter-premolar area). Multiaxial stresses were calculated as maximum (MxPS [MPa]) and minimum (MnPS [MPa]) principal stress values, compared with tensile^{39,43,50-54} and compressive^{39,50,53,55-57} failure limits and visualized based on a color measurement bar. von Mises equivalent stresses (MPa) were also calculated and used to evaluate stress field distributions on the cross-sections of the associated models.^{7,13}

RESULTS

The MxPS and MnPS values developed in the tissues and restoration elements when the models were subjected to loading are presented in Tables 2 and 3 and Figures 5 and 6; and the von Mises stress distribution patterns are shown in Figure 7. Tensile and compressive stress values in dentin, CP, FP, RMGI post cement, and resin post cement were higher in the mandibular lateral incisor models, whereas no considerable differences were observed in crown cement, composite resin core, or MC crown.

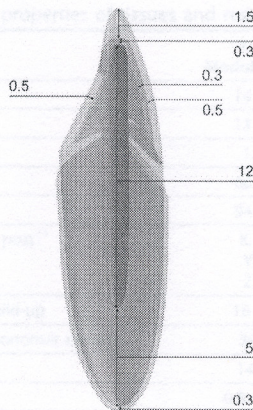


Figure 3. Model of fiber post-restored mandibular incisor without ferrule. Values (mm) and lead lines indicate magnitudes of remaining tooth structures and restorative elements.

Tooth preparation with a ferrule altered the stress generated in the dentin of the mandibular lateral incisor and mandibular canine. The dentin of the mandibular lateral incisor F- experienced reduced MxPS (22% in CP- and 16% in FP-restored models), compared with the F+ models (Table 2), where the amount of MxPS developed on the dentin of the mandibular lateral incisor F+ decreased (11% in CP- and 10% in FP-restored models). Regarding the post system, the mandibular lateral incisor FP and mandibular canine FP demonstrated increased MxPS values in dentin compared with models with CP, as it was more evident in the mandibular lateral incisor. Both of the F- models developed lower MnPS stress levels (Table 3) when restored with FP and higher levels when restored with CP. In all cases, stress parameters were below the tensile (135 MPa) and compressive (297.2 MPa) failure limits of dentin³⁹ but close in the mandibular lateral incisor FPF+ at tension (116.3 MPa for the mandibular lateral incisor CPF+ and 122.9 MPa for the mandibular lateral incisor FPF+).

The general pattern of von Mises stress distribution in dentin was comparable in all groups (Fig. 7). Stress concentrations appeared at labial and lingual root surfaces corresponding to the areas of tension and compression, as they were more pronounced in the mandibular lateral incisor. In the mandibular lateral incisor F- and mandibular canine F-, high stress field allocation was found in the coronal third, whereas F+ models showed redistribution of high stresses in both the coronal and the middle root thirds.

Stress values in the posts were sensitive to the amount of remaining dentin and to tooth type, and in the mandibular lateral incisor, F- resulted in a pronounced rise of MnPS on the cast post of the mandibular lateral incisor (29%) and mandibular canine (35%), although the MxPS was not considerably altered.

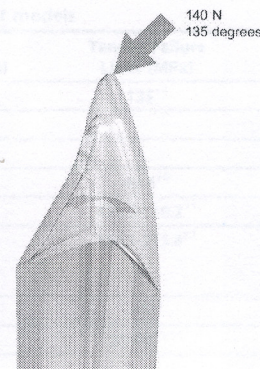


Figure 4. Direction, force, and angle of load application.

Glass fiber posts exhibited an inconsistent ferrule effect on the MnPS parameters in different teeth, lowering the stress values in the canine (33%) but increasing them in the mandibular lateral incisor (42%), if compared with the F- models; no impact on the MxPS parameters was noticed. Estimated tensile and compressive stress parameters in the post structure (Tables 2, 3) did not exceed the ultimate properties of gold CP (tensile strength, 420.6 to 510.2 MPa; compressive strength, 457 MPa) and FP (tensile strength, 180.1 to 215.8 MPa; and compressive strength, 118.8 to 151.5 MPa).

