Stress Distribution in Dental Roots Restored with Different Post and Core Materials

Guilherme da Rocha Scalzer Lopes[1], Valéria da Penha Freitas[2], Jefferson David Melo de Matos[1], Valdir Cabral Andrade[3], Renato Sussumu Nishioka[4], Estevam Barbosa de Las Casas[5]

Departments of [1]Prosthodontics and [4]Dentistry, Institute of Science and Technology, São Paulo State University (Unesp), São José dos Campos, [2]Department of Dentistry, Federal University of Espírito Santo (UFES), Vitória - Espírito Santo, [3]Department of Dentistry, Federal University of Juíz de Fora (UFJF), Governador Valadares, [5]Department of Structural Engineering, Federal University of Minas Gerais (UFMG), Minas Gerais, Brazil

Abstract

Aim: The aim of this study was to investigate the stress distribution in models of maxillary central incisors restored with different post and core systems. **Materials and Methods:** A finite-element model of a maxillary central incisor was simulated in four different configurations – model 1: an intact tooth, Model 2: received gold cast metallic post and core, Model 3: received a fiberglass post and core, and Model 4: had a fiberglass post and the composite resin core. The restored tooth models were assumed to receive a ceramic crown simulating a clinical situation. After the preparation, the geometric models were exported in mesh to the analysis software (ANSYS 10.0, ANSYS Inc., Houston, USA). A 100 N static force at a 130° angle with respect to the longitudinal axis of the tooth was applied to the palatine surface of the model along equally distributed on the element nodes. The values and stress distribution were analyzed. **Results:** The stress distribution in the radicular structure of the models restored with three different post and core systems was like each other, but the gold cast metallic post and core system slightly improved the pattern of the stress distribution. **Conclusions:** The placement of post changes the stress distribution behavior, and the material with the highest elastic modulus showed the best performance in the stress distribution.

Keywords: Endodontically treated tooth, Finite-element analysis, Stress distribution

Introduction

The posts and cores are the materials of choice to restore endodontically treated teeth with partial or total loss of coronary structure.[1] Despite this, the professional can be in doubt among which the best material to be used since that the posts can be made by different systems, among them, cast metallic post systems obtained by molding the patient's radicular canal, or even, prefabricated metallic or nonmetallic post systems.[2] Prefabricated posts require coronary reconstruction after cementation inside the radicular canal, to rebuild the core. This coronary portion will offer resistance to restorative material and can be build out of direct restorative materials.[3] Alternatively, there are prefabricated cores with different anatomical designs, corresponding to the tooth to be restored and that can be installed over the posts.[4] Although there are a lot of materials used in the reconstruction of endodontically treated teeth, mechanical and biological failures can occur. The failures range from the debonding of the post, which allows a new attempt to restore the tooth, until the fractures of the teeth, which makes any attempt to recover this tooth impossible. The analysis of the behavior of these restorative materials is carried out with several *in vitro* and *in silico* methodologies, to elucidate the clinical behavior of these materials. The intention is to obtain a mechanically homogeneous structure, minimizing the stress distribution at the tooth/post interface.[5]

According to previous research, better performance is expected when the posts and cores present a modulus of elasticity close to that of the dentin, which are found in the fiberglass posts. The metallic posts, because they have a different modulus of elasticity, tend to make the stress distribution within the root more adverse.[6,7]

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Address for correspondence: Dr. Guilherme da Rocha Scalzer Lopes, Engenheiro Francisco Jose Longo, 555, Jardim São Dimas, Sao Jose Dos Campos, SP, Brazil.
E-mail: guilherme.scalzer@unesp.br

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Using the finite-element analysis, the difference in stress distribution between an intact tooth model and restored teeth models with post and core systems was found. This was related to the use of restored materials with a different modulus of elasticity also found that the posts could change the pattern of stress distribution in dental structure.[8] In this numerical study, the restored model with carbon fiber post had the best biomechanical behavior. The tooth models restored with reinforced glass fiberglass post had higher stress in the coronal third of the radicular dentin from the buccal aspect. These posts showed in their structure a more homogeneous stress distribution with lower values.[9]

