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BASIC RESEARCH:

Current Perspective on Fiberglass Posts Length: Finite Element Study

Perspectiva actual sobre la longitud de los postes de fibra de vidrio: un estudio de elementos finitos

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ABSTRACT: The literature to date has not reported a clear consensus on the optimal length of fiberglass posts for efficient clinical performance when restoring endodontically treated maxillary incisors with severe crown destruction. This study aimed to determine the stress distribution of fiberglass posts at different lengths using finite element analysis. Five 3D finite element models (groups A-E) were created, each representing a restoration system for endodontically treated maxillary central incisors. The models included post-core crowns with crown-root ratios of 1/3, 1/2, 2/3, 4/5, and 1/1. A static load of 100N force was applied to the palatal surface at 45º to the long axis of the tooth. Von Mises values and I maximum stresses in the crown, dentin, resin cement, and post-core were evaluated separately. The maximum stress experienced was A < C < B < E < D. Von Mises stresses were located in the upper and middle buccal thirds and in the apical palatal third of post A, as well as the upper and middle buccal thirds in posts B, C, D, and E. The lowest distribution of maximum and Von Mises stresses was observed in model A.

KEYWORDS: Finite element analysis; Maxillary central incisor; Endodontically treated teeth; Fiberglass post; Post length; Fracture resistance.

RESUMEN: Hasta la fecha, la literatura no ha reportado un consenso claro sobre cuál es la longitud más óptima de los postes de fibra de vidrio para proporcionar un rendimiento clínico eficiente al restaurar dientes incisivos superiores tratados endodónticamente con destrucción coronaria severa. Determinar la distribución de tensiones de postes de fibra de vidrio en diferentes longitudes mediante análisis de elementos finitos. Se realizaron cinco modelos 3D de elementos finitos (grupos A-E), cada uno de los cuales representa un sistema de restauración para incisivos centrales superiores tratados endodónticamente. Los modelos fueron postes de corona con proporciones de corona-raíz de 1/3, 1/2, 2/3, 4/5 y 1/1. Se aplicó una carga estática de 100 N de fuerza a la superficie palatina a 45º del eje longitudinal del diente. Los valores de Von Mises y la tensión máxima en la corona, la dentina, el cemento de resina y poste se evaluaron por separado. La distribución de las tensiones máximas fue A < C < B < E < D y las tensiones de Von Mises fueron en el tercio bucal superior y medio y tercio palatino apical del poste A; así mismo, como en el tercio bucal superior y medio en los postes B, C, D y E. La menor distribución de tensiones máximas y de Von Mises se observó en el modelo A.

PALABRAS CLAVE: Análisis de elementos finitos; Incisivo central superior; Dientes tratados endodónticamente; Poste de fibra de vidrio; Longitud del poste; Resistencia a la fractura.

INTRODUCTION

One of the most common problems in restorative dentistry is the rehabilitation of endodontically treated teeth (ETT) as they exhibit qualitatively and quantitatively different mechanical properties compared to vital teeth (1). The absence of residual coronal walls presents a particularly difficult challenge when restoring these teeth; in such cases, intracanal posts are required as the primary method to retain the coronal restorative material (2, 3). In the past, custom-cast metal posts were proposed to reinforce ETT and were considered the standard treatment (4); however, concerns have been raised about the associated corrosion, toxicity, non-aesthetic appearance, and vertical root fractures (5).

To overcome these drawbacks, prefabricated posts have emerged in various materials (6, 7), with fiberglass-reinforced posts the most popular due to their appealing aesthetics and biomechanical properties similar to dentin, with regard to elastic modulus and hardness (8). Additionally, they passively fit into the root canal, reducing stress on the root dentin and preventing root fractures (9, 10). However, despite these highlighted advantages, they present a higher risk of decementation after long-term follow-up and lower fracture resistance (11). This resistance is also associated with the retention of the post in the root canal, depending on the length, type of cement used, and the diameter of the post (12).

Regarding the post length, several recommendations have been proposed since the 1970s. Baraban described in a treatment guide report that the post should be incorporated up to half the root, but care must be taken to avoid perforation (13). Willems described that the post length should be two-thirds or four-fifths of the root (14). Another frequent recommendation in the scientific literature is for the post to be at least as long as the clinical crown (15). The latest proposal suggests that the post length should be one-third of the crown (16). All these proposals are related to custom-made metal posts and have been extrapolated to prefabricated fiberglass posts without considering their unique characteristics.

