Title –

Biomechanical Effect of post materialswithin endodontically treated mandibular second premolars with different ferrule configurations : A 3D finite element analysis

Author name
1. Dr Shahinwaz Mulani
MDS
PhD Scholar
Department of Prosthodontics
Sharad Pawar Dental college and hospital, Wardha, DMIHER university Nagpur

2. Dr Surekha Dubey-Godbole
PhD , MDS
Professor
Department of Prosthodontics
Sharad Pawar Dental college and hospital, DMIHER UNIVERSITY Nagpur

Corresponding Author: Dr Surekha Dubey-Godbole

Statement of problem. Earlier research has not determined which post material favors best stress dispersal inside the post-core restoration and role of partial ferrule in longitivity of crown prosthesis.

Purpose. The goal of this research was to establish which post material produces the best stress distribution under loading and to evaluate role of partial or complete ferrule in stress distribution within tooth and associated structures.

Material and methods. 3D models of mandibular second premolar were created with the micro CT scan , further meshing with HYPERMESH program to simulate materials used for tooth and associated structure (gold alloy post, glass fiber post) and metal ceramic crowns. The occlusal surface was loaded with 200 N, and von Mises equivalent stress values were determined with the aid of ANSYS 18.1.

Results. The gold-alloy post produces higher stresses than the fibre post. Maximum stresses produced by model number 8 (tooth without ferrule) with both post materials indicating that the ferrule played a positive role in favorable stress distribution.

Conclusion. Stress in the compromised tooth was reduced because to the use of a post material with an elastic modulus close to that of dentine. When it comes to stress distribution, complete or incomplete ferrules play a crucial role.

Clinical Implications When compared to teeth rebuilt with gold alloy posts, glass-fiber posts had significantly superior fracture resistance and post bond strength.

INTRODUCTION

Endodontically treated teeth have a greater propensity to become more fragile as a result of structural loss brought on by caries, previous restorative operations, or endodontic access cavity preparation.[1] A restoration needs to produce retention and resistance in order to protect these teeth from suffering further harm. For a very long time, people have been looking for the best method possible to use when reconstructing teeth that have had endodontic treatment in a way that safeguards the residual dental tissue. The post and core procedure is a common treatment option for teeth that have been structurally compromised.[2]The ferrule effect is characterized by a metal crown collar that wraps around the dentine on all 360 degrees and extends coronally to the shoulder of the preparation.[3] The proposed function of the ferrule is to strengthen the root canal-treated tooth. To get the most out of the ferrule effect, the dentist preparing pulpless teeth for full crowns should keep as much of the coronal tooth structure as possible. This is done by putting a ferrule into the tooth preparation design. For this ferrule effect, a minimum height of 1.5 to 2 mm of the entire tooth structure above the crown edge seems to be a good rule of thumb for the whole tooth preparation. The ferrule strengthens the treated tooth by spreading forces over the remaining tooth structure.[3–6]That makes it less likely that the root or the bond between the post/core or crown and tooth will break. Ferrules have the potential to alter the pattern of root fracture in post/core-restored teeth, shifting it from debonding of the post/core to vertical root fracture in designs without ferrules to oblique or horizontal root fractures in structures with ferrules. In designs without ferrules, the pattern of root fracture in post/core-restored teeth is vertical..[7,8] Since the 1980s, stress analysis has emerged as a topic of interest in the field of dentistry.The "finite element method" is a way to do stress analysis on dental structures. A finite element method is a mathematical tool often used to study complicated and irregular structures.[9]

Dowel post location also affects the biomechanics of these teeth.[10]ome authors claim that the increased frequency of vertical root fractures is linked to the use of metallic dowel posts with a high modulus of elasticity, which focuses loads on the apical root third.Better stress distribution on the remaining tooth structure has been linked to the use of dowel posts, such as glass fibre posts, having a modulus of elasticity equivalent to dentin.However, there is scant data on how ferrule height impacts stress concentration and distribution in tooth reconstructions.[13]Dowels and the type of material should be chosen in relation to the height of the ferrule, however this is not entirely clear.

