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Original Article

Stress distribution of esthetic posts in the restored maxillary central incisor: Three-dimensional finite-element analysis

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ABSTRACT

Background: Glass fiber posts, along with their esthetic properties, may have a better stress distribution than cast posts, Therefore, the aim of the present study was to investigate the effect of glass fiber, casting, titanium, and zirconia posts on stress distribution in maxillary central tooth treated with different amounts of ferrule using finite-element analysis.

Materials and Methods: In this experimental study, three-dimensional models of maxillary central incisors that have undergone root canal treatment were designed. Then, the models were divided into four groups according to the type of post (Ni-Cr casting, glass fiber, titanium, and zirconia) used. Zirconia monolithic crowns were used in all the four groups. Ferrule heights were repeated at 0 and 2 mm in all models. Models were entered into COMSOL Metaphysics software. Then, the force of 100 N with the angle of 135° on the palatal surface was applied to the longitudinal axis of the tooth, and the stress distribution in the models was investigated.

Results: Maximum stress was observed in the middle third of posts. Stress distribution in glass fiber post was better than zirconia and casting posts. Stress accumulation in models with zirconia, titanium, and casting posts was also found in the site between the middle third and coronal third, whereas in models with glass fiber post, stress accumulation was found between the crown and the cemento-enamel junction. In models without ferrule, stress accumulation was observed in one-third of the coronal, especially in glass fiber posts.

Conclusion: The post material and ferrule height affected stress concentration. The stress in the cervical area of the dentin was more for glass fiber post when compared to other posts. The use of glass fiber post in teeth with no ferrule results in lower stress along the post, but greater stress in the simulated tooth region.

Key Words: Ceramics, crowns, dental dowel, finite-element analyses, zirconium oxide

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INTRODUCTION

Today, because of the importance of esthetic issues, the use of all-ceramic crowns is common. Therefore, instead of cast posts, nonmetallic prefabricated posts are common.[1] Elastic modulus of casting posts is much higher than that of fiber posts. This feature enables the post system to withstand higher forces before it is deformed.[2,3] However, according to laboratory studies, metal posts cause tooth fracture due to high stress transfer to the teeth.[2] Fiber posts, along with their esthetic properties, may have a

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better stress distribution than metal posts because of the proximity of their elastic modulus to the dentin structure.[4] The amount of residual structure of the tooth also affects the stress distribution and fracture resistance of the treated teeth. The literature suggests that the presence of 1.5–2 mm of tooth structure improves post conditions.[3,4] However, there is a need for further studies as to how post successes change with the type of material and shape of the post in the absence of ferrule. Thus, the interaction of post types, crown types, and cement types and the presence or absence of ferrule on the mechanical properties of the treated teeth are not clear.[5] Some researchers have suggested posts with high elastic modulus,[6] whereas some researchers have suggested posts with elastic modulus near the dentin.[7] In addition, some studies did not find any difference between the fracture resistance of teeth that were reconstructed with metal posts or fiber posts.[8]

Therefore, the aim of the present study was to investigate the effect of post (glass fiber, casting, titanium, and zirconia) and monolithic zirconia crowns on stress distribution in root canal-treated maxillary central incisors with different amounts of ferrule using finite-element analysis. The null hypothesis was that different ferrule height and post type do not affect the stress pattern within teeth.

MATERIALS AND METHODS

In this experimental study, three-dimensional (3D) virtual models of the maxillary central tooth and its supporting structures, as well as 3D models of posts, crowns, and so on, were separately designed by CATIA V5R21 SP6 (Computer-Aided 3D Interactive Application, Dassault Systems, France).

