

Do Bulk-Fill Flowable Composites Reinforce Weakened Roots?

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Abstract

Objective: The purpose of this study was to evaluate the fracture strength of weakened bovine teeth reinforced with bulk-fill flowable composite and glass fiber post.

Materials and Methods: Thirty bovine incisors with similar dimensions were selected. The root canals were flared until a dentin thickness of 1mm remained. The weakened roots were equally divided into three groups according to the reinforcing technique used. Group I: Cast metal post-and-core; Group II: Bulk-fill reinforcing technique (Filtek Bulk-Fill); Group III: Direct anatomic post (fiber post relined with composite resin). The specimens were subjected to a compressive load on the palatal surface of the cores at 135° to the long axis of the teeth using a universal testing machine (Kratos) at a crosshead speed of 0.5 mm/min until fracture occurred. Data were analyzed using one-way ANOVA. The significance level was 5%.

Results: The mean values of the fracture resistance were as follows: GI (cast metal post-and-core): 558.51 N; GII (Bulk-fill reinforcing technique): 555.30 N; GIII (direct anatomic post): 503.33 N. There was no statistically significant difference in fracture strength of the groups ($p = 0.406$). GI presented 100% of unfavorable fractures, while GII and GIII's fractures were classified as favorable mode.

Conclusions: The use of bulk-fill flowable composites can also be an alternative to metal cast posts and it seems to be a promising approach for practitioners.

Keywords: Bulk-Fill Resin Composite; Fracture Resistance; Intraradicular Posts; Root Canal

Abbreviations

CEJ: Cemento-Enamel Junction; PVC: Polyvinyl Chloride Cylinder

Introduction

Endodontically treated teeth usually need intraradicular posts for restoring their crowns. The use of cast metal posts and cores has been advocated for many years but they present some disadvantages such as unfavorable concentration of stresses in critical areas of the root, corrosion, loss of retention, and a high incidence of catastrophic root fractures [1]. Fiber posts have many advantages such as resistance to corrosion, aesthetics, single-visit office placement and easier removal for endodontic retreatment [2].

Flared root canal results from many clinical situations such as pulpal pathosis, carious extension, trauma, or canal preparation procedures [3]. In these cases, the root wall becomes thin, making the restorative procedure more difficult and it may compromise the

prognosis for a long-term successful restoration of the tooth, such as tooth strength. Widened canals with thin remaining walls are more prone to fracture and restorative techniques that may increase the fracture strength of these teeth are required [4]. The clinical success of fiber-reinforced dowels has been attributed to their modulus of elasticity, which matches that of dentin and resin luting cements, reducing stress transmission to root canal walls and decreasing the risk of vertical root fractures [4-6].

In the present study, glass fiber post associated with bulk-fill flowable composite was used to reinforce weakened roots. This new approach is based on the fact that bulk-fill resin composites have emerged as a new “class” of resin-based composites, which are claimed to enable restoration in increments of 4 or 5 mm, as recommended by the manufacturers, due to their higher depth of curing [7]. The time reduction and improvement of convenience are some of the advantages of this particular material class which shows low shrinkage stress [8], low elastic modulus [9] and easy adaptation to the cavity due to its flow consistency.

The aim of the present study was to evaluate the fracture strength of weakened bovine teeth reinforced with bulk-fill flowable composite and glass fiber post. The null hypothesis was that there is no significant difference in fracture strength of the roots reconstructed with either cast post or glass fiber post associated with bulk-fill flowable composite or microhybrid restorative.