With the help of a core substance, dentists have been able to restore badly broken teeth using prefabricated post systems..Prefabricated post systems are preferred by many dentists over custom post and cores because they save time, money, and, in certain cases, patient discomfort.[14]Numerous finite element analysis studies have failed to determine which post system is superior for reinforcing a repaired tooth.[15]Posts with a high modulus of elasticity have been recommended by certain writers, while others have argued for a value closer to that of dentin.[1]However, some research has shown that the use of fibre reinforced resin or metal supports does not significantly alter the restored teeth's ability to withstand breakage.[16]

Disagreement has arisen about which post material is best because of not just discrepancies in the outcomes of these research, but also the wide variety of post materials available. The purpose of this research is to use three-dimensional finite element analysis to determine how different post materials affect stress distribution in post-and-core-restored second mandibular premolars with either a full or partial ferrule wall.

MATERIAL AND METHODS

After gaining approval from ethical committees, the present study was carried out at theDepartment of Prosthodontics ,Crown and bridge Dentistry, SPDC, Sawangi (Meghe),Wardha;

A model of a mandibular second premolar was utilised throughout the course of this investigation.The current model was modelled from a CT scan and exported as an.stl file. The stl file format is a mesh format that can be used for analysis with minimal adjustments. The Ansys 18.0 software (Inventor AutoCAD 2010; Autodesk) was used throughout the entirety of the stress distribution analysis that was carried out.

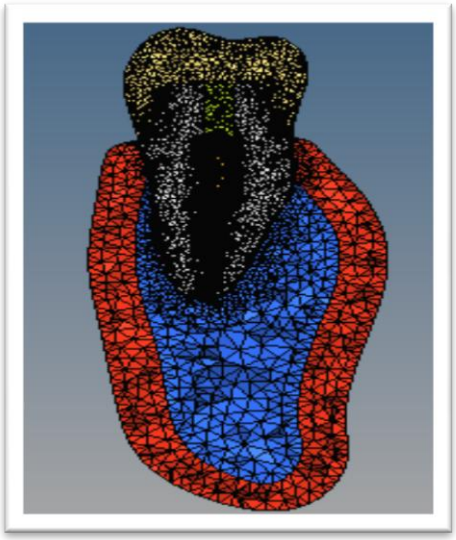

Fig :1 cross sectional view of meshed model of mandibular second premolar

In order to replicate the effects of endodontic restoration on mandibular premolars with varying coronal dentin configurations, eight 3D models were fabricated.

1) Tooth that has an access cavity and a coronal length of 4 mm remaining
2) Tooth with 2-mm complete ferrule (360 degree)
3) Tooth with one walled buccal 2-mm ferrule
4) Tooth with one walled lingual 2-mm ferrule
5) Tooth with two walled buccal-lingual 2-mm ferrule
6) Tooth with one walled proximal2-mm ferrule
7) Tooth with three walled buccal -lingual-mesial 2-mm ferrule
8) Tooth with no ferrule

Each tooth was crafted using a porcelain fused to metal crown with a porcelain thickness of 1.5 mm and a metal thickness of 0.5 mm. The top third of the post area in all models was stuffed with guttapercha. The von Mises stress measurements were evaluated after a simulated load of 200 N was applied the occlusal surface at a 45 degree angle to the vertical axis of the tooth. The models had boundary requirements imposed on them at the exterior surface of the bones, which imposed x, y, and z constraints in all three dimensions. The standard assumption was that all structures were homogenous, isotropic, and linearly elastic. Optimal cohesion between buildings was expected between associated structures of tooth.Table I displays the determined values of the Poisson ratio (n) and the modulus of elasticity (E) for oral tissue and crown material, respectively, from the aforementioned literature.[17,18]To serve as a comparison, a model of a natural tooth was created as well. All of the models' maximal von Mises stresses were compared to those of a genuine tooth and to one another

Material properties

Material	**Elastic modulus (E) (GPa)**	**Poisson ratio (μ)**
Spongy bone[18]	1.37	0.3
Cortical bone[18]	13.7	0.3
Co-Cr alloy (framework)[17]	218	0.33
Feldspathic porcelain (occlusal material)[17]	82.8	0.35
Enamel[18]	84.1	0.20
Dentine[18]	18.6	0.31
Composite resin[17]	16.6	0.24
Gutta parcha[17]	0.7	0.4
Fiber Post[17]	37	0.34

Table 1: Material properties of finite element model compounds.

