International Journal of Biomedicine 14(4) (2024) 691-695
http://dx.doi.org/10.21103/Article14(4)_OA25

INTERNATIONAL JOURNAL OF BIOMEDICINE

ORIGINAL ARTICLE

Dentistry

Comparison of the Fracture Strength and Fracture Mode of Endodontically Treated Maxillary Incisors Restored with Cast Metal and Glass Fiber Post

Tetore Olloni[1], Kujtim Shala[1*]

[1]Department of Prosthodontics, Faculty of Dentistry, University of Prishtina "Hasan Prishtina" Prishtina, Republic of Kosovo

Abstract

Background: Restoration of endodontically treated teeth with post and core systems is integral to restorative dental practice. Endodontically treated teeth are more susceptible to biological and mechanical failure and exhibit a higher fracture risk than vital teeth. The purpose of this study was to compare the fracture strength (FS) of endodontically treated maxillary incisors restored with cast metal post (CMP) and glass fiber post (GFP) with composite core using a Universal Testing Machine (UTM) and evaluate their fracture mode (FM).

Methods and Results: Sixty human maxillary incisors were extracted for periodontal reasons and selected based on their similar root canal morphology. All study teeth were randomly divided into two groups. Group 1 (n=30) was restored with CMP, and Group 2 was restored with GFP. The posts were luted with the adhesive resin cement Speedcem Plus. Prepared samples were subjected to a compressive load using a UTM (H001B:1000kN, Matest, Italy). Loads were applied at an angle of 135° in the middle of the lingual surfaces of the samples at a crosshead speed of 0.5 mm/min. Fracture loads and modes were recorded. The maximum load necessary to fracture for each specimen was measured in Newtons (N). Fractures were classified as restorable in the incisal third of the root and catastrophic if located apical to that point. The median FS of Groups 1 and 2 were 161.87±1.36N and 1220.83±2.04N. A comparative analysis of the FS values between CMP and GFP groups showed that the influence of post type on FS was significant (*P*=0.000). Group 2 exhibited higher strength values. All catastrophic fractures (n=5) belonged to Group 1. In Group 1, 40% of fractures were in the apical third and middle of roots. In Group 2, all fractures occurred in the incisal third of the roots.

Conclusion: The results have clinical implications for the selection of materials in dental practices, particularly in contexts where the material's mechanical strength is a critical factor in clinical outcomes.**(International Journal of Biomedicine. 2024;14(4):691-695.)**

Keywords: endodontically treated incisors • fracture strength • glass fiber post • cast metal post

For citation: Olloni T, Shala K. Comparison of the Fracture Strength and Fracture Mode of Endodontically Treated Maxillary Incisors Restored with Cast Metal and Glass Fiber Post. International Journal of Biomedicine. 2024;14(4):691-695. doi:10.21103/Article14(4)_OA25

Abbreviations

CMP, cast metal post, **ETI**, endodontically treated incisors; **FS**, fracture strength; **FM**, fracture mode; **GFP**, glass fiber post.

Introduction

The important role of anterior teeth in esthetics and function makes these teeth a significant component in dentition. Traumatic accidents are common in maxillary anterior teeth. Trauma and caries occurring before root completion can lead the tooth to a degenerative cycle, which eventually causes necrosis and the creation of a large flared root canal. Root canal therapy is often successfully done, but compromised dentinal walls, especially in the cervical area, make these teeth susceptible to fracture.[1] The fracture strength (FS) of endodontically treated teeth highly depends on the remaining dentine thickness around post and core systems.[2] Flared root canals are more susceptible to fracture as the remaining walls are thin, and restoring these teeth

***Corresponding author**: Kujtim Shala, Department of Prosthodontics, Faculty of Dentistry, University of Prishtina "Hasan Prishtina," Pristina, Kosovo. E-mail: kujtim.shala@uni-pr.edu*

requires techniques that will not compromise the integrity of the remaining radicular tooth structure. As a rule, endodontically treated teeth are weaker than intact teeth due to loss of tooth structure, reduction in tooth flexural strength,[3] change in the collagen crosslinks and reduction in moisture content, and tooth dehydration.[4] Canal enlargement and cavity preparation can reduce the stiffness of the teeth,[5] and brittleness could be the final result of a root canal treatment.[6] When most of the coronal structure of endodontically treated teeth has been lost, using post and core systems seems mandatory.[7] The treatment plan and post-placement decision should be based on three aspects: position of the tooth in the arch,[8] amount of remaining tooth structure,[9] and esthetic requirements.[10,11] The main goal of the post-placement is to provide optimum retention for the core, which eventually supports the crown.[12-14] The introduction of materials that can bond to dentine has created an alternative for reconstructing and rehabilitating root canals severely damaged by caries, trauma, congenital disorders, or internal resorption.[1,15-17] The choice of an appropriate restoration for endodontically treated teeth is guided by tooth structure, root morphology, strength, and esthetics.