3D virtual models of maxillary central incisor with normal dimensions (overall length of 25.4 mm, crown length 11 mm, and root length of 14.4 mm) and supporting structures including periodontal ligament (PDL) = 0.25 mm, lamina dura = 0.25 mm, and cortical and trabecular bone = 10 mm were designed, with 1.5 mm of cortical bone.[9]

To design the core model for the glass fiber post, Clearfil Photo Core (Kuraray, Tokyo, Japan) was used. In addition, the cores in the Zirconia post were of the same post and were integrated. Panavia F 2.0, Dual-Polymerized Phosphate-Modified Resin Cement (Kuraray, Tokyo, Japan) resin cement was used in all posts and crowns. The cement space required for the crowns was 0.1 mm.[9] Titanium (ParaPost XH, Coltene, Switzerland, 1.5 mm in diameter), zirconia (Cercon, Dentsply Sirona, USA), glass fiber (White Post DC Glass FGM, Size: DC 2 FGM Produtos, Odontológicos, Brasil), and posts were used in designing the post models.

To simulate the space of gutta-percha placement in the root canal of the central tooth, a cone was inserted with an apical end of 0.4 mm in diameter and coronal end of 2.4 mm in diameter. The gutta-percha removal step was then performed to incorporate the post space. The prepared root space for post in all specimens was 11 mm (from tooth cemento-enamel junction [CEJ]) and residual gutta-percha was 4 mm. All posts were designed to accommodate cement space within the root at least 0.2 mm around it.[9] In models with prefabricated posts, the coronal portion of the post was embedded in the composite core.

The design of the prepared tooth model was as follows , the finish line was prepared as a radial shoulder design with 1 mm in width and incisal edge reduced 2 mm with a linguogingival slope then all angles were rounded. The width of radial shoulder margin was 1 mm on the lingual side of all ceramics. In all models, a contra bevel with a 45° angle was created on the ferrule to create the ferrule effect in the core. In the all models, different ferrule heights (no ferrule and 2-mm ferrule) were designed. Eventually, all the separate models were assembled in the assembly environment, and the integrated models were created. Since the size and number of elements are very effective in the accuracy and precision of the results, meshed was performed by the operator and nonautomically to adjust the parameters within the acceptable software range. Elements were considered smaller in more important areas in terms of the amount and distribution of stress. This will increase the accuracy of the results. The elements used were solid tetrahedral. At the end of meshed, each model was tested for its validity, convergence test was performed, and the optimal meshed model was selected for each model. The final models had 227,833 and 41,004 (titanium post), 232,199 and 41,701 (zirconia and casting posts), and 225,073 and 405,127 (glass fiber post) elements and nodes, respectively. The physical properties of the materials including the elasticity coefficient and the Poisson's coefficient were entered into the software according to the values reported in the majority of valid articles [Table 1]. It is noteworthy that PDL

Table 1: Physical properties of isotropic materials used in modeling

Material	Elasticity coefficient GPa (E)	Poisson's coefficient (υ)	Reference number
Dentin	18.6	0.31	[10]
Enamel	80	0.30	[11]
Pulp	0.002	0.45	[11]
Cortical bone	13.7	0.30	[10]
Spongy bone or trabecular bone	1.37	0.30	[10]
PDL*	0.0689	0.45	[10]
Panavia F2.0/ED Primer II	16.8	0.30	[12]
Gutta-percha	0.14	0.45	[13]
Zirconium oxide ceramic post (Cercon)	210	0.30	[14]
Zirconia monolithic (Cercon)	210	0.30	[14]
Composite resin core	15.8	0.24	[15]
Ni-Cr alloy	200	0.33	[10,16]
Titanium	110	0.35	[16]

*PDL: Periodontal ligament

exhibits nonlinear response when it enters force. However, studies have shown that stress distribution in linear or nonlinear PDL models is very small. Dentin also exhibits anisotropic material behavior, but its elasticity coefficient varies narrowly in different directions due to the force applied.[9] Based on the above considerations, all materials in the study were considered linear and isotopic, except for glass fiber posts that have orthotropic properties [Table 2].[3] The displacement of all nodes in the cortical and trabecular bone base and the displacement of the mesiodistal nodes of the outer wall of the bone were restricted. Contact between all components was also considered to be fully bonded.[9] A static force of 100 N was applied to the middle third of the palatal surface of the tooth with an angle of 135° to the long axis of the tooth (angle of 45° to the horizontal plane).[4,15] The force was applied to a surface of 6.2-mm square. After entering all the data collected and the models designed in the simulation software through Metaphysics (Comsol, Inc., Sweden) finite-element analysis, the maximum stress of von Mises in each component of the model and their stress distribution were investigated.[4]