Materials and Methods

Tooth preparation

Bovine incisors were collected, cleaned, disinfected in 0.1% thymol solution and then stored in saline until use. Root length, mesiodistal, and buccolingual diameters at the cemento-enamel junction (CEJ) of the collected teeth were measured with a digital caliper (Mitutoyo digital caliper, Mitutoyo Corp, Kawasaki, Japan). Teeth (n = 30) with similar root sizes and lengths were selected. The overall range of root dimensions (mesiodistally /buccolingually) of all selected teeth measured at the CEJ was 6.56 (\pm 0.40) mm. The crowns of the teeth were sectioned above the cemento-enamel- junction (CEJ) with a diamond double-faced disk (KG Sorensen, Barueri, SP, Brazil) in a slow-speed hand piece under water coolant in order to obtain a root height of 17 mm.

Crown-down technique was used for the endodontic treatment. The working length was set 1 mm short of the apex. Gates-Glidden drills (sizes 6-3, Dentsply Maillefer) were used to instrument the cervical and middle thirds and stainless-steel K-files (Dentsply Maillefer) were used to instrument the apical third, under constant irrigation with 2.5% NaOCl. Apical patency was maintained throughout the procedure with a size 15 K-file (Dentsply Maillefer). In each canal, the smear layer was removed using 17% EDTA. The canals were dried and then filled with gutta-percha cones (Dentsply Indústria e Comércio Ltda., Petropolis, RJ, Brazil) and Sealer 26 resin cement (Dentsply Indústria e Comércio Ltda., Petropolis, RJ, Brazil) using the lateral condensation technique.

Teeth were then stored at 37°C and 100% humidity for 24 hours. Gates-Glidden drill (size 3) removed 12 mm of gutta-percha and 4.0-mm-thick gutta-percha layer was left for apical sealing. To simulate a flared canal, the root canals were enlarged with high-speed diamond burs (sizes 1018 and 4138, KG Sorensen, Industria e Comercio Ltda, Sao Paulo, SP, Brazil) followed by a low speed bur (DB 14; Renfert, Hilzingen, Germany), leaving approximately 1 mm of dentin thickness at the cervical margin. The remaining thickness was confirmed with a digital caliper [10].

Root surfaces were dipped into melted wax (Horus, Herpo Produtos Dentários, Petrópolis, RJ, Brazil) up to 3.0 mm below the CEJ resulting in a 0.2 to 0.3 mm thick wax layer to act as a spacer. Then, the roots were centrally embedded in polystyrene resin (Cristal, Piracicaba, SP, Brazil) along their long axis using polyvinylchloride (PVC) cylinders as molds. After setting of the resin, the wax was removed using warm water. The roots were removed from the PVC cylinders which were filled with the polyether impression material (Impregum TM Soft, 3M/ESPE AG, Seefeld, Germany) to simulate the periodontal ligament [11] and then the roots were re-inserted into the respective cylinder ‘sockets’.

Specimen Grouping

The weakened roots (n = 30) were equally divided into three groups according to there in forcing technique used.

Group I: Cast metal post-and-core (n = 10)

The cast posts and cores 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 acrylic resin (Duralay, Reliance Dental Manufacturing Company, Chicago, IL, USA). The core was built up to a height of 5.0 mm. A standardized notch was placed across the palatal surface of each crown 3 mm from the incisal edge for load application in the mechanical tests. A Ni-Cr alloy (Kromalit, Knebel, Porto Alegre, RS, Brazil) was used to cast the post and core patterns which were luted in the canals with (All Cem Core, FGM, Joinville, SC, Brazil) resin cement, following the manufacturer's instructions. An impression of the cast metal core was made using a silicone material (Elite transparent, Zhermack, RO, Italy) in order to obtain a mold to guide the subsequent fabrication of the coronal portions of the specimens from this group and the other groups.

Group II: Bulk-fill reinforcing technique (n = 10)

Scotchbond Universal adhesive (3M/ESPE) was applied onto the canal walls using a microbrush applicator and rubbed for 20s. The excess was removed with paper points and a gentle stream of air was directed over the liquid for about 5s. Curing was done for 20s. The canals were filled with a bulk-fill flowable composite shade A1 (Filtek Bulk-Fill, 3M ESPE) and then a light transmitting fiber post Exacto size 2 (Angelus, Londrina, PR, Brazil) previously lubricated with hydrosoluble gel was inserted in the canal and curing was done on top of the fiber post for 60 s using light curing unit (1,200 mW/cm², Optilight Max, Gnatus, Ribeirão Preto, SP, Brazil). The post was removed and the light activation was completed for 40s. Then, the same fiber post was luted with All Cem Core resin cement. The coronal portion was built-up with the same material using the silicone mold obtained from the impression of the cast metal core as described for group I.