As described previously, the system for cementing the cores on the posts is available for clinical applications. However, few information is available in the literature on the behavior of these materials whether in laboratory or clinical trials. In this sense, research that evaluates the behavior of different restorative materials is fundamental for a better understanding of its clinical performance and even for the purpose of assisting in the elaboration of new materials.[10-12]

Thus, the aim of the study is to investigate the stress distribution in a three-dimensional (3D) mathematical model of maxillary central incisors restored with different post and core systems, through the finite-element analysis.

Materials and Methods

The 3D models were performed using the Rhinoceros software (version 4.0 SR8, McNeel North America, Seattle, WA, EUA), to carry out a stress distribution analysis. Model 1: a maxillary central incisor healthy tooth was modeled, and the dental tissues were individually shaped containing enamel, dentin, and pulp. A 0.3 mm layer between the root and the socket bone simulated the periodontal ligament [Figure 1]. This 3D model was then modified to simulate three models with endodontic treatment containing a tapered root canal preparation. The gutta-percha was removed maintaining 4 mm in the apex region. The enamel was substituted by a ceramic crown, and the coronal dentin was replaced by the core. Each model received a different restoration modality. Model 2 received a gold cast metallic post and core. Model 3 received a fiberglass post and core and Model 4 had a fiberglass post and the composite resin core.

The dimensions of the post and core systems were kept constant in the three restored models (2, 3, and 4). The posts were modeled according to the product specifications (Reforpost® nº 3, Angelus, PR-Brazil). The fabricated post is slightly conic with retentive design in its surface. The retentions were neglected in geometric modeling because the objective was to analyze the mechanical behavior of the material used and not its geometric design.

The models were then imported into computer-aided engineering software (ANSYS 10.0, ANSYS Inc., Houston, TX, USA). The material properties such as elastic modulus and Poisson's ratio were applied based on the respective restored materials of each model [Table 1]. It was still assumed that all models of the study had the same final mesh combination, and the results with tetrahedral element SOLID 45 showed a better behavior. Tetrahedral element edge was chosen as approximately 0.8 mm, which is close to 1/10th of the largest dimension found in the mesiodistal measure in the tooth model.

A static structural analysis was used with the principal stress (in GPa) criteria which showed stress regions to evaluate the stress distribution in the posts, cores and roots. All interfaces were considered perfectly bonded and the materials considered linearly elastic, homogeneous, and isotropic. Loading was considered as static and applied to the palatal surface of the tooth model. A load of 100 N (130º) was applied on four element nodes along the occlusal line, 3.2 mm away from the incisal edge. Principal stress values were evaluated through colorimetric graphs.

Results

The principal stress distribution in the roots and the principal stress distribution in the post and core systems of the models are shown in Figures 1 and 2, respectively. To better demonstrate the difference between the groups, the colorimetric graphs showed the same range of stress (GPa). Comparing the stresses of the four models, a difference in the stress distribution in the roots was observed. The study showed that the placement of a gold cast metallic post and core system improves the pattern of the stress distribution in the dental structure, and the fiberglass

Table 1: Mechanical properties of the materials used in the analysis

Material	Elastic modulus (GPa)	Poisson coefficient	References
Enamel	84.1	0.33	Sun *et al*. (2018) Thiagarajan *et al*. (2017)
Dentin	18.6	0.31	Kantardžić *et al*. (2018)
Gold Cast	77.0	0.33	Verri *et al*. (2017)
Glass fiber post	40.0	0.22	Helal M; Wang Z. (2017)
Glass fiber core	40.0	0.22	Savychuk *et al*. (2017)
Composite resin Z100	21.0	0.30	Elsharkasi *et al*. (2018) Li *et al*. (2015)
Feldspathic ceramic (VM7)	58.0	0.25	Trindade *et al*. (2016)
Gutta-percha	6.9e−04	0.45	Aslan *et al*. (2018)
Periodontal ligament	68.9e−03	0.45	Otani *et al*. (2018)
Cortical bone	14.7	0.30	Yoda *et al*. (2018) Langsetmo *et al*. (2018)
Marrow bone	49.0e−02	0.30	Sandino *et al*. (2017) Singhal *et al*. (2018)
Dental pulp	2.0e−03	0.45	Ausiello *et al*. (2017)