High von Mises stress concentrations in CP were localized on the lingual aspect of the coronal and middle thirds of the intraradicular portion of the canines, expanding to the core in the mandibular lateral incisor, regardless of the available volume of tooth structure (Fig. 7). High stresses in FP models were located along the lingual surface of the post. Stress field expansion was found on the cross-sections of FP at the level of the dentin-composite resin core border.

In both the mandibular lateral incisor and the mandibular canine, the impact of ferrule effect manifested by a significant stress rise in composite resin core in F- models by 10 times (mandibular lateral incisor F-) and 5.5 (canine F-), approaching the tensile failure limit (37.4 MPa in the mandibular lateral incisor FPF-; 35.4 MPa in the mandibular canine FPF-; tensile strength 41 MPa). The region of tensile stress concentrators were located on the labial core margin, whereas the highest compressive stress fields were located lingually (Fig. 6).

The presence of ferrule (F+) resulted in reduction of the MxPS and MnPS values for the post cements, regardless the tooth or the post type. A pronounced distinction of stress parameters was observed in CP models (Tables 2 and 3). In the absence of ferrule (F-), the RMGI post cement of the mandibular lateral incisor presented the highest tensile (42 MPa) and compressive (-83.5 MPa) stresses, exceeding the tensile strength of RMGI (35 to 40 MPa). The stress field pattern of the root

Table 1. Mechanical properties of tissues and restorative materials associated with finite element models

Material	Young Modulus (MPa)	Poisson Ratio	Shear Modulus (MPa)	Tensile Failure Limit (MPa)	Compressive Failure Limit (MPa)
Dentin	18 600 ³⁹	0.31 ²²		135 ³⁹	297.2 ³⁹
Bone	13 700 ⁴⁰	0.3 ⁴⁰			
Periodontal ligament	1.25 ⁴¹	0.45 ⁷			
Porcelain	66700 ⁴²	0.20 ⁴²		48.8 ³⁹	162.9 ³⁹
Gold alloy	94100 ⁴²	0.39 ⁴²		420.6-510.2 ⁵¹	457 ⁵⁵
Glass fiber-reinforced post ⁴³	X, 37.0 Y, 9.5 Z, 9.5	XY, 0.27 XZ, 0.34 YZ, 0.27	XY, 3.1 XZ, 3.5 YZ, 3.1	180.1-215.8 ⁵²	118.8-151.5 ⁵⁶
Resin cement/core build-up	16 440 ⁴⁴	0.26 ⁴⁸		41 ⁵³	293 ⁵³
Resin-modified glass ionomer cement	3900 ⁴⁵	0.27 ¹³		35-40 ^{45,54}	242.5-306.2 ⁵⁷
Gutta percha	141.9 ⁴⁶	0.45 ⁴⁶			
Pulp	0.8×10 ⁻³ ⁴⁷	0.45 ⁴⁹			

Table 2. Maximum principal stress (MPa) in dentin and restorative elements

Model Type	Dentin	Cast Post	Glass Fiber Post	Composite Core	Resin-Modified Glass Ionomer Post Cement	Composite Resin Post Cement	Resin-Modified Glass Ionomer Crown Cement
Inr Vit	98.0						34.55
Inr CPF+	116.3	73.4			19.4		38.18
Inr CPF-	90.9	70.6			42.0		36.8
Inr FPF+	122.98		21.3	3.8		10.94	37.77
Inr FPF-	103.0		23.4	37.4		13.82	39.15
Cnn Vit	74.17						34.06
Cnn CPF+	78.9	64.14			14.2		35.94
Cnn CPF-	89.14	65.86			24.0		36.79
Cnn FPF+	81.3		18.05	6.46		10.34	36.47
Cnn FPF-	90.8		18.92	35.42		11.02	38.64

Cnn, canine; CP, cast post-and-core; F+, with ferrule; FP, glass fiber post and resin core; Inr, incisor; F-, nonferrule; Vit, vital.

