Original Article

A Comparison of the Fracture Resistance of Endodontically Treated Teeth Using Two Different Restoration Systems

Farideh Darabi*, Laleh Namazi**

ABSTRACT

***Background*:** Many post systems are available to clinicians, yet no consensus exists regarding the superiority of any one in restoring endodontically treated teeth. The aim of this in vitro study was to compare the fracture resistance and failure mode of endodontically treated teeth restored with a cast metal post and crown with quartz fiber post and composite crown build-up.

***Methods*:** Forty extracted maxillary canine teeth with similar size were chosen and randomly divided into 2 groups. After cutting the crowns and endodontic therapy, the teeth were restored with a quartz fiber post and composite crown build-up, or a cast metal post and crown in group 1 and 2, respectively. Fiber posts were cemented with dual cured resin cement and cast posts were luted using zinc phosphate cement. After thermocycling, a compressive load was applied at $135^{\circ C}$ to the long axis of the tooth at a crosshead speed of 1 mm/min and fracture loads and fracture modes were recorded. Mann-Whitney and t tests were used to determine the significance of the failure load values between the two groups.

***Results*:** The mean values for fracture strength in groups 1 and 2 were 344 and 446 N, respectively. The teeth in group 2 exhibited significantly higher resistance to fracture ($P < 0.01$); however, all failures occurred in the tooth structure.

***Conclusion*:** In spite of the significantly lower failure loads achieved for the teeth restored with fiber posts, all of the fractures in this group were repairable.

***Keywords*:** Endodontically-treated teeth, post and core technique, restorations.

Received: *May 2008*
Accepted: *August 2008*

Dent Res J 2008; 5(2):65-69

Introduction

Devitalized teeth usually present important biomechanical shortcomings, such as loss of dental substance due to caries or previous restorations.[1] They are also weaker and more prone to fracture than vital teeth, because of decreased moisture content, loss of tooth structure and produced stresses during post placement or function. Many endodontically treated teeth planned for fixed prosthodontic treatment require post-and-core restorations for retention purposes, and the remaining tooth structure appears to be a key factor in the use of post-and-core restorations. Many different kinds of posts have been described in the literature[2] but, considerable controversy exists regarding the best choice for post and restorative technique.[3] Some studies claim that metallic posts perform better than fiber posts because they cause low stress concentration on dentin and have higher physico-mechanical properties.[4-6] Other studies, however, state the opposite and report higher occurrence of catastrophic root fracture using metal posts because of their higher modulus of elasticity.[7-15] One reason for this controversy is lack of standardization in testing conditions and methods. In some previous studies, the cemented posts were loaded directly onto cores.[3,9,14] In some other studies, in spite of using a fiber post to make the physico-mechanical properties of the restoration more close to those of dentin, a full coverage crown made of cast metal was used.[4,7,12,13] In order to clarify the

*Assistant Professor, Department of Operative Dentistry, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.
**Dentist, Guilan University of Medical Sciences, Rasht, Iran.
Correspondence to: Farideh Darabi, Department of Operative Dentistry, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran. E-mail: f_darabi2002@yahoo.com

apparent confusion of the results found in the literature, this study compared the fracture strength and mode of failure of teeth restored with two physico-mechanically different restorative systems, quartz fiber posts with fiber-reinforced composite crown build-up and cast metal posts and crowns.