RESULTS

In response to load of 200N to occlusal surface of tooth, stress distribution analysed..Both numerical analysis and color-coding were used for interpretation. The stress, expressed as the von Mises equivalent, as calculated by the finite element analysis programme (ANSYS 18.1). The maximum von Mises equivalent stress on the restored tooth and surrounding structure was mapped out and researched so that the results could be calculated.The von Mises stress is the total stress at every point in a material. It is often used to predict how likely it is that the material will break. In this study, von Mises stress was used to figure out the risk of putting a post and core in a tooth.

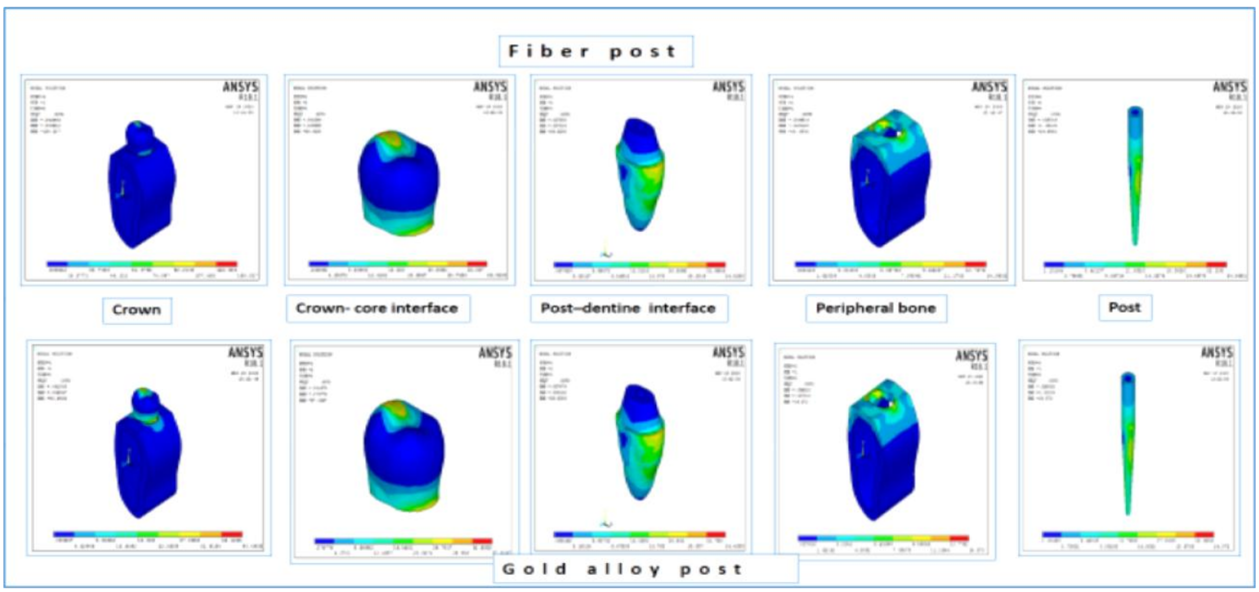

Fig.2 color coded map representing stress distribution

Model no.	Post		Crown-core interface		Post dentine interface		Peripheral bone		Crown	
	FP	GAP	FP	GAP	FP	GAP	FP	GAP	FP	GAP
1	-	-	-	-	-	-	4.19	4.20	33.02	36.92
2	4.232	24.94	6.42	7.17	24.39	25.18	4.16	4.20	42.44	43.24
3	4.230	24.86	12.66	12.57	24.48	25.29	4.16	4.20	40.58	40.64
4	4.234	25.04	16.53	16.13	24.32	25.13	4.16	4.20	47.61	48.55
5	4.228	24.85	9.08	9.17	24.55	25.39	4.17	4.21	42.86	43.73

6	4.232	24.94	22.85	23.08	24.40	25.20	4.16	4.20	45.68	46.53
7	4.232	24.93	7.89	8.271	24.41	25.21	4.16	4.20	40.58	40.64
8	4.232	24.97	16.18	16.58	24.39	25.20	4.17	4.21	47.77	48.69

(FP- Fiber post GAP- Gold Alloy Post)

Table no.2 representing values of stress distribution interms of Von mises

- ***Core-crown interface***

The post material did not influence stresses at the crown core interface. A fibre post has slightly higher stresses than a gold post. Due to the higher stiffness of the gold post, more load is taken by the gold post due to slightly less stress on the crown core interface. Model no.8 produced more than 60% more stress than model no.2, indicating that the ferrule played a positive role.