Table 3. Minimum principal stress (MPa) in dentin and restorative elements

Model Type	Dentin	Cast Post	Glass Fiber Post	Composite Core	Resin-Modified Glass Ionomer Post Cement	Composite Resin Post Cement	Resin-Modified Glass Ionomer Crown Cement
Inr Vit	-111.44						-68.5
Inr CPF+	-94.82	-127.13			-52.12		-69.2
Inr CPF-	-131	-164			-83.47		-68.16
Inr FPF+	-101.04		-75.92	-11.1		-13.5	-78.13
Inr FPF-	-96.28		-53.84	-74.42		-14.2	-69.12
Cnn Vit	-66.6						-65.97
Cnn CPF+	-63.3	-86.83			-40.64		-58.78
Cnn CPF-	-72.7	-127.6			-83.21		-53.28
Cnn FPF+	-67.8		-28.38	-25.68		-14.58	-62.82
Cnn FPF-	-65.6		-42.06	-74.90		-14.91	-69.78

Cnn, canine; CP, cast post-and-core; F+, with ferrule; FP, glass fiber post and resin core; Inr, incisor; F-, nonferrule; Vit, vital.

canal portion was distributed proportionately in each post group, as it was located predominantly on the labial apical and middle thirds (Fig. 6). In the RMGI cement, stress propagation was found lingually. The core-dentin interface was divided into regions of labial tension and lingual compression.

Differences observed between the RMGI crown cement and the MC crown were small. The stress parameters in cement were close to the tensile failure limit, although they did not exceed it (35 to 40 MPa).⁴⁵⁻⁵⁷ The tensile stress concentration appeared on the labial aspect

of the chamfer margin, corresponding to the area of potential debonding. Stress fields for the MC components presented similar patterns of distribution, with concentration mainly at the point of load application.

DISCUSSION

This study tested the null hypothesis that no differences would be found in the stress parameters of mandibular lateral incisors and canines, with or without a ferrule, when restored with different post systems. The results