Clinical studies provide a high level of scientific evidence on the quality and behavior of a material or restorative technique. However, these studies are time-consuming, difficult to implement, and costly. Therefore, laboratory tests are important evaluation tools because they allow the comparison of different materials under controlled conditions. However, standard laboratory tests are destructive and do not allow the detection of the initial crack of treatment failures (17-20). Studies using finite element analysis (FEA) are increasingly accepted as a useful tool for understanding various biomechanical properties that cannot be examined or evaluated with standard *in vitro* experimental models. In the dental field, finite element analyses have been conducted primarily to gain a deeper understanding of specific biomechanical performance, stress distribution, and strain in vulnerable areas prone to fractures, including the interface between the tooth and the restoration (12, 21, 22).

Determining the stress distributions of ETT repaired with dental posts remains a contentious topic. To the authors' knowledge, no research includes the different recommended lengths for fiberglass posts through a finite element analysis. The optimal length of fiberglass posts for successful clinical performance remains uncertain.

Therefore, this study aims to analyze the stress distribution of fiberglass posts at different lengths. The research hypothesis is that stresses in fiberglass posts at different lengths are dissimilar.

MATERIALS AND METHODS

STUDY DESIGN

An experimental, cross-sectional, comparative *in vitro* study was conducted using finite element analysis. The study variables include fiber-reinforced intracanal posts with lengths of 1/3, 1/2, 2/3, and 4/5 of the root, and 1/1 of the crown post.

PREPARATION OF SOLID MODELS AND FINITE ELEMENTS

A maxillary central incisor recently extracted due to periodontal disease was collected, with dimensions of 10.5 mm crown, 12.9 mm root, and 8.5 mm mesiodistal width. All surfaces of the tooth were scanned with a multifunctional 3D Dental UP560 scanner (3DBiotech, China). The scan in STL format was processed with Meshmixer software, where it was smoothed and the number of elements was reduced to make the tooth more uniform, then saved in SLDDRW format for use in SOLIDWORKS software. In this software, the X (mesial), Y (longitudinal of the tooth), and Z (palatal) tooth planes were identified. Several cuts were made in the horizontal and vertical planes to achieve a solid dental piece.

A single post-core model was created following the model by Huang M *et al*. (23), varying its length in the root of the tooth. The maxillary central incisor was cut in a plane perpendicular to the longitudinal axis of the tooth 9.5 mm from the incisal edge, leaving 1 mm of coronal remnant. A dental core of 7.5 mm height was then designed with 10° axial wall inclination and a rounded shoulder margin (chamfer) of 0.8 mm; the post was designed as a 20 mm long by 2 mm wide cylinder. Both designs (the core and the post) were merged to be added to the tooth models at different lengths (Figure 1). Additionally, a 0.1 mm thick layer of cement was molded around the entire post-core. Finally, the periodontal ligament was modeled around the entire root of the tooth.

Once the designs were completed, they were entered into the finite element method program of ANSYS-14 software for simulation. The nodes and elements of each model are shown in Table 1.

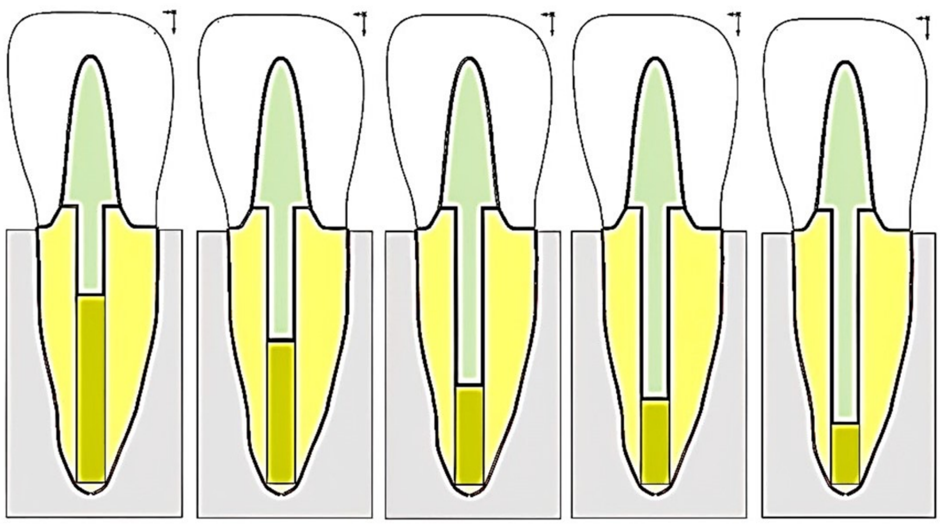

Figure 1. Dimensions of the groups.