The CMP has been regarded as the "gold standard" in post-restorations due to its superior success rate.[18,19] However, alternatives to CMP have been developed. All post and core systems produce stresses within the root dentin and cause fracture or bending of the post, root fracture, loss of retention, or core fracture. Non-tooth-colored posts decrease the depth of the coronal translucency, and the post may shine through in the cervical region, thus altering the appearance of thin gingival tissue. Another problem with CMP relates to the difference in modulus of elasticity between dentine and these posts. This difference results in unequal distribution of strains on the dentin surface and a tendency to create stress concentration areas.[8,20]

Nowadays, different tooth-colored post systems, like GFP, have been introduced to restorative dentistry. The use of GFP simplifies the restorative procedures because all steps can be completed chairside.[8] These posts have improved the esthetics of teeth restored with full ceramic restoration. It is unclear how these new systems can withstand functional or parafunctional forces in the mouth.[21] The present study evaluated the FS of ETI restored with CMP and GFP.

Materials and Methods

Sixty human maxillary canines with matured apices were obtained directly after extraction, immediately placed in 5.25% NaOCl for 5 min, and stored in 0.9% saline solution at room temperature (20-23°C) during the study, less than 6 months after extraction. Teeth with cracks, caries, restorations, and roots shorter than 10mm were discarded. Selected samples should have an inciso-apical length between 15 and 18 mm.

This study was conducted in the Prosthodontics Department at the University Dentistry Clinical Center of Kosovo. All teeth were decoronated 3 mm coronal to the most incisal point of the proximal cementoenamel junction (CEJ) under continuous water cooling with a diamond bur in a highspeed headpiece. Access cavity preparation was performed, and apical patency was maintained using a size #10 K-file (Dentsply Maillefer, USA). The root canals were instrumented using a rotary system (Pro Taper files S1, S2, F1, F2, F3) (Dentsply, Maillefer, USA). The canals were irrigated with 2% NaOCl and 17% Ethylenediamine Tetraacetic Acid (EDTA) (Glyde, Maillefer, Dentsply, USA) and dried with paper points (Protaper Paper Points, Maillefer, Dentsply, USA). The canals were filled with gutta-percha (Protaper Guttapercha Points, Maillefer, Dentsply, USA) and endodontic sealer (AH Plus; Dentsply USA) with cold lateral condensation. The access cavity was filled with temporary restorative material (Cavit, 3M, ESPE, Seefeld, Germany).

All teeth received 1.5 mm shoulder finishing line preparations using a regular and fine tapered bur in a high-speed headpiece, including a 1-2 mm ferrule.

Post spaces were prepared by removing gutta-percha, leaving 4 mm of root canal filling in the apical area. Post space preparation for all teeth was initiated 7 days after obturation by the sequential use of Gates-Glidden and Pesso reamers size #1 up to size #4. The length of the post was standardized using a digital caliper. Different post preparations were standardized using a #5 reamer (Largo; Dentsply Ind. e Com., Ltda.).

All study teeth selected based on their similar root canal morphology were randomly divided into two groups. In Group 1, a custom cast dowel core was prepared using a direct technique.[5] Acrylic resin (Duralay, Reliance Dental, worth, Il) was used to fabricate the models. The core characteristics, such as length and tapering, were similar in the two groups. The CMPs were luted with an adhesive resin cement Speedcem Plus (Ivoclar, Vivadent, Lichtenstein). The cement was spun into the canals using a Lentulo spiral (Lentulo; Dentsply Maillefer, Ballaigues, Switzerland). Group 2 was restored with GFP and composite to create anchorage for the composite core. In Group 2, the post space was cleaned and dried with ethyl alcohol, etched with 37% phosphoric acid for 10 seconds, washed for 10 seconds with water, and then dried by air spray and paper point #40. Bonding liquid (single bond, 3M ESPE, USA) was applied to the canal by microbrush. The excess bonding liquid was removed with a paper point. Posts were also luted with adhesive resin cement Speedcem Plus (Ivoclar, Vivadent, Lichtenstein). The composite material (3M, ESPE, USA) was used as core material to yield an abutment to a height of 4 mm measured from the buccal shoulder. The convergence of approximately 6 degrees was prepared for abutments. A 0.5 mm bevel was prepared around the teeth to maximize the ferrule effect.

