EFFECT OF INTRA-RADICULAR POSTS FOR STRESS DISTRIBUTION IN RADICULAR DENTIN

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Abstract *The use of intra-radicular posts of different materials and sizes for the reconstruction of the remaining dental radicular aiming a subsequent prosthetic restoration of the tooth is considered a normal practice in dentistry clinic. The technique of posts modeled from the root cavity is widely adopted normally making use of metal alloys. Nowadays, a modeled ceramic post is indicated when the esthetic compromising of the restoration becomes a preponderant factor. However, dental roots reconstructed with intra-radicular metal or ceramic posts are subject to fracture risk during masticatory loads, with regard to dental roots with small dentin thickness. The risk of fracture is influenced by the different stiffness concerning the dentin and the post materials, which increases the load transfer to the dental root. This study compares the stress and strain distribution in radicular dentin after reconstruction with metal and ceramic posts. A bidimensional finite elements mode in plane strain was adopted in order to simulate the elastic stress distribution due to masticatory loads. For each post and load condition, von Mises equivalent stresses are analyzed in the radicular dentin. Finally, the authors discuss and present recommendations for application of the models.*

Keywords: *dentistry, bioengineering, finite element method*

1. Introduction

The present restorative dentistry has the main purpose of rehabilitating the function and the esthetic of the teeth when tooth structures are lost by means of caries or fractures.

Endodontically treated teeth with large portion of coronal dentin damaged are commonly restored with post-and-core intending to provide retention for the subsequent restoration. Although some studies indicate that intra-radicular posts reinforce the pulpless tooth (Colman, 1979, Standlee and Caputo, 1988), more recent investigations have demonstrated that posts transmit the masticatory load to the root and supporting structures (Sorensen and Martinoff, 1984, Assif and Gorfil, 1994, Morgano, 1996). Therefore, researches relating dental materials biomechanics are being carried out to evaluate the effects on the structural integrity and the stress distribution within endodontically treated tooth restored with intra-radicular post (Reinhardt *et. al.*, 1983, De Sort, 1983, Lucas *et. al.,* 2001).

The efficiency and clinical longevity of the post-and-core restoration can be influenced by factors like the magnitude and direction of the occlusal load, design and material of the post, and the quantity and quality of the remaining root tissue (Hunter *et. al.,* 1989). So, when extensive loss of root dentin increases the risk of radicular fracture in presence of mastigatory loads the post mechanical behavior may be fundamental to the rehabilitation success (Assif *et. al.,* 1993, Assif and Gorfil, 1994, Ho *et. al.,* 1994, Yang *et. al.,* 2001).

Numerous methods are available for post-and-core construction, but the most widely is the indirect technique. This technique requires a pattern taken from the prepared root cavity to fabricate a cast post. The shape of the post will be conforming to the morphology of the root canal. Cast posts are frequently indicated for teeth with little remaining structure with large canal space after endodontic treatment and they are usually made of metal alloy, but more recently a technique of preparing a ceramic indirect post was developed, conferring to this post an esthetic feature.

The finite element (FE) method has been used for stress and strain analysis in dental biomechanics for nearly four decades. It utilizes a mathematical model which represents the geometry of the model to be analyzed. This method attempts to simplify the calculations by the complete subdivision of the model in small pieces resulting in a mesh, where the mechanical properties of the different materials and the load conditions are applied (Vree *et. al.,* 1983, Vasconcellos, 2001). Subdivision of the structure facilitates the determination of the uniformity of stress distribution within the tooth as well as the identification of stress concentration areas which could lead to crack formation and ultimate tooth fracture.

Accordingly, the purpose of this study was to utilize the finite element method to analyze and compare the stress distribution in a maxillary central incisor with a small thickness radicular dentin restored with two different gold and ceramic posts.

2. Material and Method

A bidimensional model of a maxillary central incisor with 21 mm in length was created by the software AutoCAD 2000 using the data of Wheeler (Wheeler, 1984) and Cantisano (Cantisano *et. al.,* 1987). This model was represented in a labial-lingual cross-section to make it possible for the direction of load application to be similar to that of the real functional load. The model included the supporting structures like periodontal ligament (0.175 mm), cortical bone (0.5 mm) and sponge bone. The cement layer that surrounds the root has the same elastic properties of the dentin, so, in this study cement and dentin were admitted as one. The average thickness of the radicular dentin was considered 1 mm to simulate a weakened root, frequently found in real clinical occurrences.

The mentioned model represents a pulpless tooth with 4 mm of remaining gutta-percha apical seal, and restored with a post obtained by the indirect technique. An all-ceramic crown is placed in the coronal portion of the tooth. This first model was subdivided in two models and used to simulate the stress distribution in a tooth subjected to loads when restored with gold post (Model 1) or ceramic post (Model 2). The difference of both models is associated with the materials' properties for each post in the numeral simulation.

