ACP AMERICAN COLLEGE OF PROSTHODONTISTS Your smile. Our specialty.

Comparative Evaluation of Fracture Resistance of Structurally Compromised Canals Restored with Different Dowel Methods

Vivek Aggarwal, MDS,[1] Mamta Singla, MDS,[1,2] Sanjay Miglani, MDS,[3] & Sarita Kohli, MDS[4]

[1]Assistant Professor, Department of Conservative Dentistry & Endodontics, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India
[2]Senior Lecturer, Department of Conservative Dentistry & Endodontics, Institute of Dental Sciences & Technology, Modinagar, India
[3]Associate Professor, Department of Conservative Dentistry & Endodontics, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India
[4] Professor & Head, Department of Conservative Dentistry & Endodontics, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India

Keywords
Cast dowel; fracture resistance; fiber dowel; mechanical loading.

Correspondence
Vivek Aggarwal, Department of Conservative Dentistry & Endodontics, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India. E-mail: drvivekaggarwal@gmail.com

The authors deny any conflicts of interest.

Accepted July 26, 2011

doi: 10.1111/j.1532-849X.2011.00827.x

Abstract

Purpose: The objective of this in vitro study was to evaluate and compare the fracture resistance and fracture mode of endodontically treated teeth with wide root canals restored with various dowel methods.
Materials and Methods: Fifty human uniradicular mandibular premolar teeth were decoronated and endodontically treated. The canals were widened with diamond points. The specimens were divided into five groups on the basis of type of dowel method used: conventional custom-made cast metal dowel; single glass fiber-reinforced resin dowel; glass fiber-reinforced resin dowel with accessory fiber dowels; relined glass fiber-reinforced resin dowel; and dowels formed with the help of polyethylene fiber ribbon-reinforced resin composite. Specimens were restored with indirect composite crowns, and 150,000 cycles of cyclic loading were applied. The specimens were loaded to test the fracture resistance and fracture mode (repairable and nonrepairable).
Results: The cast metal dowel groups had the highest fracture resistance but showed nonrepairable fracture in 90% of specimens.
Conclusions: Cast metal dowels had the highest fracture resistance but led to nonrepairable fracture while restoring the wide root canals under cyclic loading. Specimens restored with fiber dowels, accessory dowels, relined dowels, and ribbon-reinforced resin provided adequate fracture resistance with increased incidence of repairable fractures.

Restoration of endodontically treated teeth with extensive coronal damage is a common clinical problem.[1-3] Traditionally, cast metal dowels and cores were used, but recently there has been an increasing trend toward the use of fiber dowel systems.[4] They provide a more esthetic result than metallic dowels. Fiber dowels have a modulus of elasticity similar to dentin, thus reducing the stress concentrations at the dowel/dentin interface.[5] Also it has been reported that fiber dowels decrease the chances of "catastrophic" or irreparable root fractures.[6,7]

Fiber dowels are usually prefabricated and are luted with the help of dual-cured resin cements. Resin cement thickness can affect the outcome of the restoration.[8,9] A thinner resin cement layer produces minimal shrinkage stresses and thus reduces the stress at the resin/dentin margin. Therefore, it is necessary to get a good-fitting dowel luted in the canal. Fiber dowels are provided with a matching drill by the manufacturers, to "adapt" the canal according to the dowel system, but it is very difficult to get good adaptation in clinical conditions where the root canals are already weakened or structurally compromised by either caries, trauma, over preparation, or other iatrogenic causes.[6,7,9] In such conditions, the resin thickness will be increased, thus compromising the strength of the tooth. Some methods have been introduced in the past to overcome this obstacle. Martelli et al[6] proposed the use of an accessory glass dowel to fill the space between the prefabricated dowel and the canal walls. Faria-e-Silva et al[9] have proposed the modification and reline of the dowel itself according to the canal shape, with the help of composite resins. Another viable option is the use of polyethylene fiber ribbon-reinforced resin composite as a dowel material.[10] It is available in a ribbon shape, which can be mixed with the resin cement and packed and molded according to the shape of the canal.