Impressions were made for all teeth using vinyl polysiloxane impression material (Elite by Zhermarck). Full ceramic crowns were prepared and luted using type-1 glass-ionomer cement (GC Fuji PLUS). To simulate a periodontal ligament, all roots were covered with a 0.1 mm thick layer of auto polymerizing vinylpolysiloxane impression material (Speedex Light Body, Coltene Whaledent, Altstatten, Switzerland) and embedded parallel to their vertical axis in acrylic blocks.

<u>Fracture Strength Test</u>

Prepared samples were subjected to a compressive load using a UTM (H001B:1000kN, Matest, Italy). Loads were applied at an angle of 135° in the middle of the lingual surfaces of the samples at a crosshead speed of 0.5mm/min. Fracture loads and modes were recorded. The maximum load necessary to fracture for each specimen was measured in Newtons (N).

Fractures were classified as restorable in the incisal third of the root and catastrophic if located apical to that point. As some of the samples were lost due to FM, they did not allow teeth to be removed from the acryl. Twenty teeth (10 from each group) were used to evaluate the FM.

Figures 1-4 show the technical features of our *in vitro* study.

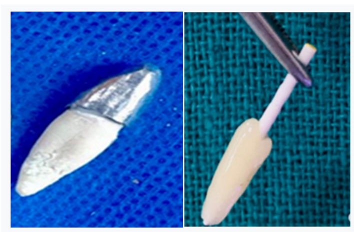

Fig. 1. CMP and GFP.

Fig. 2.
Root canal preparation.

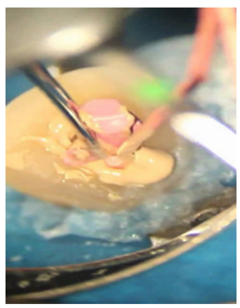

Fig. 3.
Root canal obturation.

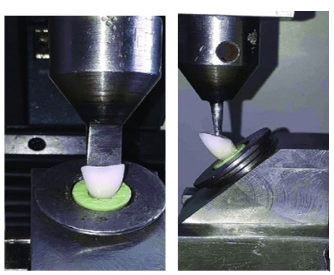

Fig. 4. Static load application.

Statistical analysis was performed using the statistical software package SPSS version 21.0 (SPSS Inc, Armonk, NY: IBM Corp). The significance of the results was assessed using Levene's test and t-test. A Fisher exact test was performed to detect group differences for fracture mode. A significance level of P<0,05 was used for all comparisons.

Results

Table 1 presents descriptive statistics for CMP and GFP. The median FS of Groups 1 and 2 were 161.87±1.36N and 1220.83±2.04N. A comparative analysis of the FS values between CMP and GFP groups showed that the influence of post type on FS was significant (P=0.000). Group 2 exhibited higher strength values. Levene's test was used to evaluate the equality of variance between two groups. As two sample groups have equal variance, the t-test was used to compare fracture loads among the two groups after the static load test (Table 2).

Table 1.

Descriptive statistics of FS values.

Material	N	Min	Mean	Max	Std. Deviation	Std. Error of Mean
CMP	30	160.01231	161.8733	165.2101	1.36203	0.24867
GFP	30	2118.1401	1220.8324	1225.20	2.03562	0.37801

Table 3 presents the fracture patterns of the two groups. It shows that all catastrophic fractures belonged to Group 1. There was no catastrophic fracture in samples of Group 2, and the number of catastrophic failures was less than five in Group 1. In Group 1, 40% of fractures were in the apical third and middle of roots. In Group 2, all fractures occurred in the incisal third of the roots.

Table 3.

The fracture patterns of ETI restored with CMP and GFP

Restoration type	Catastrophic fractures	Restorable fractures	Total
Group 1 (CMP) Group 2 (GFP)	4 0	6 10	10 10
Total	4	16	20

Table 2.

Comparison of the fracture strength of ETI restored with CMP and GFP.