RESULTS

The highest stress was observed in all posts in the middle third of them. Furthermore, in zirconia and casting posts, stress concentration was observed at the palatal side of the post and core junction site. Titanium posts also showed stress concentration at the palatal side of composite core–post junction and at the post end at the buccal side. However, in casting and zirconia post, stress concentration was equally observed in the buccal and palatal sides [Figure 1]. As shown in Figure 2, the stress concentration in the tooth assemblage is approximately at the border of middle and coronal third of tooth, and then at the crown/cement interface. However, at the glass fiber post, stress concentration occurred in the crown area and later in the CEJ region of the buccal side of the tooth. In addition, in titanium post, the stress concentration was observed equally in the crown area and buccal side of the posts [Figure 3]. Compared with root dentin regardless of post type, the results showed that the maximum stress was in the one-third of the coronal area and then in the 0-mm ferrule content, the stress was >2 mm ferrule content. The highest and lowest stresses were observed in crown, respectively, with titanium posts and zirconia posts [Table 3].

DISCUSSION

Based on these results, the null hypothesis that the type of post and ferrule heights would not affect the stress distribution for post and core restored teeth was rejected. In this study, we applied von Mises stress (VMS) stress to investigate the stress distribution. As we know, VMS shows how energy is transmitted within the structure of the body and shows the location of high stress without specifying the compressive or tensile nature of the stress.[4] In our study, stress concentration was observed in the middle-third at the buccal half of all posts and in interference with root dentin. However, the stress distribution in the glass fiber was better. This result is in line with the studies of Verri *et al*.[10] and Eraslan *et al*.[17] In our study, the stress between the zirconia and casting posts has not much difference.

Marghalani *et al.*[14] and Bittner *et al.*[18] reported that there was no difference between the zirconia and gold post and core stress distribution. Metal posts and cores, because of their dark color, create shadows around the gingival third of ceramic restorations and gingival margins, so making the result not esthetically pleasing. In the case of casting posts and cores, it is best to use warm-colored alloys. Gold posts and cores should be used under ceramic restoration because of their yellowish hue.[14,18] Therefore, it is suggested that zirconia posts and cores be used instead of Ni-Cr casting posts and cores when full ceramic restorations are used and esthetics is desired.[14] One of the disadvantages of using zirconia post and core is its failure to succeed. Some studies have suggested that nonadhesive cements such as zinc phosphate could be used to cement zirconia posts and core. Because the bonding of adhesive cements to zirconia is still challenging and the likelihood of using ultrasonic scaler to remove zinc phosphate cement is higher than that of resin cements.[14] In the present study, when the glass fiber was used, the stress in the dentine was higher than that of the other three posts. However, Eraslan *et al.*[17] reported that stress in zirconia posts in root dentin was slightly higher than that in glass fibers. However, Singh *et al.*[19] reported that the stress in dentine when using carbon fiber posts was slightly higher than that of titanium posts. However, they performed their study on the second premolar tooth. Eskitaşcioğlu *et al.*[20] observed that in casting post and core, stress transfer to supporting structures is low despite accumulation of stress within the post and core. However, in polyethylene woven fiber posts, the stress on the post and core is transferred to the surrounding structures and the tooth, while stress within the post system is low. They conclude that this feature is not suitable for teeth and support structures. In a study by Mahmoudi *et al.*,[16] the authors reported that carbon and glass fiber posts showed the highest tensile stress in dentin compared to the Ni-Cr, gold and titanium posts. Durmuş and Oyar[11] reported that as the elasticity coefficient increased, the amount of stress decreased in the root so that the least stress was when using Ni-Cr casting post and core and the highest stress was when using carbon fiber post with composite core. Asmussen *et al.*[7] reported that