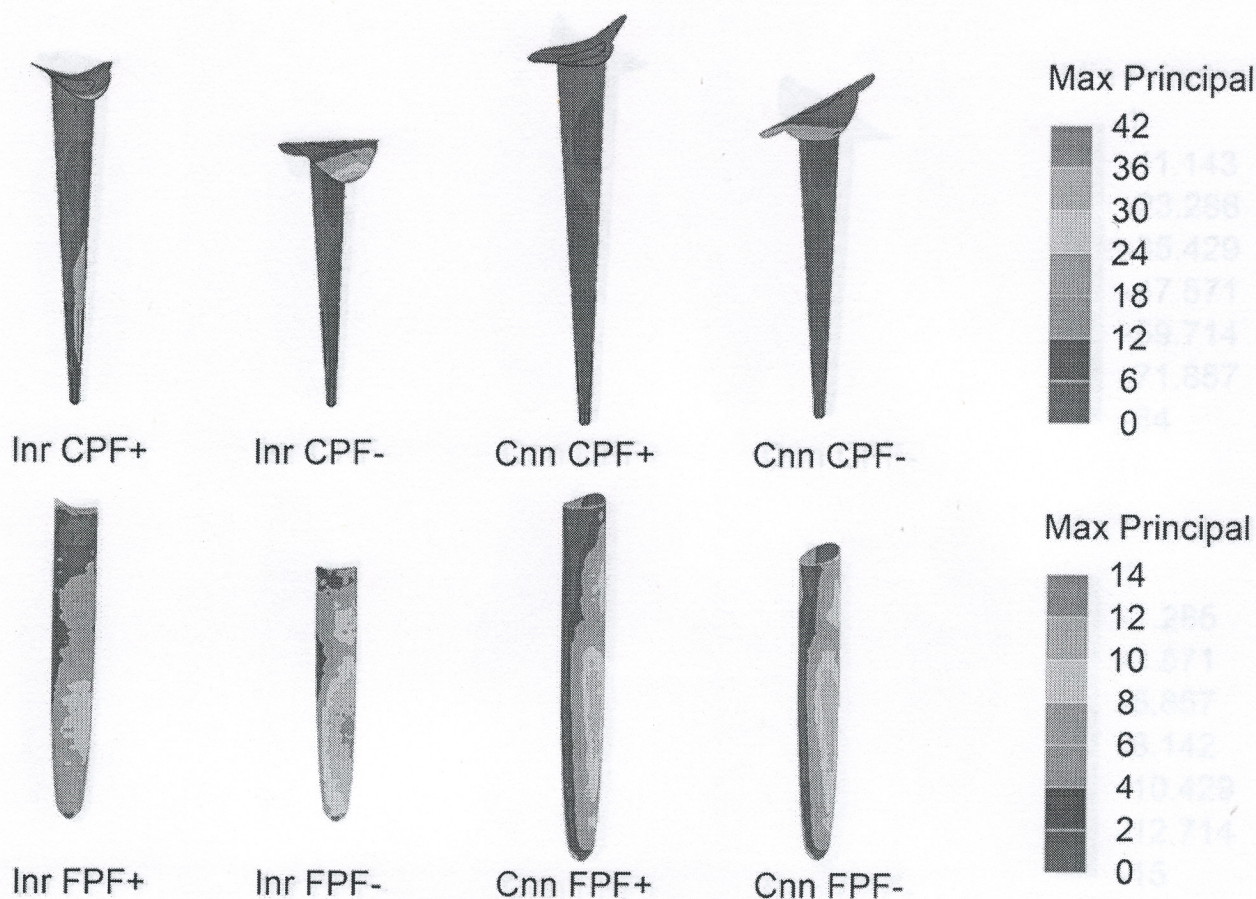


Figure 5. Distribution of maximum principal stress values in post cements of mandibular incisors and canines with and without ferrules restored with cast post-and-core or glass fiber reinforced post with composite resin core. Cnn, canine; CP, cast post-and-core; F+, ferrule; FP, glass fiber post and resin core; Inr, incisor; F-, nonferrule.

determined that the tested null hypothesis should be rejected.

Overall, data revealed that the mechanical properties of mandibular lateral incisors differ from those of larger teeth. As opposed to the mandibular canine models, the lateral incisor models generated considerably higher tensile and compressive stress values with pronounced distribution in dentin, CP, FP, and post cements, regardless of the presence of ferrule or post-and-core material. This finding corresponds to results of the study by Gluskin et al,²⁵ who reported that the mandibular lateral incisors have characteristics that set them apart from larger teeth with more uniform cross-sectional diameters. Deutsch et al⁵⁸ found that different post types with a standardized 1.5-mm diameter produced more root fractures as the root diameters decreased. This is confirmed by other studies^{59,60} that revealed a close relationship between the strength of a tooth and the thickness of dentin around the post.

This study found that the presence of a ferrule influenced the stress in dentin and was affected by tooth type.

For the small mandibular lateral incisor, the preparation with a ferrule led to increased tensile stress in dentin, close to critical parameters such as the failure limit of dentin³⁹; the opposite reaction was observed in the mandibular canine (Table 2). This phenomenon may be explained by the narrow buccolingual and mesiodistal root dimensions of the mandibular lateral incisor, resulting in reduced chamfer width and ferrule thickness and leading to expansion of high stress fields (Fig. 7). Along the same line, data from other FEA investigations disclose a relationship between the tooth type, remaining tooth structure prepared with a ferrule, and the mechanical integrity of dentin. In particular, the presence of a ferrule (F+) leads to a decrease of stress developed in the dentin of a maxillary canine,⁷ no change in stress developed in the dentin of a maxillary first premolar,¹³ and an increase of stress developed in the dentin of a maxillary incisor.^{11,35} Nevertheless, in the present investigation, the stress values for the restoration, in the presence of a ferrule, were found decreased. This observation could suggest that the presence of a