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Value	Equal variances assumed	7.657	0.008	-2355.868	57	0.000	-1058.95908	0.44950	-1059.85919	-1058.05898
	Equal variances not assumed			-2340.416	48.677	0.000	-1058.95908	0.45247	-1059.86850	-1058.04966

Discussion

The current study attempted to compare the FS of CMP and GFP. In the case of substantial horizontal loss of the clinical crown, there was no restorative alternative to fabricating a post and core build-up. In the present study, we tried to choose natural teeth with a close age range and similar lengths. One of the disadvantages of extracted natural teeth is that even if they have similar diameters, they may differ in the contour, dentin thickness, moisture content, and shape of root canals; these factors could influence the stress distribution in the remaining tooth structure.[22] On the other hand, using plastic teeth does not simulate the modulus of elasticity and bonding characteristics of natural teeth.[23] In addition, Strub et al.[24] reported a higher FS of natural teeth than artificial teeth. The environment in which the teeth are kept influences the changes in hard dental tissues, particularly dentin.[25] In previous studies, a thymol solution was utilized.[26] It has been described that thymol could negatively affect the bond strength between the post and dentin.[27] Hence, we used normal saline for tooth preservation. As suggested by Naumann et al.,[26] the teeth were collected within the previous six months.

All teeth benefited from the 2mm ferrule effect, which was clinically recommended for a higher success rate. To produce a cushioning effect, all roots were covered with a 0.1mm thick layer of auto-polymerized silicon, as in the study of Martínez-Insua et al.[28] and Akkayan et al.[29] Guzy and Nicholls [30] stated that force must be applied to anterior teeth in 135-degree angulations in *in vitro* studies to reproduce the mouth situation in class I malocclusion. The compressive force was applied at a crosshead speed of 1mm/min until fracture. Helkimo et al.[31] reported that compressive force was 100-200N in the anterior region of the mouth. Ramfjord and Ash [32] estimated mastication forces about 70-150N in anterior teeth.

Several studies have investigated the FS of GFP since its introduction and compared it with that of the CMP. Unfortunately, the results have not been consistent among all authors. The result of our study contradicted the findings of Martinez-Insua et al.[28] and Newman et al.,[15] who reported lower FS on ETI restored with GFP than that on teeth restored with CMP. However, our results are consistent with data obtained in a study by Rosentritt et al.[33] and Raygot et al.,[34] which concluded that the FS of ETI restored with GFP was significantly higher than that of ETI restored with CMP. On the contrary, a higher FS was reported in the teeth restored with GFP than with CMP.[35] This could be associated with the close modulus of elasticity of GFP and dentin.[36-38]

However, in our study, the FS of GFP was higher than CMP, and it was high enough to withstand mastication forces in anterior teeth. Plasmans et al.[39] showed the same result in their study. Heydecke et al.[8] reported that fractures commonly occurred in the apical half of the roots if rigid post systems were applied. However, their study did not cover the effect of fatigue on this post system, and the FM of the two groups differed. In the CMP group, 40% of fractures were in the apical and middle third of roots. In the GFR group, all fractures occurred in the incisal third of the roots. They were repairable in clinical situations.

In conclusion, within the limitations of our study, the FS of ETI was significantly influenced by the post type. The FS analysis with UTM is the only method that enables us to estimate the differences between the ETI restored with CMP and GFP. This study showed that based on the mean strength values obtained, the FS of ETI restored with GFP was significantly higher than that of CMP. No catastrophic fracture on ETI was restored with GFP. These results have important implications for the selection of materials in dental practices, particularly in contexts where the material's mechanical strength is a critical factor in clinical outcomes.

Competing Interests

The authors declare that they have no competing interests.

