

***In vitro* Evaluation of Fracture Resistance of Endodontically treated Teeth restored with Bulk-fill, Bulk-fill Flowable, Fiber-reinforced, and Conventional Resin Composite**

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ABSTRACT

Aim: This original research was carried out to assess the susceptibility to fracture of root canal treated teeth with composite postendodontic restorations.

Materials and methods: Seventy-two sound human mandibular premolar teeth, extracted for various reasons, were selected. For experimental purposes, they were then divided into six groups (n = 12). Groups I and II were designated the negative control (no preparation done) and positive control (cavity preparation was done but left unrestored) respectively. In all other teeth, mesio-occluso-distal (MOD) cavities were prepared, and they were then root canal treated. The other groups were also restored with the respective resins: group III: condensable bulk-fill composite, group IV: bulk-fill flowable resin composite, group V: fiber-reinforced composite, and group VI: conventional resin-based composite. Manufacturer-recommended adhesive systems for respective restorative resins were used.

To avoid desiccation of the specimens, they were kept in distilled water for 24 hours at body temperature. The specimens were then subjected to compressive loads until they fractured. Statistical analysis was performed using analysis of variance (ANOVA) and *post hoc* Tukey tests.

Results: Statistically significant results were observed among all groups. The highest and lowest values were noted with groups I and II respectively ($p = 0.05$).

Conclusion: The resistance to fracture in root canal-treated teeth with everX Posterior, fiber-reinforced bulk-fill composite was the highest.

Keywords: Bulk-fill composites, Endodontically treated, Fracture resistance, Resin-based composites.

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INTRODUCTION

Compromising sound tooth structure due to various reasons, such as removal of caries, cavity preparations, and trauma, in turn, decreases the fracture resistance of tooth.^{1,2} Literature is controversial regarding the loss of moisture content in dentin and fracture susceptibility in root canal-treated teeth nowadays.³

We, during access cavity preparations and cleaning and shaping of the root canals, do compromise the anatomic structures like the occlusal marginal ridges which lead to tooth fragility.³ The amount of residual coronal and radicular dentin decides the success or prognosis of the endodontically treated teeth.

Hence, it is always a challenging task for the operators to effectively restore an endodontically treated teeth with extensive loss of tooth structure.⁴ Endodontically treated teeth can be restored using both indirect and direct restorations, such as inlays, onlays, crowns, postretained restorations, amalgam restorations, gold restorations, and, last but not least, resin-based composite restorations.

The main advantages of resin-based composite restorations over the other above-mentioned procedures are that they require minimal tooth preparations, and the entire restorative procedure could be completed in one single appointment and also they are cost-effective.⁵ Resin-based composites since their introduction in dentistry five decades ago,^{6,7} are marketed as various products.

Hence, it becomes mandatory to determine which materials are useful in determining the better survival of the endodontically treated teeth and thus, a successful outcome. The main disadvantage of the resin-based composite is polymerization shrinkage. Placing conventional composites incrementally has been advocated to overcome polymerization shrinkage.

The incremental layering technique suggests placement of resins in thickness of 2 mm. This is time-consuming. The other significant disadvantages of this include increased risk of contamination between layers, and also the inclusion of voids in the restoration.^{8,9} The chemistry of the polymers can be altered, and newer layering techniques were adopted thereby counteracting the polymerization shrinkage.

This led to the novel idea of low shrinkage composites.¹⁰ This consumes less time because a 4 mm thickness

composite resin can be placed in one or two layers and cured.¹¹⁻¹³ Esthetics and bulk-fill composite restorations go hand in hand with the use of various opaque and translucent shades.

Such esthetic shade match makes the restoration mimic the natural tooth structure and can rival the all-ceramic restorations. Bulk-fill materials are present in unidoses, syringes, or tubes. Based on their filler content and incorporation of fibers, the bulk-fill composites are classified into various types.

There are not many studies available to know about the fracture resistance of endodontically treated teeth restored with fiber-reinforced, condensable bulk-fill resin composites and conventional resin-based composites.¹⁴ The current study was aimed to evaluate the fracture resistance of endodontically treated teeth restored with bulk-fill, bulk-fill flowable, fiber-reinforced, and nano-hybrid composites to gain knowledge about the same.

The null hypothesis was that there would be no statistically significant differences in the fracture resistance of endodontically treated teeth.¹⁵

MATERIALS AND METHODS

Seventy-two sound human mandibular premolars extracted for various purposes were used for the study. Any calculus and soft tissue deposits were removed from the teeth using a hand scaler (H6, H7, Hygienist Scaler, Hu-Friedy, Europe).