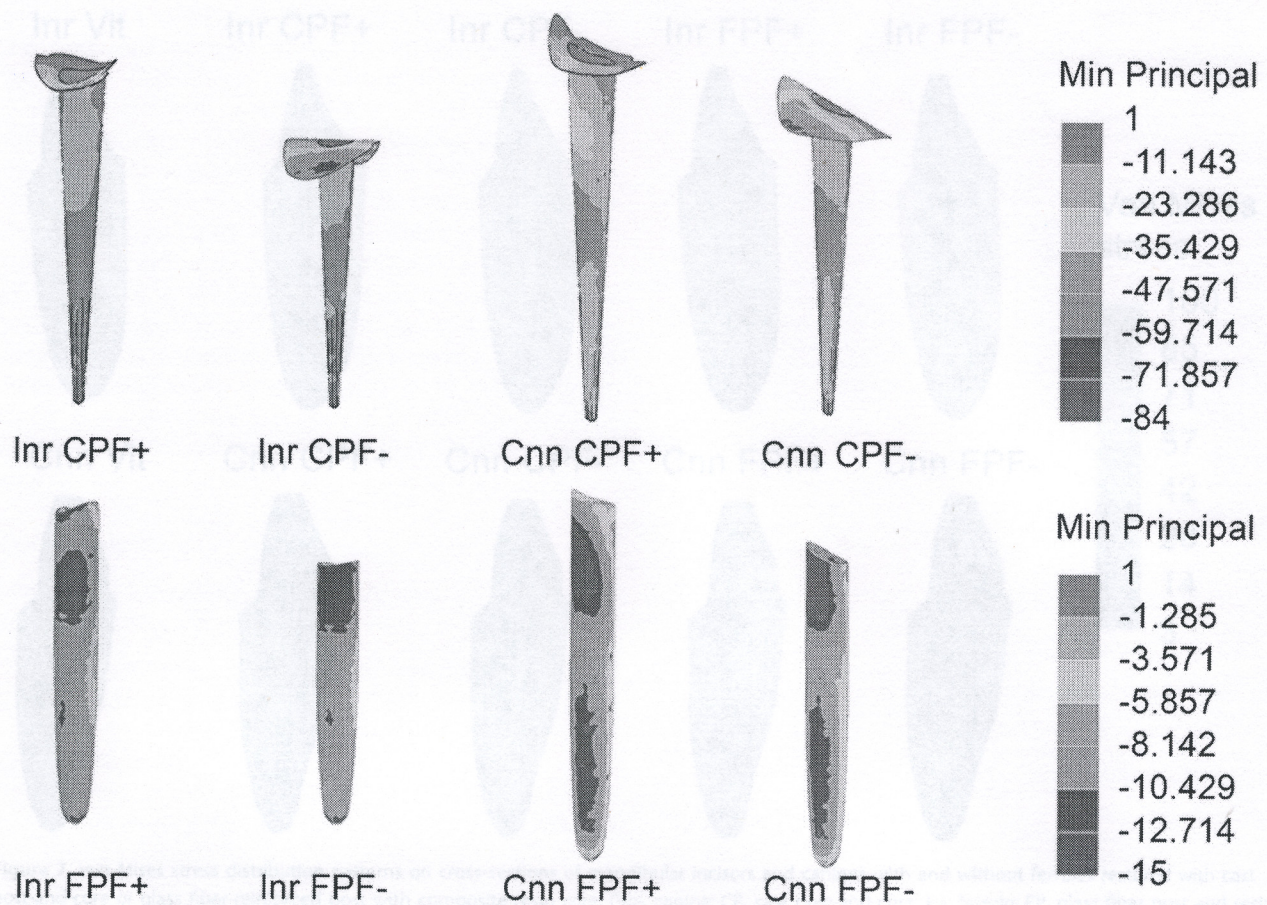


Figure 6. Distribution of minimum principal stress values in post cements, mandibular incisors, and canines with and without ferrules restored with cast post-and-core or glass fiber-reinforced post with composite resin core. Cnn, canine; CP, cast post-and-core; F+, ferrule; FP, glass fiber post and resin core; Inr, incisor; F-, nonferrule.

ferrule resulted in strengthening of the entire "dentin-restorative construction" complex. This is consistent with data from Gluskin et al,²⁵ who concluded that the mandibular lateral incisor CPF+ withstood much higher loads (up to 203.5 N) than in the present study. Moreover, in accordance with the study by Ichim et al,¹¹ the presence of a ferrule increases the tensile stress developed in dentin but simultaneously improves the mechanical resistance of cemented restorative elements by reducing the stress values in the luting interfaces and decreasing the potential for displacement.