Table 1. Number of nodes and elements of the different models analyzed using the finite element method.

	Post-core				
	A (4.3mm)	**B (6.45mm)**	**C (8.6mm)**	**D (9.32mm)**	**E (10.5mm)**
Nodes	804851	813698	822699	825967	830183
Elements	456942	461550	466307	468028	470161

MODEL AND GROUP DESIGN

A model with a 1 mm high coronal remnant from the cemento-enamel junction was created. Five groups of models with different lengths were established.

A. Post-core group with 1/3 of the root length (4.3 mm).
B. Post-core group with 1/2 of the root length (6.45 mm).
C. Post-core group with 2/3 of the root length (8.6 mm).
D. Post-core group with 4/5 of the root length (9.32 mm).
E. Post-core group with 1/1 of the crown length (10.5 mm).

EXPERIMENTAL ASSUMPTIONS, BOUNDARY CONDITIONS, AND PARAMETER SETTINGS

Assuming that all the materials and tissues of the model are linear elastomers with the same isotropy, achieving a low degree of deformation, the specific mechanical parameters for each material are as detailed in Table 2.

The post-cores were made of fiberglass because of the higher survival rate compared to metal posts (5) and the lower, more homogeneous stress distribution than metal, titanium, and zirconia posts (24). The crown was made of lithium disilicate ceramic, considered the best restorative material due to its high mechanical strength, strong adhesion to the tooth structure, and superior aesthetic appearance (25). Additionally, Variolink II resin cement (Ivoclar, Vivadent AG, Schaan, Liechtenstein), a fourth-generation adhesive cement offering better adhesion strength, was used (26).

LOADING METHODS

Simulating chewing forces, a static load of 100N was applied to the middle third of the palatal surface at a 45° angle to the tooth's long axis (19,20.23,27,28) and with a load area of 2 mm². The average maximum force of the maxillary central incisor is known to be 12 Kg (117.2N) (28).

LOADING AND STRESS INDICATORS METHODS

The distribution and maximum Von Mises stresses across the different components involved in the restoration (crown, resin cement, dentin, and post-core) were analyzed.

Table 2. Mechanical parameters of the materials.

Material	Modulus of Elasticity (GPa)	Poisson´s ratio
Dentine	18.618.6	0.310.30.310.3
Cement	18.6	0.310.3
Bone	18.0	0.24
Periodontium	0.0690.069	0.450.45
Gutta-percha	0.140.14	0.400.40
Resin Cement	8.38.3	0.350.30.35
Fiberglass post (3M)	36	0.3
Lithium Disilicate Ceramic	103,0	0.23

RESULTS

The distribution across the crown, dentin, resin cement, and post are shown in Figure 2. The distribution of Von Mises stresses in the crown was concentrated in the prosthetic crown neck, both vestibular and palatal, across all study groups. In the cement, the distribution of Von Mises stresses in the dentin was located in the cervical third of the vestibular surface of the tooth in all study groups. The distribution of stress was in the apical third for group A, in the middle and apical thirds for group B, and in the middle third of the entire adhesive layer for groups C, D, and E. The distribution of Von Mises stresses in the post was in the cervical and middle thirds of the vestibular surface and the apical third of the palatal surface in group A, and in the cervical and middle thirds of the vestibular surface in groups B, C, D, and E.

Regarding the distribution of l maximum stresses in teeth rehabilitated post-endodontics with posts of different lengths, the lowest distribution stress in the crown was observed for groups A and C, while the distribution stress in the dentin and cement was homogeneous. In the post, the highest distribution was found in group E (Table 3).