The purpose of this study was to evaluate and compare the fracture resistance of structurally compromised endodontically

Table 1 Experimental groups and dowel-core techniques

Experimental group	Dowel-core technique
Group I/CD	Cast metal dowel and core luted with zinc phosphate cement
Group II/FD	One glass fiber dowel luted with resin cement; core buildup with composite resin
Group III/AFD	One glass fiber dowel luted with resin cement along with accessory glass fiber dowels; core buildup with composite resin
Group IV/DL	A relined dowel was made with a glass fiber dowel and composite resin
Group V/RRR	Customized dowel-core was made with ribbon-reinforced resin composite

treated teeth restored with various dowel methods including: conventional custom-made cast metal dowel; single glass fiber-reinforced resin dowel; glass fiber-reinforced resin dowel with accessory fiber dowels; relined glass fiber-reinforced resin dowel; and a dowel formed with the help of polyethylene fiber ribbon-reinforced resin composite. The specimens were subjected to mechanical loading. The fracture mode was classified as repairable or nonrepairable. The null hypothesis was that there is no difference in fracture resistance between the different dowel systems.

Materials and methods

Fifty human uniradicular mandibular premolar teeth, with a mesiodistal width of 5.0–5.5 mm and buccolingual width of 7–8 mm, were selected for the study. The teeth were extracted for orthodontic or periodontal reasons. Teeth with caries or restoration on the cervical third, large root canals or cracks/fissures were excluded from the study. The teeth were decoronated, and the root length was standardized to 16 mm. To structurally compromise the teeth, the canal entrances were enlarged with a 3 mm diameter round bur. The root canals were enlarged to 11 mm, with a safe-ended tapered bur, according to the external root canal wall anatomy. The roots were embedded in acrylic molds with epoxy resin liner to simulate the periodontal ligament, such that 3 mm of the root surface was exposed. The apical 5 mm of the root canals were then manually prepared to size no. 50 under constant irrigation with 1% NaOCl and a final rinse with 10 ml of distilled water, followed by thermo-plasticized gutta-percha filling. The canal entrances were sealed with a noneugenol temporary filling material (Cavit-G, 3M ESPE, St. Paul, MN). The specimens were stored at 100% humidity at 37°C for 7 days.

The specimens were randomly divided into five groups ($n = 10$), according to the dowel method used (Table 1). Group I/CD (cast dowel): the cast metal dowel and core were fabricated by making an impression of the canal space with the help of a plastic burn-out casting dowel, adapted to the canal with Duralay acrylic resin (Reliance Dental Manufacturing Company, Chicago, IL). The core was built up with Duralay acrylic resin to a height of 6 mm. The resin patterns were cast in Ni-Cr alloy (Heraeus Kulzer, Hanau, Germany), sandblasted, and luted in the canals with zinc phosphate (SS White, Rio de Janeiro, Brazil).

Group II/FD (fiber dowel): a serrated glass fiber dowel (Reforpost; Angelus Science and Technology, Londrina, Brazil) was passively fitted in the canal. The canals were rinsed with 17% EDTA and distilled water and dried with #50 absorbent paper points. Canals were etched with 37% phosphoric acid (3M Scotchbond etchant; 3M ESPE) for 30 seconds. Canals were washed with 10 ml of distilled water. Excess water was removed with no. 50 absorbent paper points. Two coats of the Adper single bond 2 adhesive system were applied to the canal walls with a Cavi-tip brush. Excess adhesive material was removed with absorbent paper points, and canals were light cured for 40 seconds. The dowel was also etched with phosphoric acid for 1 minute and coated with the Adper single bond 2 adhesive system. Five clicks of RelyX ARC (3M ESPE) were mixed, the cement was applied to the dowel, and the root canal was filled with cement with a Lentulo no. 40 spiral (Dentsply Maillefer, Ballaigues, Switzerland). The dowels were cemented into the root canals with light pressure, and the core buildup was done using Filtek Z350 restorative composite resin (3M ESPE).

Group III AFD (accessory fiber dowels): a serrated glass fiber dowel, passively fitting in the canal, was chosen as in group II. Two to three small diameter accessory glass fiber dowels were tried along with the main dowel. The dowels were luted, and the core buildup was done as in group II.

Group IV/DL (dowel relining): the canal walls were coated with a layer of glycerin, which acted as a water soluble lubricant. A serrated glass fiber dowel, passively fitting in the canal, was chosen and was etched and primed as in group II. The dowel was covered with Filtek Z350 restorative composite resin (3M ESPE) and gently inserted into the canal. The composite was cured for 40 seconds. The dowel was gently removed, and the relined portion was cured for 20 seconds from each side. The canal and the relined dowel were copiously rinsed and washed to remove the layer of lubricant. The dowel was luted, and core buildup was done as in group II.