- ***Center of Post***

The stress distribution picture shows maximum stresses for gold posts compared to fiber posts. This can be mainly attributed to material properties. Generally, stresses are proportional to the elastic modulus of the material.

- ***Post dentine interface***

The gold post has a significant influence because the post dentine interface has higher stresses with a gold post than with a fibre post. An explanation for this may be due to the similar elastic properties of fibre post to dentin. As a result, fibre post is preferable for reducing stress along the post-dentine interface. Lowering the stress on the members can result in increased safety.

- ***Crown***

The table and figure show a minor effect of post material on the crown stresses. However, the gold-alloy post produces higher stresses than the fibre post. Maximum stresses produced by model number 8 with both post materials represent favourable ferrule effect results.

- ***Cortical and spongy bone***

Also, the fibre post stresses on the peripheral bone are decreasing. This can be mainly attributed to the high strength of the gold post compared to the soft fiber post.

According to the findings, the preparation of the ferrule was able to lower the stresses at the dentin as well as those at the interface and cements.In point of fact, the preparation of a ferrule covers a greater length of the post and, as a result, decreases the post's tendency to bend.Taking into account the ferrule effect allowed for a reduction in the strains caused by this reason.Due to the nearly identical modulus of elasticity of dentine and fibre post, fibre post has exhibited more advantageous stress distribution than gold alloy post.

DISCUSSION

In this study, two different post systems were considered when comparing the failure mode of fibre post to gold alloy post-restored teeth. Confirmatory evidence was shown in stress distribution analysis using FEA studies; glass-fiber posts give better biomechanical performance and homogenous stress distribution, with more excellent fracture resistance. Gold alloy's high modulus of elasticity compared to dentine might be responsible for its catastrophic fractures. In contrast, the fibre post gives good biomechanical performance due to the constitution of a homogeneous post, core, cement, and dentine ensemble. Because of this, the tooth, the core, the cement, and the post will all deform in the same way while the tooth is functioning. When this happens, the interface between the core and the dentin or between the dentin and the post-cement breaks down since it is the weakest place. Therefore, post-bond strength loss, core fracture, post fracture, or marginal seal loss will occur as the failure mode.

The metal composition of the prefabricated post includes gold alloy, nickel-chrome stainless steel, titanium alloy or pure titanium. Compared to custom-fabricated cast posts, chair-side time spent with prefabricated metal posts is significantly reduced because only one visit is necessary to finish the foundation. In addition, there is no need for any laboratory procedures. Prefabricated metal posts, on the other hand, have a few drawbacks, such as the fact that the root canal is made to fit the post rather than the post being made to fit the root canal. This is one of the disadvantages of using prefabricated metal posts.[6] Prefabricated metal posts present an aesthetic challenge after developing aesthetic restorative ceramic materials analogous to custom-fabricated cast posts and cores. The presence of a metal post within a toothdisrupts the natural flow of light through the tooth and may be visible through the root. This effect will be more noticeable in areas of the gingiva with thinner gingival tissue.[6,19,20]

In general, rigid and high-modulus posts, such as metal prefabricated and custom-fabricated posts, can transfer functional stresses to the tooth and root structure, which raises the risk of root fracture.[21,22] While the rigid metallic cast post and core have been linked to irreversible clinical failures like vertical root fractures, prefabricated metal posts, on the other hand, offer some functional improvements but are still linked to a high incidence of catastrophic root fractures. This differs from the rigid metal cast post and core, which have been linked to vertical root fractures.[21,23]

In the 1990s, after introducing fibre-reinforced posts, more interest was shown in these new rivals to metal posts. Over this period, there has been a range of different fiber posts introduced by many manufacturers, and a vast number of studies have been published. Both retrospective and prospective in vivo clinical trials Indicated the superior clinical performance of fiber posts in terms of failure rate and mode.[24–27]

Ferrari et al. (2007) assessed the clinical performance of three types of fiber posts over 7 to 10

years in the same patients as the previously mentioned study. The failure rate ranged between 7% and 10%. Prospective clinical trials also show that putting fibre posts in place may help keep restorations from failing.[25]