Materials and Methods

In this in vitro study, 45 recently extracted human canine teeth free of caries, cracks or erosion with similar root size were selected. They had a mesial-distal width of 4.4 to 5 mm and a buccal-lingual width of 6.7 to 7.9 mm measured at the CEJ and root length of 16 to 17 mm. Measurements of the buccolingual and mesiodistal dimensions for each tooth were made with a digital caliper. After debridement, the specimens were stored first in aqueous buffered solution of formaldehyde (5%) for two hours and then in water when they were not under testing. The selected teeth were randomly divided into two experimental groups, twenty specimens each. Before crown removal, custom molds were made to preserve the individual coronal dimensions. Custom molds were made of a soft and translucent plastic material (such as that used in making bleaching trays) in group 1 and they were made of a silicon rubber-based impression material (Speedex; Coltene, Altstatten, Switzerland) in group 2. After that, all of the crowns were removed at a level of 2 mm coronal to the cementoenamel junction with diamond disk under full water spray coolant. At this level, a chamfer was prepared around the full circumference of the roots with 2 mm height and a half millimeter depth with approximately 6 degrees convergency. All of the roots were subjected to endodontic treatments through conventional step-back technique to a number 60 master file (Dentsply, Maillefer, Ballaigues, Switzerland) and obturated by gutta percha and zinc-oxide eugenol root canal sealer (Gol-Chaie, Iran). After 24 hours, gutta percha was removed from the root canal with a 3-sized pesso drill (Dentsply, Maillefer, Ballaigues, Switzerland) to a depth of 11 mm. The root canal walls of each specimen were enlarged with special preparation drill number 2 provided by the manufacturer (RTD, St. Egreve, France) and the post spaces were cleaned with ethanol. In group 1, quartz fiber posts (D. T. light-post, Recherches Techniques Dent aires, RTD, St. Egreve, France) were placed. A post size of 2 was selected, marked and cut at a distance of 14 mm from its apical end. The posts were cemented with dual-cured resin cement (Panavia F 2.0, Kuraray Medical Inc., Okayama, Japan). In this group, the crowns were restored with a fiber reinforced composite resin (Nulite F, NSI, Australia). First, the composite resin was used incrementally and then, it was used by the individual translucent molds. In group 2, Duralay acrylic resin (Reliance Dental Mfg. Co., Chicago, USA) was used to cast the non-precious metal post and crown (Richmond type). The individual mold made of a heavy body of Speedex was used to shape the crown for each tooth. Metal posts and crowns were luted by zinc phosphate cement (Ariadent, Asia Chemi Teb Co, Tehran, Iran). During cementation, hydrolic back pressure was allowed to release and the post was gently reseated. All the teeth were mounted in resin blocks simulating the periodontal ligament (PDL). In order to achieve this goal, the roots were dipped into melted wax to a depth of 2 mm below the CEJ and were then embedded in acrylic resin blocks. Each root was removed from the resin block when the first signs of polymerization were observed. The wax spacer was removed and a silicon-based impression material (Speedex; Coltene, Altstatten, Switzerland) was injected into the acrylic resin alveolus. The tooth was then reinserted into the resin block, and the impression material was allowed to set. The excess impression material was removed with a surgical blade at the predetermined limit of 2 mm below the CEJ. The specimens were thermo cycled 1000 times between $5^{\circ C}$ and $55^{\circ C}$ for 30 seconds in each temperature and with 15 seconds rest time. After that, the specimens were secured in a universal load testing machine (Zwick Z010; Zwich Gmbh & Co. KG, Ulm, Germany) using a custom-made stainless steel device that allowed loading the tooth on the palatal side at a 135-degree angle to the long axis. A compressive force was applied at the cross head speed of 1 mm/min until fracture occurred. The fracture load was determined, and the mode of fracture was recorded. Mann-Whitney and t tests were used to determine the significance of the failure load values between the 2 groups.

Results

The mean and standard deviations for failure loads were recorded in table 1. A statistically significant difference was observed between the failure loads

Table 1. Descriptive statistics of fracture resistance and fracture mode of the two studied groups.

Group	Mean (SD)	Min	Max	Mode of Fracture		
				In core (repairable)	In root (catastrophic)	
					Vertical	Oblique
1	344.01 (45.578)	265.9	412.6	20	0	0
2	445.92 (48.812)	362.2	518	0	9	11

of teeth restored using a cast metal post and crown in group 2 (445 N) and those teeth restored using glass fiber posts and composite crown build-up in group 1 (344 N) ($P < 0.01$). The mode of failure of the restored teeth was also different between the two groups. In group 1, all the fractures occurred at the interface of fiber post and composite crown; in group 2 all the fractures occurred in the roots with oblique or vertical patterns (table 1).