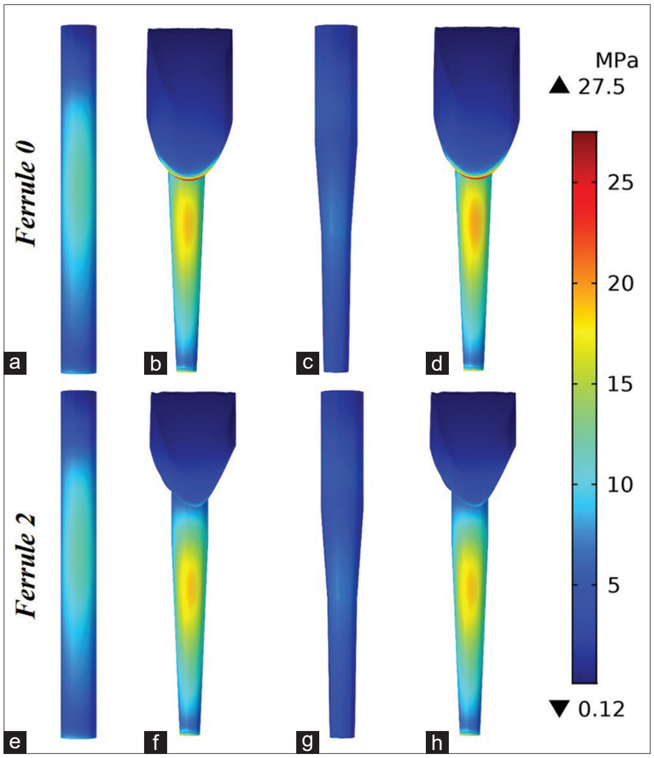

Figure 1: von Mises stress tension pattern at the study sites after the 100 N force input, (a and e) titanium post, (b and f) casting post and core, (c and g) fiberglass post, (d and h) zirconium post and core.

Table 2: Elastic properties of orthotropic materials (glass fiber post)

Elasticity coefficient GPa (E)	Poisson's coefficient (υ)	Shear modulus (G)
X=37	*Xy*=0.27	*Gxy*=3.1
Y=9.5	*Xz*=0.34	*Gxz*=3.5
Z=9.5	*Yz*=0.27	*Gyz*=3.1

Table 3: Maximum von Mises stress values in MPa

Post	Core	Crown	Ferrule	Root dentin	Post cement	Crown cement	Crown
Titanium: 11.959	Composite: 9.952	Zirconia	0	26.058	11.959	21.637	32.804
Titanium: 11.941	Composite: 9.063		2	25.591	11.941	24.241	35.917
Glass fiber: 11.941	Composite: 5.831	Zirconia	0	27.217	6.885	23.200	35.624
Glass fiber: 6.898	Composite: 3.481		2	27.376	6.898	23.441	34.281
Zirconia: 27.512	Zirconia	Zirconia	0	27.414	20.672	26.955	29.890
Zirconia: 20.672			2	23.513	20.852	20.127	29.821
Casting Ni-Cr: 26.746	Ni-Cr	Zirconia	0	26.650	20.313	26.186	30.100
Casting Ni-Cr: 20.127			2	23.680	20.127	20.265	30.023