Group V/RRR (ribbon-reinforced resin composite): the canals were etched and rinsed. Two coats of the Adper single bond 2 adhesive system were applied and light cured. Two strips of 3 mm wide and 17 mm long polyethylene fiber ribbon (Ribbond Inc., Seattle, WA) were cut. The strips were saturated with the adhesive system. Seven clicks of RelyX ARC were mixed, and the fiber ribbon was embedded in the resin cement. The root canal was filled with cement with a no. 40 Lentulo spiral. The fiber ribbons were inserted and packed into the root canals. The two strips of the fiber ribbon were twisted outside the root canal to get a core over the root. The fiber ribbon and the resin cement were light cured for 60 seconds. The exposed twisted strips were covered with Filtek Z350 restorative composite resin, and a core buildup was done.

Indirect composite crowns were fabricated with SR Adoro® (Ivoclar Vivadent) and a Lumamat 100 furnace (Ivoclar Vivadent) in all the specimens. The specimens, along with the acrylic mold, were placed in a metallic base at a 45° angle, so that a 1.5 mm stylus at the upper rod of the cycling machine could induce load pulses of 60 N, at a frequency of 5 Hz.

Table 2 Resistance to fracture

Experimental group	Fracture resistance (N)
Group I/CD	484 ± 41
Group II/FD	338 ± 28
Group III/AFD	352 ± 34
Group IV/DL	368 ± 24
Group V/RRR	256 ± 22

Specimens were subjected to cyclic loading of 150,000 cycles at 60 N (simulating 6 months of oral masticatory stresses). The fracture resistance was measured with a Universal Instron testing machine (Zwick GmbH and Co., Ulm, Germany). A compressive load was applied on the lingual surface, 2 mm below the incisal edge. The acrylic block was placed at an angulation to provide a 45° angle between the lingual surface and 2 mm wide spherical loading tip. The specimens were stressed to failure at a 0.5 mm/min crosshead speed. The specimens were analyzed to ascertain the mode of failure and were divided into two groups: repairable [fractures above cementoenamel junction (CEJ), cervical fracture, core-tooth fracture]; and nonrepairable (fracture below CEJ, oblique fracture, fracture in the middle or apical third of the root). The data were recorded and statistically analyzed using one-way ANOVA for the fracture resistance and Fisher's exact test for the mode of fracture.

Results

The fracture resistances of all groups are presented in Table 2. The cast dowel group had the highest fracture resistance (484 ± 41 N), which was significantly higher than all the groups ($p < 0.05$) (Fig 1). There was no significant difference between the fiber dowel group (338 ± 28 N), accessory dowel group (352 ± 34 N), and the relined dowel group (368 ± 24 N). The specimen restored with ribbon-reinforced resin composite (group V) showed the least resistance to fracture, which was significantly lower than all the groups. Cast metal dowel groups showed nonrepairable fracture in 90% of specimens (Table 3), significantly higher than all other groups.

Discussion

The use of traditional cast dowel and cores has been gradually replaced by the prefabricated dowel, especially fiber dowels.[1,4,5] Various advantages of fiber dowels over cast dowels have been cited in the literature. Santos et al[5] concluded that endodontically, roots restored using fiber dowels were less prone to catastrophic fractures than cast dowels. The modulus of elasticity of the fiber dowel is similar to root dentin, thus dissipating the stresses and preventing the formation of stress concentrations at the dowel/cement/tooth interface, but various clinical conditions present structurally compromised roots, creating a "mismatch" between the prefabricated dowels and the canal walls.[6,7] Some articles have even reported higher stresses in endodontically treated roots with fiber dowels.[11] The present study aimed to evaluate the fracture resistance and fracture pattern of structurally compromised roots restored with various dowel options.

The fracture resistance of the cast dowel group was 484 ± 41 N, significantly higher than the other groups. This was in accordance with previous studies showing that metallic dowels provide higher loads than fiber dowels.[6,7,12-14] Though the cast dowel group provided the highest fracture resistance, 90% of the specimens had a nonrepairable fracture. The cast dowels' higher modulus of elasticity resisted greater forces but lead to stress concentrations, mainly in the middle and apical third, leading to "catastrophic" fractures.