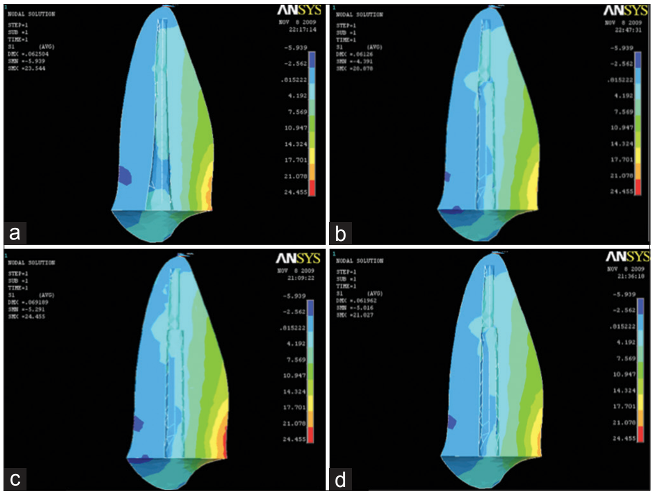

Figure 1: (a) Distribution of the principal stress on the healthy natural tooth (distal plane). (b) Gold cast metallic post and core. (c) Fiberglass post and core. (d) Fiberglass post and a composite resin core

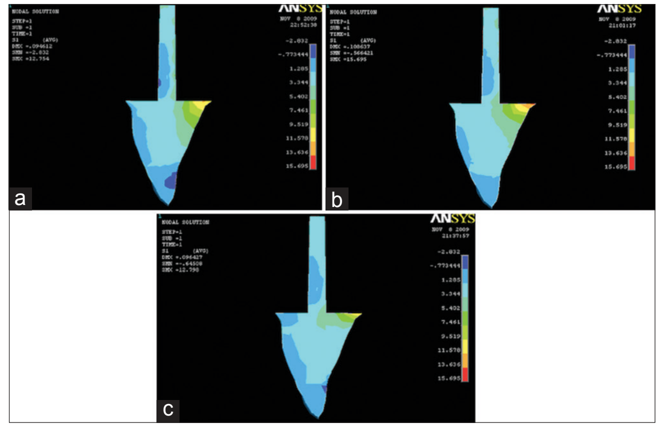

Figure 2: (a) Distribution of the principal stress on the gold cast metallic post and core (Model 2). (b) Fiberglass post and core (Model 3). (c) Fiberglass post and a composite resin core (Model 4)

post and core model showed a higher stress distribution in the dental structure.

In fiberglass post and core, Model 3, slightly higher stresses were developed in the region around the palatal post surface than Model 2 and Model 4. Analyzing only the coronary portion of the models, it was verified that the composite resin core showed a similar stress distribution to the intact tooth.

The voltage distribution at the internal interface is more uniform, reducing the variability of the test, which is a great advantage of the evaluation method when comparing the different posts, thus allowing a reliable evaluation of the behavior of each pin within the channel, with this observing a significant decrease in the number of cohesive failures.