Glazer et al. (2000) evaluated the clinical behaviour of 59 fiber post restorations carried out for 47 patients over 45 months. Two failures were recorded after debonding and crown de-cementation without root fracture. [28]In addition, when compared to metal posts, fiber posts had a

higher success rate than metal posts, confirmed in both prospective and retrospective clinical studies.[24,29]

Two issues with this study need to be addressed in follow-up research. To begin, it was assumed throughout this investigation that all materials were homogeneous, isotropic, and linear elastic. The structure of teeth, in fact, is not uniform nor symmetrical. Second, it was expected that the interfaces between components of tooth structure were seamless and precise.
Higher von Mises stress levels are a clear indication of possible failure, therefore this study may assist clinicians choose the optimum post and core material for maximum durability. This is because failure rates increase with increasing von Mises stresses.This experiment was primarily concerned with the mechanical qualities of various post and core combinations utilised for

restorations. Alterations in loading behaviour ought to be looked into in forthcoming clinical research.

CONCLUSIONS

The purpose of this 3D FEA study was to investigate the impact of post material on stress distribution in the post, crown-core interface, post dentine interface, peripheral bone and crown of the mandibular second premolar with different ferrule configurations.

Taking into account the constraints of the current FEA investigation, the following outcomes were reached:

1. The post material has a substantial impact on stress concentration. The stiffness of the post material resulted in eminent stress values in the tooth, post and at the various interfaces.

2. When compared to teeth rebuilt with gold alloy posts, glass-fiber posts had significantly superior fracture resistance and post bond strength.

3. Complete and partial ferrules have been proven to enhance the mechanical properties of restored tooth in comparison to designs without ferrules.

Bibliography

1. de Castro Albuquerque R, Polleto LT de A, Fontana RHBTS, Cimini CA. Stress analysis of an upper central incisor restored with different posts. J Oral Rehabil. 2003 Sep;30(9):936–43.

2. Toparli M, Sasaki S. Finite element analysis of the temperature and thermal stress in a postrestored tooth. J Oral Rehabil. 2003 Sep;30(9):921–6.

3. Sorensen JA, Engelman MJ. Ferrule design and fracture resistance of endodontically treated teeth. J Prosthet Dent [Internet]. 1990 May [cited 2022 May 25];63(5):529–36. Available from: https://linkinghub.elsevier.com/retrieve/pii/002239139090070S

4. Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: A study of endodontically treated teeth. J Prosthet Dent [Internet]. 1984 Jun [cited 2021 Jul 24];51(6):780–4. Available from: https://linkinghub.elsevier.com/retrieve/pii/0022391384903767

5. Tjan AHL, Whang SB. Resistance to root fracture of dowel channels with various thicknesses of buccal dentin walls. J Prosthet Dent [Internet]. 1985 Apr [cited 2021 Jul 24];53(4):496–500. Available from: https://linkinghub.elsevier.com/retrieve/pii/002239138590633X

6. Torbjörner A, Karlsson S, Dr O, Ödman PA. Survival rate and failure characteristics for two post designs. J Prosthet Dent [Internet]. 1995 May [cited 2022 Jun 19];73(5):439–44. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022391305800721

7. Barkhordar RA, Radke R, Abbasi J. Effect of metal collars on resistance of endodontically treated teeth to root fracture. J Prosthet Dent [Internet]. 1989 Jun [cited 2021 Jul 23];61(6):676–8. Available from: https://linkinghub.elsevier.com/retrieve/pii/S002239138980040X

8. Ng YL, Glennon JP, Setchell DJ, Gulabivala K. Prevalence of and factors affecting post-obturation pain in patients undergoing root canal treatment. IntEndod J [Internet]. 2004 Jun [cited 2022 Jun 19];37(6):381–91. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2591.2004.00820.x

9. Geng JP, Tan KBC, Liu GR. Application of finite element analysis in implant dentistry: A review of the literature. J Prosthet Dent [Internet]. 2001 Jun [cited 2022 Jun 19];85(6):585–98. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022391301574314

10. 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 [Internet]. 2009 Mar 1 [cited 2022 Dec 25];34(2):223–9. Available from: https://meridian.allenpress.com/operative-dentistry/article/34/2/223/107322/Influence-of-Post-and-Resin-Cement-on-Stress

11. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, Part II (Evaluation of fatigue behavior, interfaces, and in vivo studies). Quintessence IntBerlGer 1985. 2008 Feb;39(2):117–29.