Boschian et al³⁷ reported that post materials with higher elastic moduli could transfer nonhomogeneous and destructive critical stresses to the tooth structures. They recommended the FP type to best preserve the integrity of the restored tooth. Along the same line, Santos-Filho et al³⁵ emphasized the importance of approximation between mechanical properties of the dental tissues and the restorative materials used. The use of an FP considerably increased the tensile stress developed in dentin compared with teeth restored with a CP

but without significant changes in the stress pattern. Furthermore, this observation was found regardless of the tooth type; however, it was more pronounced for the mandibular lateral incisor. This finding agrees with that of Asmussen et al,⁷ who found that by increasing the elastic parameters of the post, a decrease in the stress developed in dentin was observed. This finding further agrees with another ferrule effect simulation study²⁸ and an in vitro study for the resistance to cyclical loading.²⁹

When stress concentrations exceed the failure limit of the cement interface, they can result in loss of adhesion. This allows bacterial invasion, followed by development of periapical lesions,⁸ which may cause biological failure before a clearly mechanical failure takes place. In the present study, such increased tensile stresses were found for the mandibular lateral incisor CPF- and were localized on the labial aspect of the core-dentin interface, corresponding to areas of potential decementation (Fig. 6). In contrast, the canine CPF- presented with considerably lower tensile stress values concentrated in the post cement, suggesting that the CP could provide