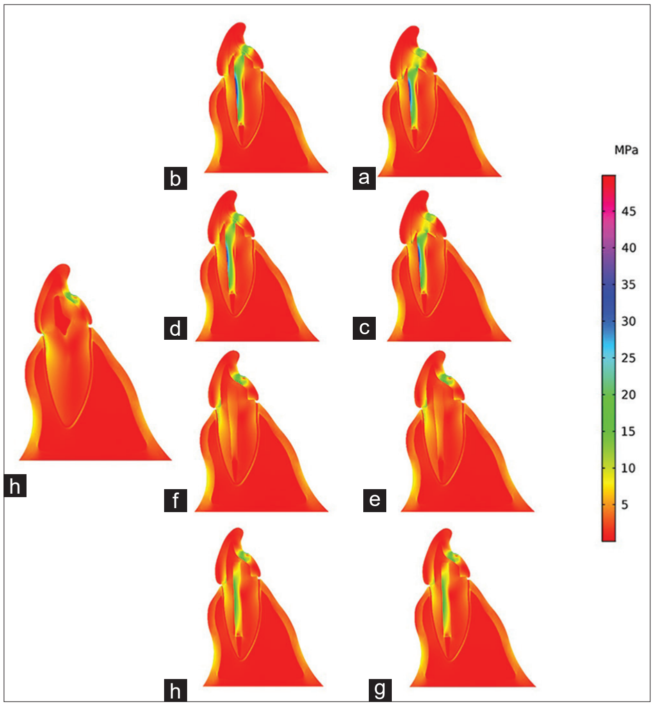

Figure 2: von Mises stress distribution profile in the models studied after applying 100 N force, (a) zirconia post and core with 0-mm ferrule, (b) zirconia post and core with 2-mm ferrule, (c) casting post and cores with 0-mm ferrule (d) casting post and core with 2-mm ferrule (e) glass fiber post and composite core with 0-mm ferrule, (f) glass fiber post and composite core with 2-mm ferrule, (g) titanium post and composite core with 0-mm ferrule, (h) titanium post and composite core with 2-mm ferrule, (i) natural tooth.

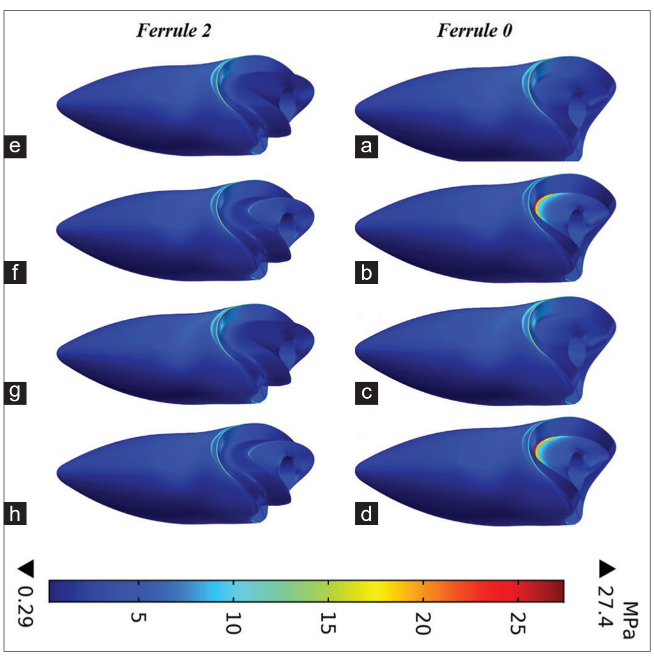

Figure 3: von Mises stress distribution profile among different posts in root dentin, (a and e) titanium post, (b and f) casting post and core, (c and g) fiberglass post, (d and h) zirconium post and core.

increased elastic modulus at the posts reduced stress in dentin. This finding is also consistent with the results of cyclic loading and finite-element method experiments.[20] To achieve optimum results, dental posts must have similar physical properties to dentin and should be bonded to, should be biocompatible with the oral environment, must be capable of absorbing shock, and should transfer limited amounts of stress to the remaining tooth structure.[21] Low elasticity coefficient in the post causes more stress to be transferred to the surrounding dentin, but the stress values remain favorable for the post. Whereas posts with high elasticity coefficients absorb more stress and transfer less of it to root dentin.[11] Accordingly, studies by Balkaya and Birdal[22] and Asmussen *et al*.[7] have suggested that teeth restored with casting posts have a higher fracture resistance than teeth restored with glass fiber posts. In the prefabricated posts of the present study, their core was made of resin composite; although it reduced stress concentration in the dentin–post interface, it increased stress concentration in the cervical area of the tooth. Another point is that in the titanium post, there is stress in the cervical area of the tooth due to the composite core. Furthermore, the accumulation of stress in the cervical area of the tooth reconstructed with glass fiber was greater in comparison between the titanium posts and the glass fibers. Whereas in models with specific post and core, stress accumulation was not in the cervical area of the tooth, but it was observed in the dentin–post interface. These findings are in line with the study by Pierrisnard *et al*.[23] They conclude that composite core with Ni-Cr posts causes more stress in the cervical area when compared to casting posts. In the study by Nokar *et al*.,[24] stress accumulation in cervical area of dental models using fiberglass posts and composite core with all-ceramic restorations was higher when compared to that in zirconia post and core models. This conclusion may be connected with the greater flexibility of the fiber posts and composite core when compared to the zirconia and casting posts.