Discussion

This study evaluated the stress distribution in endodontically treated maxillary incisors with three different rehabilitation approaches.[13,14] The simulation of the periodontium in the models between the tooth and the alveolar bone allowed the tooth movements, improving the stress distribution.[15] New dimensions were also defined for the buccal and lingual cortical bone to better represent the tooth anatomy in jaws.[16]

In masticatory, the load is applied on the crown of the tooth and subsequently transmitted to the underlying structures.[17] In the present study, it was observed that the highest stresses were located at the load application site.[18] Because it was a maxillary central incisor, the load was applied over four nodes of the lingual surface of the tooth model trying to simulate an area of contact with a mandibular central incisor.[18,19] The distance between each node was 0.8 mm; regarding the contact angle, the mean value of the interincisal angle found in a study was used.[20]

Regarding the mechanical properties of materials and biological structures, the values that were most frequently described in experimental scientific works were used.[21,22] To simplify the 3D model, the cementation line, both in the prosthetic crowns and the posts, was neglected since its thin thickness will not change the biomechanical behavior. For this same reason, the cement, which covers the root portion of the tooth, was also disregarded too. In addition, cement has mechanical properties similar to dentin, so did not appear to be so significant to include cement in the study.[23,24] As for post and core models, all of them were restored in a standardized way.

In all models, slightly higher stress levels were identified in the cervical area, mainly on the lingual surface, in addition to the load application sites (control model). The authors have demonstrated that in the presence of posts, the loads are transmitted by them and not by the dentin.[25] The change in the pattern of stress distribution was also identified by others.[26]

The rigidity of the metallic posts restricts the tooth displacement, and the stresses are concentrated in the interior of the root, especially in the cervical third.[27] The metallic posts have a high modulus of elasticity, and the stress distribution is concentrated in the structure with the highest modulus of elasticity when they are subjected to a functional load, that is, at the postcement interface.[28] However, the present study showed that the gold cast metallic post showed better performance and a homogeneous stress distribution, what is more similar to the intact tooth than the fiberglass posts. Possible differences in the performances between metallic and nonmetallic posts may be explained when using reduced length posts since this reduction is more deleterious to metallic posts.[29,30]

The ideal restorative system would be the one that had the post with a modulus of elasticity equal to or close to the dentin, and the fiberglass posts have a modulus of elasticity similar to the tooth.[31] This allows lower flexion and a lower stress distribution inside the root.[32-34] Nevertheless, the fiberglass posts of the present study present a worse performance than the gold cast metallic posts.[35,36] The modulus of elasticity of the fiberglass posts is approximately 40 GPa with the incidence of oblique loads; however, because it is an anisotropic material, its properties vary depending on the load application.[37] Depending on the angle of incidence of the load, the mechanical properties of the fiberglass posts may exceed the modulus of elasticity of the metallic posts.[38]

The results indicate that there were differences in stress distribution in the tooth structure when different post and core systems are analyzed.[39] The finite-element method requires basic knowledge of mechanics, computer science, and the domain of analysis for the study of stresses, deformations, and displacements in an extremely complex virtual model such as the tooth.[40,41]

Therefore, clinical decisions should not be taken based solely on *in silico* studies, and hence to evaluate the behavior of maxillary central incisors restored with different post and core systems under load, more laboratory and clinical studies should be conducted to improve the knowledge of these restorative proposals evaluated.

Conclusions

The use of a post and core system changes the pattern of stress distribution along the tooth; the stress distribution in the radicular dentin of the restored models and the intact tooth was similar to each other. Although the current literature says the opposite, the gold cast metallic post, the material with the highest elastic modulus, showed the best performance in the stress distribution.

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Conflicts of interest

There are no conflicts of interest.