Discussion

In this study, the teeth were carefully selected for standardized size and quality; and there was slight difference in root size of selected teeth between the two groups. However, the shape of the root canals and internal diameter of the roots were not evaluated. Although Eugenol-containing sealer was chosen because of its common use, the posts were cemented 24 hours after root canal obturation. After 24 hours, no adverse effect on resin materials was shown by eugenol-containing sealer.[16] As previous studies[3,17] by finite element analysis confirmed, in a system made with many components, the use of materials having elastic properties similar to dentin determines a homogenous distribution of stress. In our study, using a quartz fiber post combined with a fiber reinforced composite resin with modulus of elasticity (30 and 14 GPa, respectively) more close to that of dentin (15-25 GPa) resulted in similar physical-mechanical behavior at the whole components of restored teeth in group 1. As previously mentioned, considerable controversy exists regarding the optimal choice of dowel. Some authors[4-6] believe that using a material with a higher modulus of elasticity creates less dentinal stress concentration and others[3,7,11,12] believe that better performance is achieved if the stiffness of the post material is similar to that of dentin. According to the result of this study, the teeth restored with cast metal post and crown exhibited significantly higher failure load values in comparison with those teeth restored with quartz fiber post and composite crown build-up. This is in agreement with many studies.[4,8,13,14] This result may be attributable to the fact that cast metal posts and crowns have higher strength than the composite resin that was used for crown build-up. However, the result of our study is different from a number of other investigations. Mc Donald et al.[18], Hu et al.[19] and Raygot et al.[20] reported no significant differences in fracture resistance among carbon fiber posts and metal posts. Some other researchers reported more fracture load values for the teeth restored with fiber reinforced posts in comparison with metal posts.[3,7,12] These findings are in contrast to the results obtained in the present study. This might be due to sample selection, different sizes of the selected posts and different testing procedures. In the present study in relation to the mode of failure, all of the teeth with cast posts had non-repairable failures such as oblique or vertical root fracture, but no tooth fracture occurred in any of the fiber post treated teeth. This finding is also corroborated by other experimental results from the literature. Isidor et al.[9] and Ferrari et al.[10] emphasized the better biomechanical performance of carbon fiber versus steel. In this case, carbon fiber was the material with an elastic modulus that was most similar to dentin. Akkayan and Gulmez[7] demonstrated that teeth restored with FRC posts allowed repeated fracture repair. Similar results were reported in other studies.[4,8,9,11,14] While the result from finite element models estimated better performance for the materials with a modulus of elasticity similar to that of dentin,[3,17] Asmussen et al.[5] and Toksavul et al.[6] showed that increasing the elastic modulus of the bonded dowel caused decreased dentin stress. In both latter studies, all materials were assumed to be rigidly bounded together but, that is not actually practical. In agreement with some other research, cast metal restoration components didn't break, resisted the force and transferred it to the root.[7,11,21] Although post and cores used for the restoration of pulpless teeth should have high strength properties, they have to fail before the remaining dental structure in response to mechanical stress.[22,23] In spite of the significantly lower failure loads achieved for the teeth in group 1, their performance should be considered favorable because there wasn't any root fracture and the mean failure load in this group (344 N) was higher than 200 N which was reported as routine bite force on cuspids.[24] However, to improve the failure load, the stronger material such as indirect composite resin can be used to make the crown. In our study, the quartz fiber posts were bonded, whereas the cast metal posts were not. According to the study of Asmussen et al.[5] bonded dowels result in less dentin stress than non-bonded dowels. It is conceivable that a bonded dowel may strengthen the tooth similarly to the strengthening effect that a bonded composite exerts on the cusps of endodontically treated teeth.[25] So, the bond strength between the root and fiber posts should be improved.