The program used for the stress calculations was ANSYS 7.0 (Swanson Analysis Systems, Inc., Houston, Penn.). All materials used in this simulation were assumed to be homogeneous, isotropic and linear elastic and their elastic properties (elastic modulus and Poisson's ratio) are presented in Table 1.

The models were meshed in 11.274 quadratic elements with 11.455 nodes. All nodes on the bone surface below the apex were constrained to avoid movement in the X (horizontal) and Y (vertical) directions. To simulate the efforts of mastication and cut associated with the central incisors, two 100 N static loads were applied to each model acting uniformly across a thickness of 8 mm: 45-degree diagonal load on the lingual surface (Lo1) and vertical load on the incisal edge of the tooth (Lo2).

Table 1. Elastic constants for the different materials (Amarante, 2003)

MATERIAL	ELASTIC MODULUS (MPa)	POISSON'S RATIO (*v*)
Dentin	18.6×10^3	0.31
Periodontal ligament	69	0.45
Cortical bone	13.7×10^3	0.30
Sponge bone	1.37×10^3	0.30
Gutta-percha	0.69	0.45
Gold post	99.3×10^3	0.33
Ceramic post	150×10^3	0.25
Ceramic crown	96×10^3	0.26

3. Results and Discussion

The stress distribution within the teeth restored with both materials can be visualized in color graphics and, then, compared for the proposed analysis.

The results obtained with FE simulations are presented in terms of von Mises equivalent stress values. Von Mises equivalent stress combines the effects of normal and shear stresses in a resultant tensile stress. As brittle materials, to which human teeth belong, fail primary due to tensile-type normal stress, the von Mises criterion suggests that areas with stress concentrations are areas more solicited mechanically presenting higher probability for fracture.

Figures 1 to 4 present graphically the regions of the models where stresses were located according to the numerical solution.

The incisor restored with the two different materials' post, gold post (Model 1) and ceramic post (Model 2), presented a similar pattern of stress distribution when subjected to mastigatory load as much as vertical load, as following described.

In the presence of mastigatory load (45°), von Mises equivalent stress concentration (Figs. 1 and 2) was observed in the inner posts, especially at the post/dentin interface of the middle portion of both tooth, with higher values on the labial side, opposite to the load application. In radicular dentin, stress was observed next to the apical end of the posts in the two models, also mainly on the labial side of the teeth. Equivalent stress concentrated on the palatine side of the posts in both models when loaded vertically (180°), with higher stress in dentin near the end of the posts in both sides (Figs. 3 and 4).

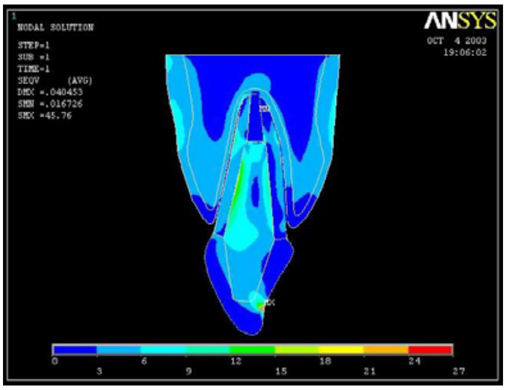


Figure 1. Von Mises distribution on Model 1 after Lo1 application.

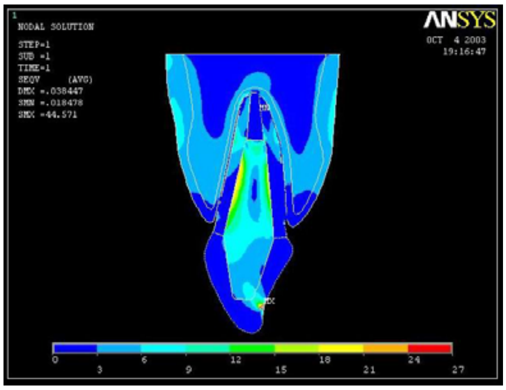


Figure 2. Von Mises distribution on Model 2 after Lo1 application.

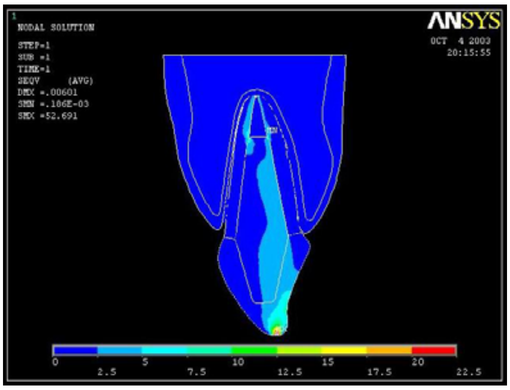


Figure 3. Von Mises distribution on Model 1 after Lo2 application.