References

1. Yaman P, Thorsteinsson TS. Effect of core materials on stress distribution of posts. J Prosthet Dent 1992;68:416-20.
2. Assif D, Bitenski A, Pilo R, Oren E. Effect of post design on resistance to fracture of endodontically treated teeth with complete crowns. J Prosthet Dent 1993;69:36-40.
3. Duret B, Duret F, Reynaud M. Long-life physical property preservation and postendodontic rehabilitation with the composipost. Compend Contin Educ Dent Suppl 1996;20:S50-6.
4. Hatayama T, Chiba A, Kainose K, Nakajima M, Hosaka K, Wakabayashi N, *et al.* Stress distribution in tooth resin core build-ups with different post-end positions in alveolar bone level under two kinds of load directions. Dent Mater J 2018;37:474-83.
5. Spazzin AO, Galafassi D, de Meira-Júnior AD, Braz R, Garbin CA. Influence of post and resin cement on stress distribution of maxillary central incisors restored with direct resin composite. Oper Dent 2009;34:223-9.
6. Katranji A, Misch K, Wang HL. Cortical bone thickness in dentate and edentulous human cadavers. J Periodontol 2007;78:874-8.
7. Hamed HA, Marzook HA, Ghoneem NE, El-Anwar MI. Angulated dental implants in posterior maxilla FEA and experimental verification. Open Access Maced J Med Sci 2018;6:397-401.
8. Yaman SD, Alaçam T, Yaman Y. Analysis of stress distribution in a maxillary central incisor subjected to various post and core applications. J Endod 1998;24:107-11.
9. Cailleteau JG, Rieger MR, Akin JE. A comparison of intracanal stresses in a post-restored tooth utilizing the finite element method. J Endod 1992;18:540-4.
10. Bauer FX, Heinrich V, Grill FD, Wölfle F, Hedderich DM, Rau A, *et al.* Establishment of a finite element model of a neonate's skull to evaluate the stress pattern distribution resulting during nasoalveolar molding therapy of cleft lip and palate patients. J Craniomaxillofac Surg 2018;46:660-7.
11. Carvalho VF, Soares PB, Verissimo C, Pessoa RS, Versluis A, Soares CJ. Mouthguard biomechanics for protecting dental implants from impact: Experimental and finite element impact analysis. Int J Oral Maxillofac Implants 2018;33:335-43.
12. Oenning AC, Freire AR, Rossi AC, Prado FB, Caria PH, Correr-Sobrinho L, *et al.* Resorptive potential of impacted mandibular third molars: 3D simulation by finite element analysis. Clin Oral Investig 2018;22:3195-203.
13. Freire SM, Nishio C, Mendes Ade M, Quintão CC, Almeida MA. Relationship between dental size and normal occlusion in Brazilian patients. Braz Dent J 2007;18:253-7.
14. Memon S, Mehta S, Malik S, Nirmal N, Sharma D, Arora H. Three-dimensional finite element analysis of the stress distribution in the endodontically treated maxillary central incisor by glass fiber post and dentin post. J Indian Prosthodont Soc 2016;16:70-4.
15. Oskui IZ, Hashemi A, Jafarzadeh H, Kato A. Finite element investigation of human maxillary incisor under traumatic loading: Static vs. dynamic analysis. Comput Methods Programs Biomed 2018;155:121-5.
16. Jafari T, Alaghehmad H, Moodi E. Evaluation of cavity size, kind, and filling technique of composite shrinkage by finite element. Dent Res J (Isfahan) 2018;15:33-9.
17. Yoon HG, Oh HK, Lee DY, Shin JH. 3-D finite element analysis of the effects of post location and loading location on stress distribution in root canals of the mandibular 1st molar. J Appl Oral Sci 2018;26:e20160406.
18. Heydecke G, Butz F, Strub JR. Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: An *in vitro* study. J Dent 2001;29:427-33.
19. de Castro Albuquerque R, Polleto LT, Fontana RH, Cimini CA. Stress analysis of an upper central incisor restored with different posts. J Oral Rehabil 2003;30:936-43.
20. Veríssimo C, Simamoto Júnior PC, Soares CJ, Noritomi PY, Santos-Filho PC. Effect of the crown, post, and remaining coronal dentin on the biomechanical behavior of endodontically treated maxillary central incisors. J Prosthet Dent 2014;111:234-46.
21. Eraslan Ö, Eraslan O, Eskitaşçıoğlu G, Belli S. Conservative restoration of severely damaged endodontically treated premolar teeth: A FEM study. Clin Oral Investig 2011;15:403-8.
22. Chiba A, Hatayama T, Kainose K, Nakajima M, Pashley DH, Wakabayashi N, *et al.* The influence of elastic moduli of core materials on shear stress distributions at the adhesive interface in resin built-up teeth. Dent Mater J 2017;36:95-102.
23. Savychuk A, Manda M, Galanis C, Provatidis C, Koidis P. Stress generation in mandibular anterior teeth restored with different types of post-and-core at various levels of ferrule. J Prosthet Dent 2018;119:965-74.
24. Navimipour EJ, Firouzmandi M, Mirhashemi FS. Finite element analysis of the endodontically-treated maxillary premolars restored with composite resin along with glass fiber insertion in various positions. J Contemp Dent Pract 2015;16:284-90.
25. Durmuş G, Oyar P. Effects of post core materials on stress distribution in the restoration of mandibular second premolars: A finite element analysis. J Prosthet Dent 2014;112:547-54.
26. Okamoto K, Ino T, Iwase N, Shimizu E, Suzuki M, Satoh G, *et al.* Three-dimensional finite element analysis of stress distribution in composite resin cores with fiber posts of varying diameters. Dent Mater J 2008;27:49-55.
27. Huysmans MC, Van der Varst PG. Finite element analysis of quasistatic and fatigue failure of post and cores. J Dent 1993;21:57-64.
28. Sorrentino R, Aversa R, Ferro V, Auriemma T, Zarone F, Ferrari M, *et al.* Three-dimensional finite element analysis of strain and stress