Group III: Direct anatomic post (fiber post relined with composite resin), (n = 10)

The direct anatomic post was fabricated using the method described by Grandini and others [12]. After lubricating the canal walls with hydrosoluble gel, the fiber post Exacto size 2 (Angelus, Londrina, PR, Brazil) was covered with resin composite (Filtek Z 350 XT, shade A1, 3M ESPE) and inserted into the canal. The resin composite was photoactivated for 10 sand the post-resin composite was removed from canal and light activation was completed for 60s. Copious rinsing was used to remove the lubricant gel from the canal. The post was luted with All Cem Core resin cement. The core was built-up as described for Group GII. Materials used for root reinforcement are listed in Table 1.

Material (Manufacturer)	Description	Composition and batch number
Filtek Bulk Fill Flowable Restorative (3M/ESPE)	Light-cure flowable composite	BisGMA, UDMA, Bis-EMA and Procrylat resins. The fillers are a combination of zirconia/silica and ytterbium trifluoride. The inorganic filler loading is approximately 64.5% by weight (42.5% by volume). (M721690)
All Cem Core (FGM, Joinville, SC, Brazil)	Dual-cured resin cement	Base: TEGDMA, Bis-EMA, Bis-GMA, camphorquinone, co-initiators, glass microparticles of barium - aluminum silicates, silicon dioxide nanoparticles, inorganic pigments and preservatives. Catalyst: methacrylate monomers, dibenzoylperoxide, stabilizers and barium-aluminum-silicate glass microparticles (151015)

ScotchbondUniversal adhesive (3M/ESPE)	Light-cure total-etch and self-etch adhesive system	MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond™ Copolymer, Filler, Ethanol, Water, Initiators, Silane (582957)
Exacto post (Angelus, Londrina, PR, Brazil)	Post	Glass fiber (80%), epoxy resin (20%) (11409112)
Filtek Z 350 XT (3M/ ESPE)	Resin composite	Bis-GMA, UDMA, TEGDMA and Bis-EMA resins. The fillers are a combination of silica, zirconia and zirconia/silica cluster filler (N726058)

Table 1: Materials used for root reinforcement.

Fracture Strength Testing

The specimens were placed in a specially fabricated jig and were subjected to a compressive load on the palatal surface of the cores at 135° to the long axis of the teeth (Figure 1) using a universal testing machine (Kratos, K 2000) at a crosshead speed of 0.5 mm/min until fracture occurred. The maximum load required to cause fracture was recorded for each specimen. After testing, the failure mode was classified under microscope analysis. Root fractures at the cervical third or displacement of the nucleus were classified as favorable, while fractures at the middle and apical thirds were classified as unfavorable. Favorable fractures are the ones which are repairable and would allow a new restoration, while the unfavorable fractures are those which are non repairable and would condemn the tooth to extraction.

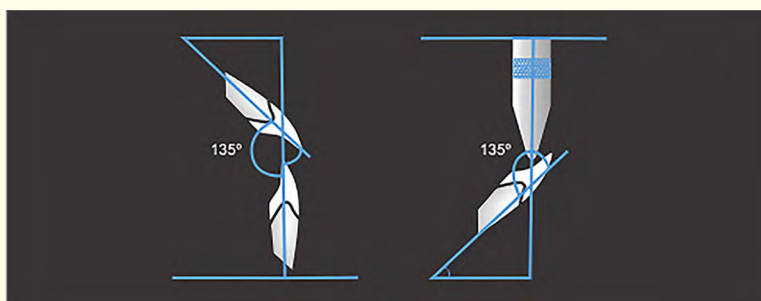


Figure 1: Device positioned for load application.