References

1. Katebzadeh N, Dalton BC, Trope M. Strengthening immature teeth during and after apexification. J Endod. 1998 Apr;24(4):256-9. doi: 10.1016/s0099-2399(98)80108-8. PMID: 9641130.
2. Marchi GM, Mitsui FH, Cavalcanti AN. Effect of remaining dentine structure and thermal-mechanical aging on the fracture resistance of bovine roots with different post and core systems. Int Endod J. 2008 Nov;41(11):969-76. doi: 10.1111/j.1365-2591.2008.01459.x. PMID: 19133086.
3. Michael MC, Husein A, Bakar WZ, Sulaimanb E. Fracture resistance of endodontically treated teeth: An in vitro study. Arch Orofac Sci 2010; 5: 36-41.
4. Helfer AR, Melnick S, Schilder H. Determination of the moisture content of vital and pulpless teeth. Oral Surg Oral Med Oral Pathol. 1972 Oct;34(4):661-70. doi: 10.1016/0030-4220(72)90351-9. PMID: 4506724.
5. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod. 1989 Nov;15(11):512-6. doi: 10.1016/S0099-2399(89)80191-8. PMID: 2639947.
6. Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod. 1992 Jul;18(7):332-5. doi: 10.1016/S0099-2399(06)80483-8. PMID: 1402595.
7. Makade CS, Meshram GK, Warhadpande M, Patil PG. A comparative evaluation of fracture resistance of endodontically treated teeth restored with different post core systems - an in-vitro study. J Adv Prosthodont. 2011 Jun;3(2):90-5. doi: 10.4047/jap.2011.3.2.90. Epub 2011 Jun 30. PMID: 21814618; PMCID: PMC3141125.
8. Heydecke G, Butz F, Hussein A, Strub JR. Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. J Prosthet Dent. 2002 Apr;87(4):438-45. doi: 10.1067/mpr.2002.123849. PMID: 12011861.
9. Kimmel SS. Restoration of endodontically treated tooth containing wide or flared canal. N Y State Dent J. 2000 Dec;66(10):36-40. PMID: 11199524.
10. Rosentritt M, Fürer C, Behr M, Lang R, Handel G. Comparison of in vitro fracture strength of metallic and tooth-coloured posts and cores. J Oral Rehabil. 2000 Jul;27(7):595-601. doi: 10.1046/j.1365-2842.2000.00548.x. PMID: 10931252.