distributions in endodontically treated maxillary central incisors restored with different post, core and crown materials. Dent Mater 2007;23:983-93.
29. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canal posts. Dent Mater 2004;20:29-36.
30. Santos-Filho PC, Veríssimo C, Soares PV, Saltarelo RC, Soares CJ, Marcondes Martins LR. Influence of ferrule, post system, and length on biomechanical behavior of endodontically treated anterior teeth. J Endod 2014;40:119-23.
31. Drummond JL, Bapna MS. Static and cyclic loading of fiber-reinforced dental resin. Dent Mater 2003;19:226-31.
32. Rippe MP, Santini MF, Bier CA, Borges AL, Valandro LF. Root canal filling: Fracture strength of fiber-reinforced composite-restored roots and finite element analysis. Braz Dent J 2013;24:619-25.
33. Gharechahi J, Sharifi E, Nosohian S, Aghdaee NA. Finite element method analysis of stress distribution to supporting tissues in a class IV aramany removable partial denture (Part II: Bone and mucosal membrane). J Contemp Dent Pract 2008;9:49-56.
34. Meira JB, Espósito CO, Quitero MF, Poiate IA, Pfeifer CS, Tanaka CB, *et al.* Elastic modulus of posts and the risk of root fracture. Dent Traumatol 2009;25:394-8.
35. Coelho CS, Biffi JC, Silva GR, Abrahão A, Campos RE, Soares CJ. Finite element analysis of weakened roots restored with composite resin and posts. Dent Mater J 2009;28:671-8.
36. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 1999;27:275-8.
37. Verri FR, Okumura MH, Lemos CA, Almeida DA, de Souza Batista VE, Cruz RS, *et al.* Three-dimensional finite element analysis of glass fiber and cast metal posts with different alloys for reconstruction of teeth without ferrule. J Med Eng Technol 2017;41:644-51.
38. Helal MA, Wang Z. Biomechanical assessment of restored mandibular molar by endocrown in comparison to a glass fiber post-retained conventional crown: 3D finite element analysis. J Prosthodont 2017:1-9.
39. Li Y, Carrera C, Chen R, Li J, Chen Y, Lenton P, *et al.* Fatigue failure of dentin-composite disks subjected to cyclic diametral compression. Dent Mater 2015;31:778-88.
40. Sandino C, McErlain DD, Schipilow J, Boyd SK. Mechanical stimuli of trabecular bone in osteoporosis: A numerical simulation by finite element analysis of microarchitecture. J Mech Behav Biomed Mater 2017;66:19-27.
41. Ausiello P, Ciaramella S, Martorelli M, Lanzotti A, Zarone F, Watts DC, *et al.* Mechanical behavior of endodontically restored canine teeth: Effects of ferrule, post material and shape. Dent Mater 2017;33:1466-72.