There was no significant difference of fracture resistance between groups II, III, and IV. Accessory dowels and dowel relining were introduced to reduce the cement thickness in the case of flared root canals, thus minimizing the polymerization shrinkage stresses,[6,9] but none of the methods increased the fracture resistance in the present study; however, the incidence of nonrepairable fracture was significantly less than the cast metal group. The incidence was similar to previously reported studies and was because of a similar modulus of elasticity.[6,7] Despite weakened roots, the fiber dowel/dowels, resin cement, and composite resin act as a single unit along with the root dentin, thus evenly spreading the forces. The fracture sites were clinically supragingival in nature and will not pose a problem while rerestoring the teeth. On the other hand, the options of restoring the teeth with nonrepairable fracture are very limited and in most of the cases lead to the extraction of the tooth.

Group V tested the use of the dowel formed with the help of polyethylene fiber ribbon-reinforced (Ribbond) resin composite. Ribbond has also been termed Leno Weave Ultra High Modulus (LWUHM) polyethylene fiber.[15] It was suggested that use of Ribbond along with bonding agent and flowable composite increases the fracture resistance of MOD cavities.[15] Some clinical reports have used it as a dowel-core buildup material.[10] Theoretically, Ribbond can be classified as a custom dowel, as the woven fibers are packed and adapted into the canal, according to the shape and anatomy of the canal. Thus it provides an intimate contact of the restoration with the canal walls. Though fracture resistance of the Ribbond group was significantly less than all the groups, all the specimens failed in a repairable manner.

The values of fracture resistance in all groups were less than reported studies, but this could be explained on the basis of the structurally compromised roots and mechanical loading. The teeth are unavoidably subjected to masticatory stresses.[16,17] These stresses are not constant in nature and provide a fatigue

Table 3 Mode of failure

Experimental group	Type of failure	
	Repairable	Nonrepairable
Group I/CD	1	9
Group II/FD	8	2
Group III/AFD	7	3
Group IV/DL	7	3
Group V/RRR	10	0

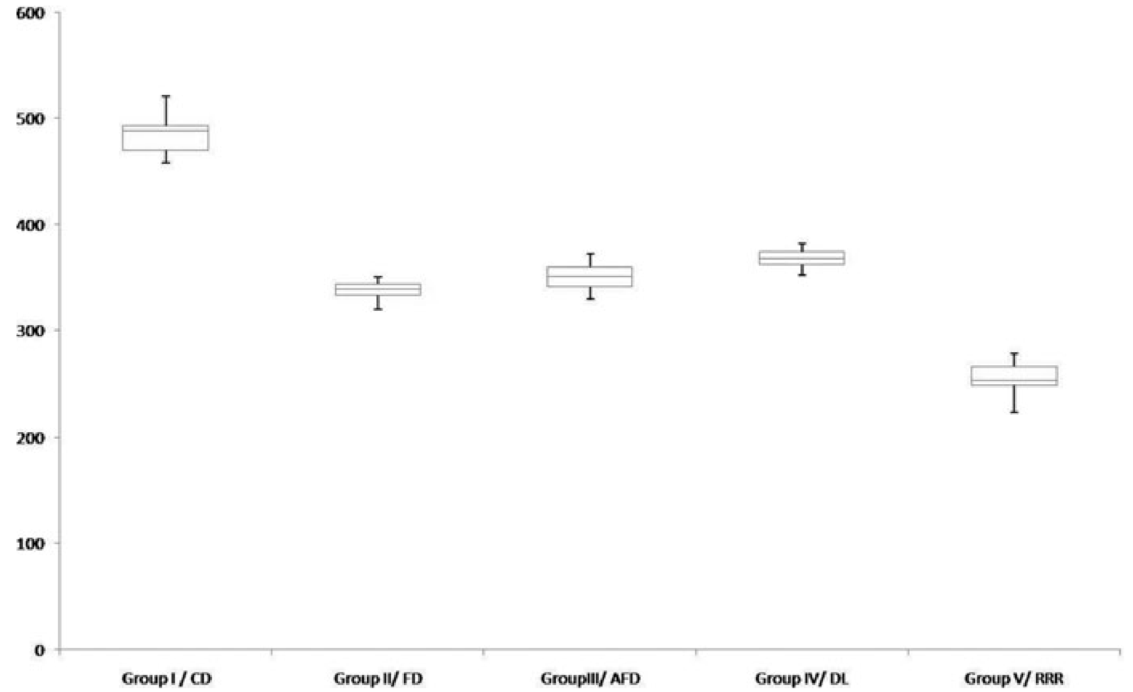

Figure 1 Box-plot diagram of fracture resistance values (N).

loading. To simulate these stresses, 150,000 cycles of cyclic loading were applied, equivalent to 6 months of clinical service. These stresses could also have played a role in the reduction of the overall fracture resistance in all groups.