The selected teeth were examined under a light microscope (Micron DPTIK, Micron Instrument Industries, India) at 20× magnification for any existing enamel cracks or fractures. The samples were stored in distilled water (Sankalp Scientific & Associates, Nagpur, India) at 37°C for up to 1 month before use. Class II MOD cavities were prepared with a new # 2 diamond bur (SS White, Lakewood, USA) that were replaced after every cavity preparation in such a way that the gingival floor was 1.0 mm above the cemento-enamel junction. Standard cavity preparation protocols were followed and the same were verified with a divider.

Endodontic access cavities were prepared using a high-speed handpiece (KaVo LED fiber-optic high-speed handpiece, Columbia, USA). Working length determination was done using a size 10 K (Mani Inc, Tochigi, Japan).

The cleaning and shaping of root canals were done by using ProTaper rotary instruments (Dentsply-Maillefer, Ballaigues, Switzerland) up to master apical rotary size F3 (#30), in conjunction with 2 mL of 5.25% sodium hypochlorite (Sodium Hypo Vishal, Bangalore, India) irrigation between each file.

Debridement of the prepared root canals was done by rinsing with 5 mL of 17% ethylenediaminetetraacetic acid (M D Cleanser, Meta Biomed), followed by 5 mL of distilled water. The root canals were then dried using

paper points (SS White, Lakewood, USA). After that, the roots were filled with ProTaper F3 gutta-percha and AH Plus (Dentsply DeTrey, Konstanz, Germany) epoxy resin-based root canal sealer by single-cone technique.

The coronal gutta-percha was removed and the canal orifices were sealed with a heated instrument, and samples were stored in 100% humidity for 7 days to allow the sealer to set. The canal orifices were then sealed with a thin layer of resin-modified glass ionomer cement (Novaseal, President Dental, Munich, Germany). A universal metal matrix band/retainer (Tofflemire, Dentsply Sirona, Pennsylvania, United States) was placed around each prepared tooth.

The teeth were divided into six groups of 12 teeth, as follows:

Group I: Negative control. Includes natural teeth without any cavity preparation.

Group II: Positive control. The MOD cavities were prepared but left unrestored with any restorative material.

Group III: Condensable bulk-fill composite (Tetric N Ceram, Ivoclar Vivadent). Total-etch dentin bonding system was used for adhesive procedures with Tetric-N Bond (Ivoclar Vivadent) adhesive system. The solvent was air-dried for 5 seconds and then light cured for 10 seconds using C8 Blue Phase light curing unit.

Group IV: Flowable bulk-fill composite (Beautiful Bulk, Shofu). Clearfil SE Bond (Kuraray Medical, Japan) was applied according to the manufacturer's instructions and light cured for 10 seconds. The cavities were filled with bulk-fill flowable composite (Beautiful Flow) at up to 4 mm in thickness and were then cured for 40 seconds.

Group V: Fiber-reinforced bulk-fill composite (everX Posterior, GC Corp). A one-step self-etch adhesive, G-aenial Bond (GC Corp, Tokyo, Japan), was applied, and teeth were then dried for 5 seconds under maximum air pressure and light-cured for 10 seconds. Fiber-reinforced composite (GC everX posterior, GC Corp) measuring approximately 4 mm in thickness was placed and the resin composite was cured for 40 seconds.

Group VI: Conventional resin-based composite (Filtek Z 250, 3M ESPE). Adper Single Bond Universal Adhesive (3M ESPE) was applied according to the manufacturer's instructions and light cured for 10 seconds. The cavities were restored with a conventional resin composite, Filtek Z 250, (3 M ESPE), incrementally. Each layer was 2 mm thick and was light-cured for 40 seconds.

The materials for the restorative procedures are listed in Table 1.

Finishing was achieved under air/water spray using diamond finishing burs (SS White) at high speeds. Subsequently, polishing was completed with Shofu Mini Polishing Kit (Shofu, Inc, Kyoto Japan). The specimens were stored in distilled water at 37°C for 24 hours.

Table 1: Materials used in the study

Product name	Type	Manufacturer	Composition
Tetric N Ceram	Condensable bulk-fill composite	Ivoclar Vivadent AG, Schaan, Liechtenstein	Bis-GMA, DMA, barium aluminosilicate glass, prepolymer filler, 80% by wt. of filler load
Beautiful Bulk	Flowable bulk-fill composite	Shofu, Inc, Kyoto Japan	Bis-GMA, UDMA, bis-MPEPP, TEGDMA, S-PRG filler based on fluoroboroaluminosilicate glass, polymerization initiator, 73% by wt. of filler load
EverX Posterior	Fiber-reinforced bulk-fill composite	GC Corporation, Tokyo, Japan	Bis-GMA, TEGDMA, PMMA, hybrid filler fractions and E-glass fibers, 74% by wt. of filler load
Filtek Z 250	Conventional resin-based composite	3M ESPE, ESPE, St. Paul, MN, USA	Inorganic fillers, bis-GMA, UDMA, bis-EMA, procrylat resins, 70% by wt. of filler load