11. Zalkind M, Hochman N. Direct core buildup using a preformed crown and prefabricated zirconium oxide post. J Prosthet Dent. 1998 Dec;80(6):730-2. doi: 10.1016/s0022-3913(98)70062-9. PMID: 9830080.
12. Belli S, Erdemir A, Ozcopur M, Eskitascioglu G. The effect of fibre insertion on fracture resistance of root filled molar teeth with MOD preparations restored with composite. Int Endod J. 2005 Feb;38(2):73-80. doi: 10.1111/j.1365-2591.2004.00892.x. PMID: 15667628.
13. Mannocci F, Ferrari M, Watson TF. Intermittent loading of teeth restored using quartz fiber, carbon-quartz fiber, and zirconium dioxide ceramic root canal posts. J Adhes Dent. 1999 Summer;1(2):153-8. PMID: 11725680.
14. Boudrias P, Sakkal S, Petrova Y. Anatomical post design meets quartz fiber technology: rationale and case report. Compend Contin Educ Dent. 2001 Apr;22(4):337-40, 342, 344 passim; quiz 350. PMID: 11913279.
15. Newman MP, Yaman P, Dennison J, Rafter M, Billy E. Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent. 2003 Apr;89(4):360-7. doi: 10.1067/mpr.2003.75. PMID: 12690348.
16. Hornbrook DS, Hastings JH. Use of bondable reinforcement fiber for post and core build-up in an endodontically treated tooth: maximizing strength and aesthetics. Pract Periodontics Aesthet Dent. 1995 Jun-Jul;7(5):33-42; quiz 44. PMID: 7548893.
17. Kimmel SS. Restoration and reinforcement of endodontically treated teeth with a polyethylene ribbon and prefabricated fiberglass post. Gen Dent. 2000 Nov-Dec;48(6):700-6. PMID: 12004666.
18. Bergman B, Lundquist P, Sjögren U, Sundquist G. Restorative and endodontic results after treatment with cast posts and cores. J Prosthet Dent. 1989 Jan;61(1):10-5. doi: 10.1016/0022-3913(89)90099-1. PMID: 2644413.
19. Creugers NH, Mentink AG, Käyser AF. An analysis of durability data on post and core restorations. J Dent. 1993 Oct;21(5):281-4. doi: 10.1016/0300-5712(93)90108-3.
20. Qualtrough AJ, Mannocci F. Tooth-colored post systems: a review. Oper Dent. 2003 Jan-Feb;28(1):86-91. PMID: 12540124.
21. Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE. Fundamental of Fixed Prosthodontics. Illinois, Quintessence Publishing Co, Inc 1997:202-4.
22. Allen EP, Bayne SC, Brodine AH, Cronin RJ Jr, Donovan TE, Kois JC, Summitt JB; Committee on Scientific Investigation of the American Academy of Restorative Dentistry. Annual review of selected dental literature: report of the Committee on Scientific Investigation of the American Academy of Restorative Dentistry. J Prosthet Dent. 2003 Jul;90(1):50-80. doi: 10.1016/s0022-3913(03)00299-3. PMID: 12869974.
23. Toksavul S, Toman M, Uyulgan B, Schmage P, Nergiz I. Effect of luting agents and reconstruction techniques on the fracture resistance of pre-fabricated post systems. J Oral Rehabil. 2005 Jun;32(6):433-40. doi: 10.1111/j.1365-2842.2005.01438.x. PMID: 15899022.
24. Strub JR, Pontius O, Koutayas S. Survival rate and fracture strength of incisors restored with different post and core systems after exposure in the artificial mouth. J Oral Rehabil. 2001 Feb;28(2):120-4. doi: 10.1046/j.1365-2842.2001.00720.x. PMID: 11298259.
25. Frank RM. Ultrastructure of human dentine 40 years ago--progress and perspectives. Arch Oral Biol. 1999 Dec;44(12):979-84. doi: 10.1016/s0003-9969(99)00109-0.
26. Naumann M, Metzdorf G, Fokkinga W, Watzke R, Sterzenbach G, Bayne S, Rosentritt M. Influence of test parameters on in vitro fracture resistance of post-endodontic restorations: a structured review. J Oral Rehabil. 2009 Apr;36(4):299-312. doi: 10.1111/j.1365-2842.2009.01940.x. Epub 2009 Feb 11. PMID: 19220719.
27. Goodis HE, Marshall GW Jr, White JM, Gee L, Hornberger B, Marshall SJ. Storage effects on dentin permeability and shear bond strengths. Dent Mater. 1993 Mar;9(2):79-84. doi: 10.1016/0109-5641(93)90079-6. PMID: 8595846.
28. Martínez-Insua A, da Silva L, Rilo B, Santana U. Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. J Prosthet Dent. 1998 Nov;80(5):527-32. doi: 10.1016/s0022-3913(98)70027-7. PMID: 9813801.
29. Akkayan B, Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent. 2002 Apr;87(4):431-7. doi: 10.1067/mpr.2002.123227. PMID: 12011860.
30. Guzy GE, Nicholls JI. In vitro comparison of intact endodontically treated teeth with and without endo-post reinforcement. J Prosthet Dent. 1979 Jul;42(1):39-44. doi: 10.1016/0022-3913(79)90328-7. PMID: 379307.
31. Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta Odontol Scand. 1977;35(6):297-303. doi: 10.3109/00016357709064128. PMID: 271452.
32. Ramfyord SJ, Ash MM. Periodontology and Periodontics. Philadelphia: WB Saunders;1979.
33. Rosentritt M, Sikora M, Behr M, Handel G. In vitro fracture resistance and marginal adaptation of metallic and tooth-coloured post systems. J Oral Rehabil. 2004 Jul;31(7):675-81. doi: 10.1111/j.1365-2842.2004.01286.x. PMID: 15210029.
34. Raygot CG, Chai J, Jameson DL. Fracture resistance and primary failure mode of endodontically treated teeth restored with a carbon fiber-reinforced resin post system in vitro. Int J Prosthodont. 2001 Mar-Apr;14(2):141-5. PMID: 11843450.
35. Möllersten L, Lockowandt P, Lindén LA. A comparison of strengths of five core and post-and-core systems. Quintessence Int. 2002 Feb;33(2):140-9. PMID: 11890028.
36. Upadhyaya V, Bhargava A, Parkash H, Chittaranjan B, Kumar V. A finite element study of teeth restored with post and core: Effect of design, material, and ferrule. Dent Res J (Isfahan). 2016 May-Jun;13(3):233-8. doi: 10.4103/1735-3327.182182. PMID: 27274343; PMCID: PMC4878207.
37. 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. doi: 10.1016/s0022-3913(98)70103-9. PMID: 9710815.
38. Freilich MA. Rationale for the clinical use of fiber -reinforced composites, in: Freilich MA, Meiers JC, Duncan JP, Goldberg AJ. Fiber -Reinforced Composites in Clinical Dentistry. Hanover Park, IL, Quintessence Publishing Co., Ltd., 2000:16,17.
39. Plasmans PJ, Visseren LG, Vrijhoef MM, Kayser AF. In vitro comparison of dowel and core techniques for endodontically treated molars. J Endod. 1986 Sep;12(9):382-7. doi: 10.1016/S0099-2399(86)80071-1. PMID: 3531376.