Conclusions

Within the limitations of the present study, the following conclusions can be drawn: 1) Significantly higher fracture resistance was recorded in the cast post and crown group. 2) A more favorable mode of failure was observed in teeth restored with fiber post and composite crown build-up.

Acknowledgement

We would like to acknowledge the financial support of the vice president of Guilan University of Medical Sciences (grant number 1070).

References

1. Torabinejad M, Walton RE. Principles and Practice of Endodontics. 3rd ed. Philadelphia: Saunders; 2002.
2. Fernandez AS, Shetty S, Coutinho I. Factors determining post selection: A literature review. Prosthet Dent 2003; 90(6): 556-562.
3. Barjau-Escribano A, Sancho-Bru JL, Forner-Navarro L, Rodriguez-Cervantes PJ, Perez-Gonzalez A, Sanchez-Marin FT. Influence of prefabricated post material on restored teeth: fracture strength and stress distribution. Oper Dent 2006; 31(1): 47-54.
4. Martinez-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; 80(5): 527-32.
5. Asmussen E, Peutzfeldt A, Sahafi A. Finite element analysis of stresses in endodontically treated, dowel-restored teeth. J Prosthet Dent 2005; 94(4): 321-9.
6. Toksavul S, Zor M, Toman M, Gungor MA, Nergiz I, Artunc C. Analysis of dentinal stress distribution of maxillary central incisors subjected to various post-and-core applications. Oper Dent 2006; 31(1): 89-96.
7. Akkayan B, Gulmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002; 87(4): 431-7.
8. Fokkinga WA, Kreulen CM, Vallittu PK, Creugers NH. A structured analysis of in vitro failure loads and failure modes of fiber, metal, and ceramic post-and-core systems. Int J Prosthodont 2004; 17(4): 476-82.
9. Isidor F, Odman P, Brondum K. Intermittent loading of teeth restored using prefabricated carbon fiber posts. Int J Prosthodont 1996; 9(2): 131-6.
10. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. Am J Dent 2000; 13(Spec No): 9B-13B.
11. 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; 1(2): 153-8.
12. 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; 87(4): 438-45.
13. Sidoli GE, King PA, Setchell DJ. An in vitro evaluation of a carbon fiber-based post and core system. J Prosthet Dent 1997; 78(1): 5-9.
14. Sirimai S, Riis DN, Morgano SM. An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-coresystems. J Prosthet Dent 1999; 81(3): 262-9.
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; 89(4): 360-7.
16. Vano M, Cury AH, Goracci C, Chieffi N, Gabriele M, Tay FR, et al. The effect of immediate versus delayed cementation on the retention of different types of fiber post in canals obturated using a eugenol sealer. J Endod 2006; 32(9): 882-5.
17. Chen XT, Li XN, Guan ZQ, Liu XG, Gu YX. [Effects of post material on stress distribution in dentine]. Zhonghua Kou Qiang Yi Xue Za Zhi 2004; 39(4): 302-5.
18. McDonald AV, King PA, Setchell DJ. In vitro study to compare impact fracture resistance of intact root-treated teeth. Int Endod J 1990; 23(6): 304-12.
19. 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(5): 349-53.

20. 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; 14(2): 141-5.
21. Mitsui FH, Marchi GM, Pimenta LA, Ferraresi PM. In vitro study of fracture resistance of bovine roots using different intraradicular post systems. Quintessence Int 2004; 35(8): 612-6.
22. Christensen GJ. Post concepts are changing. J Am Dent Assoc 2004; 135(9): 1308-10.
23. Qualtrough AJ, Mannocci F. Tooth-colored post systems: a review. Oper Dent 2003; 28(1): 86-91.
24. Craig RC, Powers JM, Editors. Restorative dental materials. 11th ed. Philadelphia: C.V. Mosby; 2006.
25. Hansen EK, Asmussen E. In vivo fractures of endodontically treated posterior teeth restored with enamel-bonded resin. Endod Dent Traumatol 1990; 6(5): 218-25.