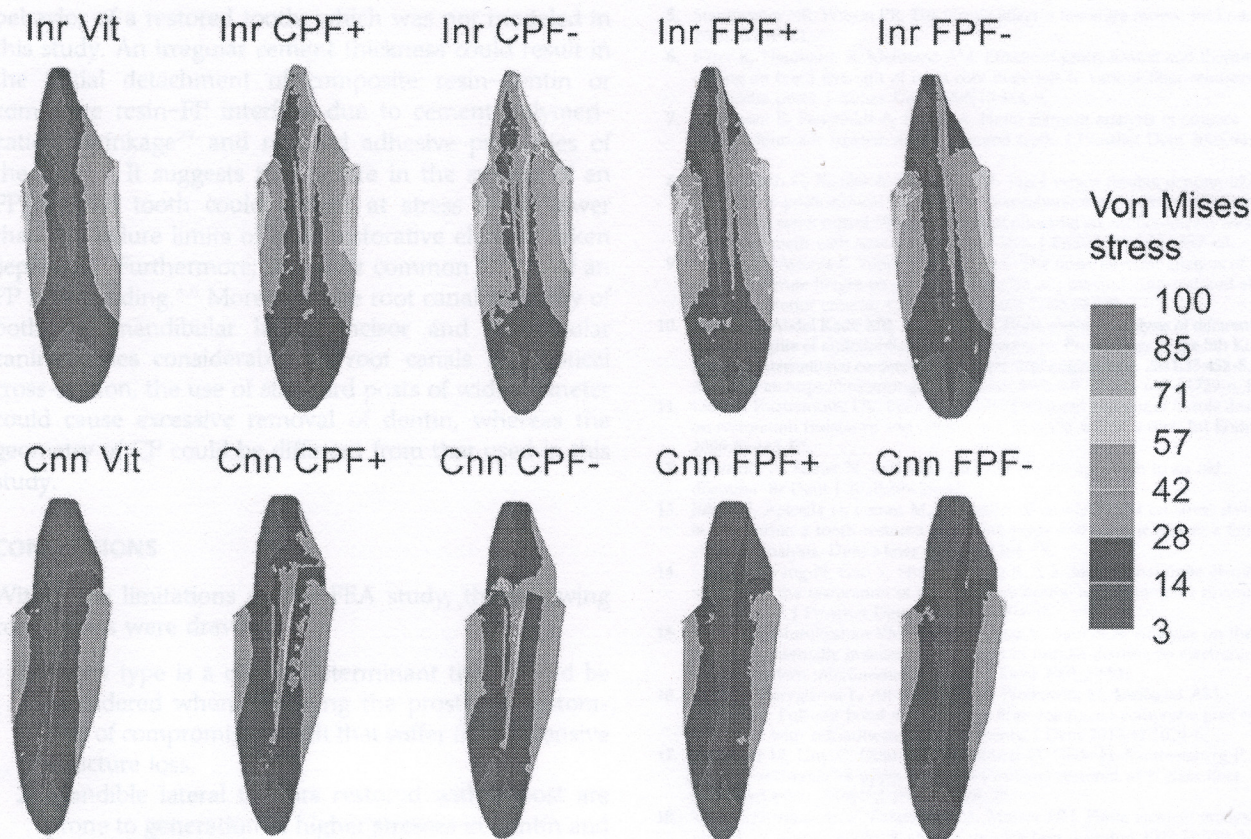


Figure 7. von Mises stress distribution patterns on cross-sections of mandibular incisors and canines with and without ferrules restored with cast post-and-core or glass fiber-reinforced post with composite resin core. Cnn, canine; CP, cast post-and-core; F+, ferrule; FP, glass fiber post and resin core; Inr, incisor; F-, nonferrule; Vit, vital.

better stability in the restoration of teeth with a more pronounced anatomy and severe coronal destruction, which agrees with findings of other authors.^{25,61} Remarkably lower stresses were detected in composite resin cement. This confirms the findings that FPs combined with composite resin cements could improve the restoration of endodontically treated teeth without a ferrule compared with CP.^{35,62,63}

Meanwhile, tensile stress analysis of the composite resin core of the mandibular lateral incisor FPF- and canine FPF- models revealed values critically close to the tensile failure limit of the composite resin core material.⁵³ This finding suggests that the prosthetic rehabilitation of severely compromised teeth is challenging and depends on the tooth type. Therefore, treatment planning should be performed based on the individual clinical condition. The results of this investigation indicate that the use of a FP or a CP for the restoration of the mandibular lateral incisor in the absence of ferrule (F-) results in the generation of critical stresses. The finding that the stress parameters exceeded the tensile failure limit for CP cement and were close to the tensile limit of composite resin core in the mandibular lateral incisor FP highlights

the complexity of treatment planning for the mandibular lateral incisor, as well as the need for further investigations. Orthodontic extrusion or surgical clinical crown lengthening have been proposed as alternatives in achieving additional clinical crown height for the establishment of a ferrule effect.^{64,65}

Finite element analysis allows controlled analysis of mechanical parameters. However, it is limited by simplification and an approximation of the material properties and conditions. It is chiefly an informative tool for determining the general principle of the biomechanical behavior of restored teeth. It allows qualitative visualization of the stress fields distribution at any point of 3D model but leads to generalized quantitative results for a statistical approach. Thus, the reproducibility and the interpretation of the results should be verified by in vitro or clinical studies. Within the limitations of this study, post space preparation in the investigated tooth models was designed to achieve maximum adaptation between the posts and root dentin (0.03mm). Under clinical conditions, the post-dentin distance is variable, especially for prefabricated posts. This results in an irregular cement width that affects the mechanical

behavior of a restored tooth, which was not modeled in this study. An irregular cement thickness could result in the initial detachment of composite resin–dentin or composite resin–FP interface due to cement polymerization shrinkage²⁷ and reduced adhesive properties of the FP.^{15,16} It suggests that failure in the system of an FP-restored tooth could appear at stress levels lower than the failure limits of each restorative element taken separately. Furthermore, the most common failure of an FP is debonding.^{4,6} Moreover, the root canal anatomy of both the mandibular lateral incisor and mandibular canine varies considerably. In root canals of elliptical cross-section, the use of standard posts of wide diameter could cause excessive removal of dentin, whereas the geometry of CP could be different from that used in this study.

CONCLUSIONS

Within the limitations of this FEA study, the following conclusions were drawn:

1. Tooth type is a critical determinant that should be considered when designing the prosthetic restoration of compromised teeth that suffer from extensive structure loss.
2. Mandible lateral incisors restored with a post are prone to generation of higher stresses in dentin and major restorative elements compared to teeth with a bulk anatomy.
3. Tooth preparation with a ferrule leads to a remarkable increase in stress for the dentin of the mandibular lateral incisors.
4. Tooth preparation with a ferrule favors the mechanical integrity of the restorative elements, regardless of post or tooth type.
5. The cast post is an enabling prosthetic treatment for the restoration of mandibular canines with a ferrule. In the absence of a ferrule, the composite resin core or resin-modified glass ionomer post cement develop stresses close to or higher than the failure limit of the material.

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