Statistical Analysis

Shapiro-Wilk test showed that the data were normally distributed. The homogeneity of variance was tested using the Levene test and one-way ANOVA was used to compare fracture resistance of the groups. The significance level was 5%. (SPSS, V21, Chicago, USA).

Results

Table 2 shows fracture strength data (N) for each group according to the reinforcing technique used. GI and GII showed the highest fracture strength mean values, but the results of the one-way ANOVA test indicate that there is no statistically significant difference among the groups (p = 0.406). GI presented 100% of unfavorable fractures, while GII and GIII’s fractures were classified as favorable. Modes of failure of each group are presented in Table 3.

Experimental Group	Mean	Standard Deviation
Cast metal post-and-core (GI)	558.51	82.2
Bulk-fill reinforcing technique (GII)	555.30	116.5
Direct anatomic post (GIII)	503.33	100.1

Table 2: Mean fracture resistance (N) and standard deviation values of experimental groups (n = 10).

	Fracture Plane Location		
	Favorable	Unfavorable	
	C	M	A
Cast metal post-and-core (GI)	0	6	4
Bulk-fill reinforcing technique (GII)	10	—	—
Direct anatomic post (GIII)	10	—	—

Table 3: Modes of failure among the tested groups

Abbreviations: C: cervical, M medium, A: apical.

Discussion

The null hypothesis tested in the present study was accepted, as post systems and restorative techniques did not influence the fracture strength of weakened roots. Cast posts and fiber posts associated with bulk-fill flowable composite or microhybrid restorative, when used in flared root canals, resulted in similar fracture strength values. The predominant failure mode for the cast metal post-and-core group was unfavorable fractures, while those for the groups reinforced with fiber post and bulk-fill flowable composite or microhybrid restorative were favorable fractures. The reported mode of failure for cast metal posts and fiber posts corroborates other studies [4,6,10,13-16].

Previous studies [10,17- 20] and the present study were common in that no crown restorations were made for teeth since artificial crowns could alter the distribution and transmission of stresses into a post-root complex [21] masking the reinforcing effect of tested approaches [19]. Although the test conditions are not identical to the clinical situation, they allow the comparison of different materials within given standards [17]. The impact of completed crowns should be considered in further laboratory studies [19].

Some previous studies [14,15] showed that metallic dowels provide higher strengths than fiber dowels. However, in the current study, there was no significant differences between the groups. The cast dowels resisted greater forces but led to stress concentrations, mainly in the middle and apical third, leading to “catastrophic” fractures, while relined dowels provided adequate fracture resistance with increased incidence of repairable fractures [15] as seen in the present study. Research [4] confirmed the highest fracture resistance provided by the cast dowel group, but 90% of the specimens had non repairable fractures.

The objective of the dowel relining technique is to reduce the cement thickness in the clinical situations of flared root canals, thus minimizing the polymerization shrinkage stresses [14,22]. A study [4] concluded that the method did not increase the fracture resistance, however, the incidence of non repairable fracture was significantly less than the cast metal group. Despite weakened roots, the fiber dowel/dowels, resin cement and composite resin act as a single unit along with the root dentin helping to spread the forces. Other studies [23,24] corroborate the importance of glass fiber-reinforced dowels relined with composite resin in weakened roots. Amin., *et al.* [24] found out that the group restored with glass fiber-reinforced dowels relined with composite resin in flared root canals showed significantly higher fracture strength values than the group restored with glass fiber-reinforced dowels and a thick layer of luting cement.