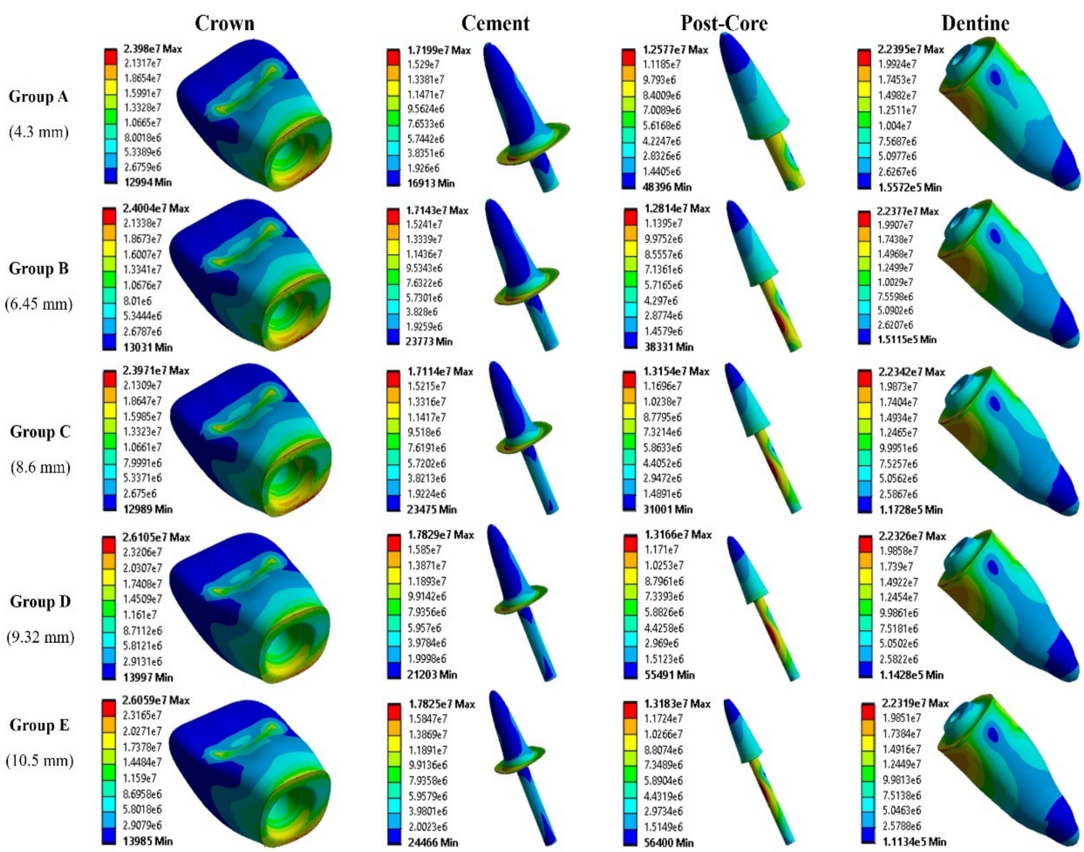

Figure 2. Distribution of Von Mises stresses.

Table 3. Maximum Von Mises stress values in restored teeth in MPa.

	I Maximum stress of fiberglass posts				
	A (4.3mm)	**B (6.45mm)**	**I C (8.6mm)**	**I D (9.32mm)**	**I E (10.5mm)**
Crown	23.98	24.00	23.97	26.10	26.05
Dentine	22.39	22.37	22.34	22.32	22.31
Cement	17.19	17.14	17.11	17.82	17.82
Post	12.57	12.81	13.15	13.16	13.18

DISCUSSION

The stress distribution pattern in a natural tooth differs from that in a tooth restored with a dental post system. During occlusion, an intact upper central incisor can flex, showing areas of I maximum stress concentration in the cervical vestibular portion of the root below the clinical crown (6, 21). In contrast, a tooth restored with a post-core-crown system exhibits different regions of stress concentration in the prosthetic crown, cement, post, and dentin due to the presence of individual components.

In the present study, after restoring the teeth with a post-core and crown, it was observed that the prosthetic crown exhibited higher stress levels in the force application area, which were transferred to the neck of the prosthetic crown both vestibularly (compressive stresses) and palatally (tensile stresses). This stress increased with greater post length due to the larger lever arm. These results are similar to those found by Lin *et al*. (3) and Alshabib *et al*. (6).