When the root dentin was examined, it was found that in different models, stress accumulation had occurred in the coronal third of the root, approximately in the vicinity of the alveolar crest. There are several studies that believe cervical area of the root as a site of stress accumulation.[10,16,17,24] Perhaps, this is because of different materials with different elastic properties have come together in this section. In the present study, the maximum VMS in the root dentin without ferrule was more than 2-mm ferrule. However, this was not the case with glass fiber posts. In addition, when the ferrule was 0, the stress accumulation at the buccal edges of the casting and zirconia cores was quite evident, which was clearly transferred to the cervical dentine of the root. In root dentin with 0 ferrule, the highest stress was observed with zirconia post and core and fiberglass. In the glass fiber post, ferrule had no effect on the stress in the root dentin. In fact, casting, zirconia, and titanium posts create less stress when compared to glass fibers in root dentin. Savychuk *et al*.[25] concluded that ferrule had an effect on dentin stress by the type of tooth. Lateral incisors with ferrule lead to increased tensile stress in dentin. However, in the mandibular canine teeth, the opposite was the case. They attributed this phenomenon to the reduced width of the chamfer margin and the ferrule thickness of the lateral tooth due to the narrow buccolingual and mesiodistal dimensions of the tooth. The presence or absence of ferrule in different studies has led to different results.[7,26,27] However, in our study and other studies,[4,17,25] the presence of ferrule reduced stress in the root dentin. Ferrule reduces the tensile and compressive stresses on the palatal side of the middle-third of the root and also reduces the rotational torque of the crown. In addition, it inhibits labial tilting and distal rotation and has anti-rotational effect. In general, it can be said that it results in mechanical resistance of the post and core and the crown against labial displacement and axial rotation. It also reduces compressive stress in the root canal walls and dentin of the labial region.[27,28]

CONCLUSION

Considering the limitations of this study, the following can be mentioned:

1. Prefabricated posts (titanium and glass fiber) and composite core lead to high stress in the cervical part of the tooth
2. The stress distribution of the casting post was not much different from that of the zirconia post. In cases where esthetic is an important issue, zirconia posts can be used
3. Glass fiber posts cause more stress in the root dentin
4. Type of post material has a great impact on stress concentration. The higher the elasticity coefficient, the less the stress on the root of the tooth.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Rajambigai A, Kumar A, Sabarinathan, Raja R. Comparison of stress distribution in a maxillary central incisor restored with two prefabricated post systems with and without ferrule using finite element method. J Clin Diagn Res 2016;10:ZC52-5.
2. Bacchi A, Dos Santos MB, Pimentel MJ, Caetano CR, Sinhoreti MA, Consani RL. Influence of post-thickness and material on the fracture strength of teeth with reduced coronal structure. J Conserv Dent 2013;16:139-43.
3. Bacchi A, Caldas RA, Schmidt D, Detoni M, Matheus Albino Souza, Cecchin D, *et al*. Fracture strength and stress distribution in premolars restored with cast post-and-cores or glass-fiber posts considering the influence of ferule. Biomed Res Int 2019;2019:2196519.
4. 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.
5. Al-Omiri MK, Mahmoud AA, Rayyan MR, Abu-Hammad O. Fracture resistance of teeth restored with post-retained restorations: An overview. J Endod 2010;36:1439-49.
6. 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.
7. Asmussen E, Peutzfeldt A, Sahafi A. Finite element analysis of stresses in endodontically treated, dowel-restored teeth. J Prosthet Dent 2005;94:321-9.
8. Hu YH, Pang LC, Hsu CC, Lau YH. Fracture resistance of endodontically treated anterior teeth restored with four post-and-core systems. Quintessence Int 2003;34:349-53.
9. González-Lluch C, Pérez-González A, Sancho-Bru JL, Rodríguez-Cervantes PJ. Mechanical performance of endodontic restorations with prefabricated posts: Sensitivity analysis of parameters with a 3D finite element model. Comput Methods Biomech Biomed Engin 2014;17:1108-18.
10. 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.
11. 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.
12. Zicari F, Van Meerbeek B, Scotti R, Naert I. Effect of fibre post length and adhesive strategy on fracture resistance of endodontically treated teeth after fatigue loading. J Dent 2012;40:312-21.
13. Chen D, Wang N, Gao Y, Shao L, Deng B. A 3-dimensional finite element analysis of the restoration of the maxillary canine with a complex zirconia post system. J Prosthet Dent 2014;112:1406-15.