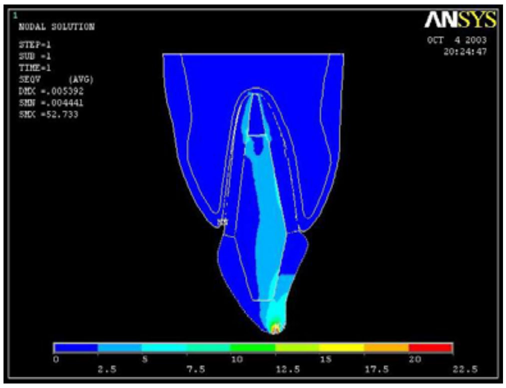
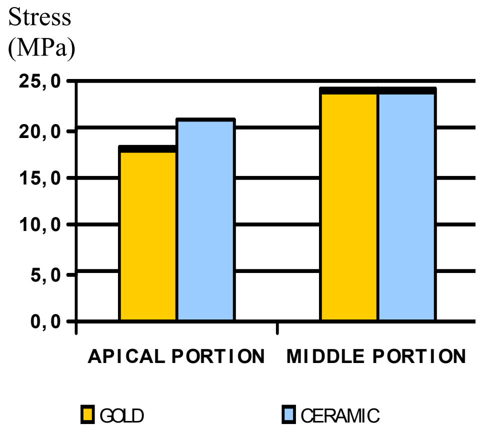


Figure 4. Von Mises distribution on Model 2 after Lo2 application.

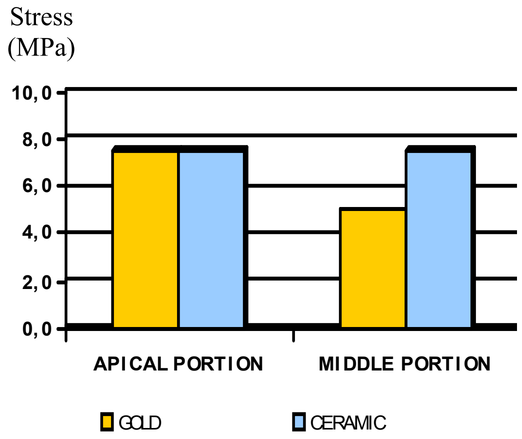
The ability of the intra-radicular post, which is substituting the lost tissue, to support the coronal restoration under occlusal loads is a critical factor of this type of dental treatment and, as consequence, the failure of the post will lead the failure of the coronal restoration (Shillinburg *et.al.,* 1987, Cohen *et.al.,* 1997).

According to the results of von Mises equivalent stress present in the Figs. 1, 2, 3 and 4, the apical end of the post concentrated stress, suggesting that the geometry of the post at its final portion can contribute to a higher stress state in this region. So, acute angles should be avoided to prevent crack initiation and consequently radicular fractures. As presented early by Mori (1994), this study showed that the vestibular side of the tooth is more subjected to tensile stresses, indicating that during the root preparation, the option of more wearing can be the palatine side. However, radicular fractures are observed in treatments well achieved, leading researchers to investigate in a more effective way the stress state that the restored teeth are subjected in the presence of occlusal loads. It must be emphasized that failure in treatments involving post-and-core restorations are related to masticatory loads, restoration geometry and restoration material. In this sense, the finite element method permits the simultaneous analysis of the influence of the various factors mentioned.

Graphs 1 and 2 summarize the von Mises higher stress values in the apical and middle portions of the tooth. Despite the similarity of the stress distribution patterns among the gold and ceramic intra-radicular posts presented in the Fig. 1 to 4, a correlation analysis revealed that ceramic posts presented higher stress values in compare to gold posts. When subjected to a masticatory load, i.e., loading at 45^o (Graph 1), the higher stress presented in the model of ceramic post located in the apical region of the tooth. Under vertical load, i.e., 180^o (Graph 2), the higher stress in the same post located in the middle portion of the tooth. The coronal portion was discarded in this study, due to the fact that the higher stress concentration located at the loading point was not considered. The two graphs also showed that the masticatory load promoted higher stress values than that associated with vertical load in both restored teeth.



Graph 1. Von Mises stress distridution in the tooth portions after Lo1 application.



Graph 2. Von Mises stress distribution in the tooth portions after Lo2 application.

4. Concluding Remarks

The purpose of this study was to utilize the finite element method to compare and analyze the stress distribution in a maxillary central incisor with a small thickness radicular dentin restored with gold and ceramic posts. From the results, the following conclusions can be drawn:

1. The gold and ceramic posts, on the basis of their high elastic modulus, promote stress concentration in the post and preserve the radicular dentin.
2. Both models analyzed in this study presented stress concentration at the region of the apical end of the post, which leads to conclude that this region is critical on the dentistry treatment.
3. Despite the similarity of the stress distribution, ceramic posts present higher values of stress concentration than gold posts, especially with regard to the apical portion of the tooth.
4. The vertical load (180^{O}) was less traumatic to the central incisor than the masticatory load (45^{o}).

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6. Responsibility notice

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