A possible limitation of the present study was the absence of a ferrule while restoring the specimens. In the present study, the specimens had a mesiodistal width of 5.0–5.5 mm and buccolingual width of 7–8 mm. The canal entrances were enlarged with a 3 mm diameter round bur. Thus, the minimal dentinal thickness of the root canals was at least 1.5–2.5 mm. Though this thickness was sufficient to prevent vertical root fractures, it was insufficient to provide a clinically acceptable ferrule thickness.

Conclusions

Under the limitations of this in vitro study (absence of a ferrule), it can be concluded that a metallic cast dowel had the highest fracture resistance but led to nonrepairable fracture (fracture below CEJ, oblique fracture, fracture in the middle or apical third of the root) while restoring the wide root canals under cyclic loading. Specimens restored with fiber dowels, accessory dowels, relined dowels, and ribbon-reinforced resin provided adequate fracture resistance with an increased incidence of repairable fractures (i.e., fractures above CEJ and core-tooth fracture).

References

1. Baraban DJ: The restoration of endodontically treated teeth: an update. J Prosthet Dent 1988;59:553-558.
2. Fernandes AS, Shetty S, Coutinho I: Factors determining post selection: a literature review. J Prosthet Dent 2003;90:556-562.
3. Aggarwal V, Logani A, Shah N: Complicated crown fractures—management and treatment options. Int Endod J 2009;42:740-753.
4. Qualtrough AJ, Mannocci F: Tooth-colored post system: a review. Oper Dent 2003;28:86-91.
5. Santos AF, Meira JB, Tanaka CB, et al: Can fiber posts increase root stresses and reduce fracture? J Dent Res 2010;89:587-591.
6. Martelli H Jr, Pellizzer EP, Rosa BT, et al: Fracture resistance of structurally compromised root filled bovine teeth restored with accessory glass fiber posts. Int Endod J 2008; 41:685-692.
7. Bonfante G, Kaizer OB, Pegoraro LF, et al: Fracture strength of teeth with flared root canals restored with glass fiber posts. Int Dent J 2007;57:153-160.
8. D'Arcangelo C, Cinelli M, De Angelis F, et al: The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. J Prosthet Dent 2007;98:193-198.
9. Faria-e-Silva AL, Pedrosa-Filho Cde F, Menezes Mde S, et al: Effect of relining on fiber post retention to root canal. J Appl Oral Sci 2009;17:600-604.
10. Bayrak S, Tunc ES, Tuloglu N: Polyethylene fiber-reinforced composite resin used as a short post in severely decayed primary anterior teeth: a case report. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e60-e64.
11. Santos AF, Tanaka CB, Lima RG, et al: Vertical root fracture in upper premolars with endodontic posts: finite element analysis. J Endod 2009;35:117–120.
12. Butz F, Lennon ÁM, Heydecke G, et al: Survival rate and fracture strength of endodontically treated maxillary incisors with moderate defects restored with different post-and-core systems: An *in vitro* study. Int J Prosthodont 2001;14:58-64.

13. Heydecke G, Butz F, Strub JR: Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in-vitro study. J Dent 2001; 29:427-433.
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 post-and-core systems. J Prosthet Dent 1999;81:262-269.
15. Belli S, Erdemir A, Yildirim C: Reinforcement effect of polyethylene fiber in root-filled teeth: comparison of two restoration techniques. Int Endod J 2006;39:136-142.
16. Aggarwal V: An *in vitro* evaluation of effect of ionizing radiotherapy on push-out strength of fiber posts under cyclic loading. J Endod 2009;35:695-698.
17. Aggarwal V, Logani A, Jain V, et al: Effect of cyclic loading on marginal adaptation and bond strength in direct vs. indirect class II MO composite restorations. Oper Dent 2008;33:587-592.