14. Marghalani TY, Hamed MT, Awad MA, Naguib GH, Elragi AF. Three-dimensional finite element analysis of custom-made ceramic dowel made using CAD/CAM technology. J Prosthodont 2012;21:440-50.
15. Maroli A, Hoelcher KAL, Reginato VF, Spazzin AO, Caldas RA, Bacchi A. Biomechanical behavior of teeth without remaining coronal structure restored with different post designs and materials. Mater Sci Eng C Mater Biol Appl 2017;76:839-44.
16. Mahmoudi M, Saidi AR, Amini P, Hashemipour MA. Influence of inhomogeneous dental posts on stress distribution in tooth root and interfaces: Three-dimensional finite element analysis. J Prosthet Dent 2017;118:742-51.
17. Eraslan O, Aykent F, Yücel MT, Akman S. The finite element analysis of the effect of ferrule height on stress distribution at post-and-core-restored all-ceramic anterior crowns. Clin Oral Investig 2009;13:223-7.
18. Bittner N, Hill T, Randi A. Evaluation of a one-piece milled zirconia post and core with different post-and-core systems: An *in vitro* study. J Prosthet Dent 2010;103:369-79.
19. Singh SV, Bhat M, Gupta S, Sharma D, Satija H, Sharma S. Stress distribution of endodontically treated teeth with titanium alloy post and carbon fiber post with different alveolar bone height: A three-dimensional finite element analysis. Eur J Dent 2015;9:428-32.
20. Eskitaşcioğlu G, Belli S, Kalkan M. Evaluation of two post core systems using two different methods (fracture strength test and a finite elemental stress analysis). J Endod 2002;28:629-33.
21. Fernandes AS, Shetty S, Coutinho I. Factors determining post selection: A literature review. J Prosthet Dent 2003;90:556-62.
22. Balkaya MC, Birdal IS. Effect of resin-based materials on fracture resistance of endodontically treated thin-walled teeth. J Prosthet Dent 2013;109:296-303.
23. Pierrisnard L, Bohin F, Renault P, Barquins M. Corono-radicular reconstruction of pulpless teeth: A mechanical study using finite element analysis. J Prosthet Dent 2002;88:442-8.
24. Nokar S, Bahrami M, Mostafavi AS. Comparative evaluation of the effect of different post and core materials on stress distribution in radicular dentin by three-dimensional finite element analysis. J Dent (Tehran) 2018;15:69-78.
25. 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.
26. Batista VE, Bitencourt SB, Bastos NA, Pellizzer EP, Goiato MC, Dos Santos DM. Influence of the ferrule effect on the failure of fiber-reinforced composite post-and-core restorations: A systematic review and meta-analysis. J Prosthet Dent 2020;123:239-45.
27. Ichim I, Kuzmanovic DV, Love RM. A finite element analysis of ferrule design on restoration resistance and distribution of stress within a root. Int Endod J 2006;39:443-52.
28. Pereira JR, Neto Tde M, Porto Vde C, Pegoraro LF, do Valle AL. Influence of the remaining coronal structure on the resistance of teeth with intraradicular retainer. Braz Dent J 2005;16:197-201.