12. Meira JBC, Espósito COM, Quitero MFZ, Poiate IAVP, Pfeifer CSC, Tanaka CB, et al. Elastic modulus of posts and the risk of root fracture. Dent TraumatolOffPublIntAssoc Dent Traumatol. 2009 Aug;25(4):394–8.

13. 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 [Internet]. 2009 Jun [cited 2022 Oct 8];13(2):223–7. Available from: http://link.springer.com/10.1007/s00784-008-0217-5

14. Newman MP, Yaman P, Dennison J, Rafter M, Billy E. Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent [Internet]. 2003 Apr [cited 2022 Dec 25];89(4):360–7. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022391303000076

15. Asmussen E, Peutzfeldt A, Sahafi A. Finite element analysis of stresses in endodontically treated, dowel-restored teeth. J Prosthet Dent. 2005 Oct;94(4):321–9.

16. Cormier CJ, Burns DR, Moon P. In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. J Prosthodont Off J Am CollProsthodont. 2001 Mar;10(1):26–36.

17. Barjau-Escribano A, Sancho-Bru JL, Forner-Navarro L, Rodríguez-Cervantes PJ, Pérez-González A, Sánchez-Marín FT. Influence of Prefabricated Post Material on Restored Teeth: Fracture Strength and Stress Distribution. Oper Dent [Internet]. 2006 Jan 1 [cited 2022 Nov 2];31(1):47–54. Available from: https://meridian.allenpress.com/operative-dentistry/article/31/1/47/107250/Influence-of-Prefabricated-Post-Material-on

18. Farah JW, Craig RG, Meroueh KA. Finite element analysis of a mandibular model. J Oral Rehabil [Internet]. 1988 Nov [cited 2022 Nov 2];15(6):615–24. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2842.1988.tb00199.x

19. Cheung W. A review of the management of endodontically treated teeth. Post, core and the final restoration. J Am Dent Assoc 1939. 2005 May;136(5):611–9.

20. Meyenberg KH, Lüthy H, Schärer P. Zirconia Posts: A New All-Ceramic Concept for Nonvital Abutment Teeth. J EsthetRestor Dent [Internet]. 1995 Mar [cited 2022 Nov 6];7(2):73–80. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1708-8240.1995.tb00565.x

21. Arvidson K, Wróblewski R. Migration of metallic ions from screwposts into dentin and surrounding tissues. Scand J Dent Res. 1978 May;86(3):200–5.

22. Sorensen JA, Martinoff JT. Clinically significant factors in dowel design. J Prosthet Dent. 1984 Jul;52(1):28–35.

23. Standlee JP, Caputo AA. The retentive and stress distributing properties of split threaded endodontic dowels. J Prosthet Dent. 1992 Sep;68(3):436–42.

24. Cagidiaco MC, Goracci C, Garcia-Godoy F, Ferrari M. Clinical studies of fiber posts: a literature review. Int J Prosthodont. 2008 Aug;21(4):328–36.

25. Ferrari M, Cagidiaco MC, Grandini S, De Sanctis M, Goracci C. Post Placement Affects Survival of Endodontically Treated Premolars. J Dent Res [Internet]. 2007 Aug [cited 2022 Oct 8];86(8):729–34. Available from: http://journals.sagepub.com/doi/10.1177/154405910708600808

26. Fredriksson M, Astbäck J, Pamenius M, Arvidson K. A retrospective study of 236 patients with teeth restored by carbon fiber-reinforced epoxy resin posts. J Prosthet Dent. 1998 Aug;80(2):151–7.

27. Mannocci F, Ferrari M, Watson TF. Microleakage of endodontically treated teeth restored with fiber posts and composite cores after cyclic loading: A confocal microscopic study. J Prosthet Dent [Internet]. 2001 Mar [cited 2022 Oct 10];85(3):284–91. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0022391301961712

28. Glazer B. Restoration of endodontically treated teeth with carbon fibre posts--a prospective study. J Can Dent Assoc. 2000 Dec;66(11):613–8.

29. King PA, Setchell DJ, Rees JS. Clinical evaluation of a carbon fibre reinforced carbon endodontic post. J Oral Rehabil. 2003 Aug;30(8):785–9.