A study [6] investigated if fiber posts would lead to a lower risk of post debonding and a lower risk of root fracture. A 3D finite element model of a premolar restored with a metallic or a fiber post was used to analyse stress. The lower elastic modulus of the glass fiber post (9.5 GPa) led to lower stresses in the post/cement interface compared with a metallic post (200.0 GPa), thus, resulting in a reduced risk of debonding. When the post/cement bond failed, root stresses in the glass fiber post were higher than in the metallic cast post restored tooth. However, the glass fiber post restored root would still be less prone to fracture, because the fracture risks of the composite core and the post were higher than those of the root. It may explain the reason that in the present study both groups that used fiber posts associated with composite resin to reinforce the weakened roots showed 100% of favorable fractures.

Another finite element analysis study [25] tested the effect of different restorative techniques on stress distribution in roots with flared canals. The authors concluded that the use of composite resin to increase the thickness of the root walls produced less stress towards the remaining root dentin structure but still showed higher total stress accumulation values at dentin when compared to the anatomic post model. Anatomic posts maintained the stress inside the post body and produced less stress towards the remaining root structure. Therefore, the authors stated that anatomic posts may safely be used in roots with flared canals.

Some studies [20,26,27] have compared the fracture strength of non-weakened roots with weakened roots and the results have revealed that non-weakened roots show significantly higher fracture strength values than the weakened roots reinforced with different intraradicular posts. The healthy remaining radicular dentin is more important to increase fracture resistance than the root reinforcement protocol. Roots restored with custom cast cores are significantly affected by the remaining dentine thickness [27]. A previous study [28] showed that the fracture strength of the weakened roots reinforced with composite resin or direct anatomic post was similar to the non-weakened roots restored with a prefabricated fiber post. Seyam and Mobarak [19] concluded that the fracture resistance of weakened roots reinforced with resin composite, cured by a modified layering technique, and fiber posts was comparable to the non-weakened roots, reinforced with fiber posts and resin cement.

A study [10] evaluated the fracture strength of flared bovine roots restored with different intraradicular posts. This study and the present study was common in that the fracture strength of the cast metal post-and-core group was similar to that of the anatomic post group and the second group presented 100% of favorable fractures.

El-Damanhoury and Platt [29] assessed the polymerization shrinkage stress kinetics of three high viscosity and two low viscosity bulk-fill resin composites and a microhybrid restorative. The results showed that the shrinkage stress of all bulk-fill materials were significantly lower than those of the microhybrid restorative except for one high viscosity bulk-fill composite. All tested bulk-fill materials achieved acceptable curing efficiency at 4-mm depth. Another study [30] compared a bulk-fill flowable composite (Filtek Bulk-Fill), the same composite used in the current study, with a conventional packable composite (Filtek Z250) and the results showed that the bulk-fill flowable composite produced lower polymerization stress when used as a base material. It demonstrates that although bulk-fill flowable composites show higher polymerization contraction than the conventional composites [31], they produce lower polymerization stress [29] due to their lower modulus of elasticity [9] and greater exotherm during polymerization, inducing a significant thermal expansion [30].

Reinforcing weakened roots with the bulk-fill technique, undoubtedly, simplifies the restorative procedure and saves clinical time. The bulk-fill flowable composite can be inserted in the root canal in an injectable way, decreasing the risk of bubble formation. This material shows easy adaptation to the internal root walls. The use of thicker increments in bulk-fill resin composites is due to both developments in photoinitiator dynamics and their increased translucency [32], which allows additional light penetration and a deeper cure [7,33]. Such characteristics are very important when this material is used in the root canal and they may have contributed to reinforce the weakened roots.

Based on this study, reinforcement of weakened roots was achieved with bulk-fill flowable composite associated with fiber post that were applied using the new approach presented in the current study. Nevertheless, further long-term in vivo and in vitro studies with human teeth are still required.

Conclusion

Within the limitations of this in vitro study, it can be concluded that the use of bulk-fill flowable composites can also be an alternative to metal cast posts and it seems to be a promising approach for practitioners.

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Conflict of Interest

No financial interest or any conflict of interest exists.

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