Furthermore, the stress distribution in the dentin was homogeneous in all groups in the cervical third of the vestibular surface; however, it slightly decreased with increasing post depth. These results are similar to those found by Corrêa G. *et al*. (17) and Lima M. *et al*. (27). In contrast to previous findings, Kharboutly N. *et al*. observed that the highest concentration of stresses occurred in the middle and apical third of the vestibular surface in conical posts of 2/3 root length as these posts create a wedge effect, distributing the stresses toward the apex (10).

The I maximum stresses produced in the post in group A were in the cervical and middle third of the vestibular surface and the apical third of the palatal surface; whereas in the other groups, they were only distributed in the cervical and middle third. Additionally, the stresses increased with greater post depth, indicating that deeper posts have a higher probability of fracture. Similar results were found by Hatta M. *et al*., who observed that short fiber posts, 1/3 of the root length, had much higher fracture resistance than posts with 1/2 and 2/3 lengths as these increased the stress concentration in the cervical area of the vestibular surface. This makes short posts more repairable in the event of a fracture at that level, allowing for reintervention and tooth preservation (8).

This result may be due to a greater challenge in achieving a reliable bond with the cementing agent due to deeper post insertion, which causes a reduction in the number of dentinal tubules in the apical part of the root and limited cleaning of the canal walls. This can lead to debonding and subsequent fracture (7). It could also be attributed to the limited light transmission capacity of fiber posts, which results in a reduced degree of conversion of the resin cement. Additionally, when the cement is mixed by hand, air bubbles may be introduced, especially in the apical portion (22).

The anatomical complexity of the apical part of the root and the presence of accessory and lateral canals can increase the risk of apical pathology resulting from long posts, which can be detrimental to the apical seal of the root (4). Contrary to the aforementioned studies, Lin J. *et al*. analyzed fiber posts of lengths 7.5 mm, 11 mm, and 15 mm, with coronal heights of 3 mm and 5 mm, and found that the 15 mm long posts with a 5 mm coronal height had the highest fracture resistance due to the coronal remnant causing a different lever effect compared to the absence of a coronal remnant (3).

Another study by Marinescu A. *et al*. found that intracanal posts of 7 mm resisted higher fracture forces than those inserted at lengths of 5 mm as a longer post can lead to greater intracanal stress accumulation. However, in fiber posts, due to similar modulus of elasticity to dentin, root fractures are less likely. Nevertheless, there is a risk of canal perforation during preparation, and in the event of a fracture at this level, the loss of the tooth is imminent (18).

Contrarily, in the study by Özarslan M. *et al*., no noticeable variation in fracture resistance was found between short (7.5 mm) and long (10 mm) fiber posts, concluding that adding length to the post does not increase its fracture resistance. However, post retention increases with greater length of the canal (19). This is also evidenced in the study by Junqueira R. *et al*., where they evaluated posts of 7 mm, 9 mm, and 12 mm (20), as well as in the study by Palepwad A. *et al*., where they evaluated posts of 6 mm and 8 mm, concluding that increasing the post length does not provide additional fracture resistance (4).

The finite element method is currently very useful due to its great versatility and quick mechanical analysis. However, it is very difficult to fully simulate all the masticatory forces present in the oral cavity. Therefore, a limitation of this study is that it only analyzes ideal stress conditions, i.e., static loads. The authors recommend continuing in vitro studies including other variables such as diameter, materials, etc. for confirmation through clinical trials.

CONCLUSION

Based on the results of the present study and within its limitations, it can be concluded that anterior teeth treated endodontically with fiberglass posts placed at a shallower depth (1/3 of the root length) exhibited a lower distribution of stresses.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization and design: F.H.C.O and A.V.A.
Literature review: F.H.C.O. and L.C.A.J.
Methodology and validation: D.A.O.D. and A.V.A.
Formal analysis: H.I.A.V. and F.H.C.O.
Investigation and data collection: L.C.A.J and D.A.O.D.
Resources: F.H.C.O.
Data analysis and interpretation: A.V.A and D.A.O.D.
Writing-original draft preparation: F.H.C.O and A.V.A.
Writing-review & editing: F.H.C.O. and H.I.A.V.
Supervision: F.H.C.O.

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