Bis-GMA: Bisphenol A glycidyl methacrylate; DMA: Dimethacrylate; UDMA: Urethane dimethacrylate; Bis MPEPP: 2,2-bis [(4-methacryloyloxy polyethoxy) phenyl]propane; TEGDMA: Triethylene glycol dimethacrylate; S-PRG: Surface pre reacted glass ionomer; PMMA: Poly methyl methacrylate; bis EMA: Ethoxylated bisphenol A glycol dimethacrylate; wt: weight

The root surfaces were filled with a thin coat of poly-vinyl siloxane impression material (Aquasil, Dentsply Chaulk) to simulate the periodontal ligament and the teeth were stabilized in a block of self-cure acrylic resin. Fracture resistance was evaluated in a Universal Testing machine (Instron 44BG, Lloyd, UK).

Fracture resistance was evaluated by placing the self-cure acrylic resin blocks between two rectangular steel blocks in contact with the occlusal slopes of buccal and palatal cusps, and an occlusal load was applied perpendicular to the long axis of the tooth. The load was applied until fracture occurred and was recorded in Newtons.

Means and standard deviations were determined for each group, and data were statistically analyzed with ANOVA followed by the *post hoc* Tukey tests. Analyses were carried at the 5% significance level using Statistical Package for the Social Sciences version 16 for Windows (SPSS Inc, Chicago, Illinois, USA). The fractured specimens were examined under a stereomicroscope (403) to evaluate the fracture patterns, which were classified as follows¹⁶:

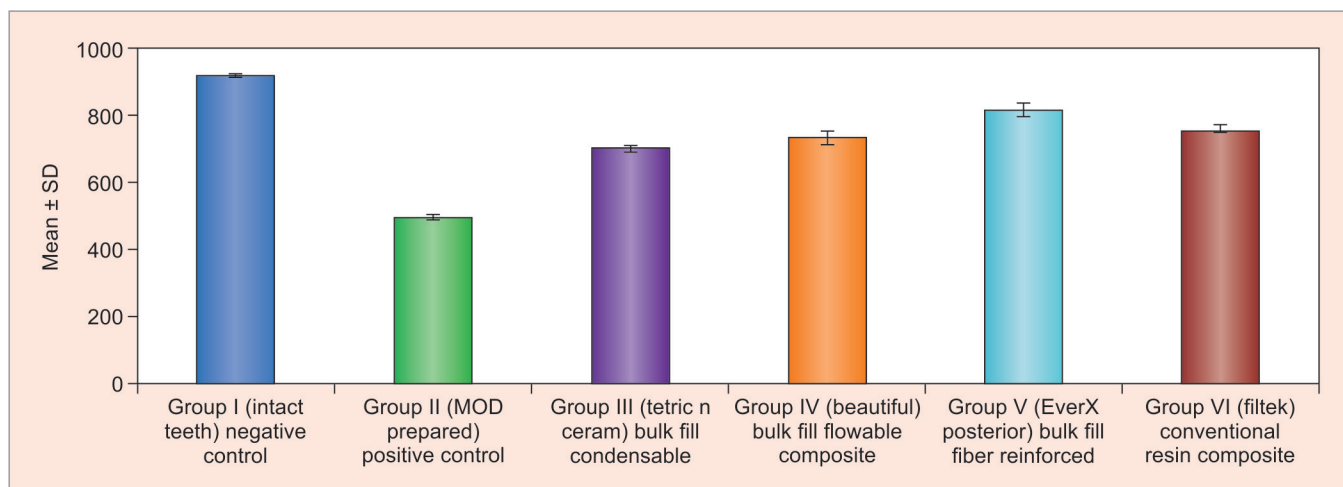
- Mode I: Minimal destruction of teeth
- Mode II: Fracture of one cusp, intact restoration
- Mode III: Fracture of at least one cusp, involving up to one-half of restoration
- Mode IV: Fracture of at least one cusp, involving more than one-half of restoration; and
- Mode V: severe fracture, involving tooth structure completely or longitudinal fracture.

RESULTS

The mean fracture resistance values (N) and the standard deviations for each group are presented in Table 2. The graphical representation of the same is depicted in Graph 1. The negative control (923.7 N) showed higher fracture resistance and the positive control group (499.8 N), the lowest.

Table 2: Mean fracture resistance values (N) and the standard deviations for each group

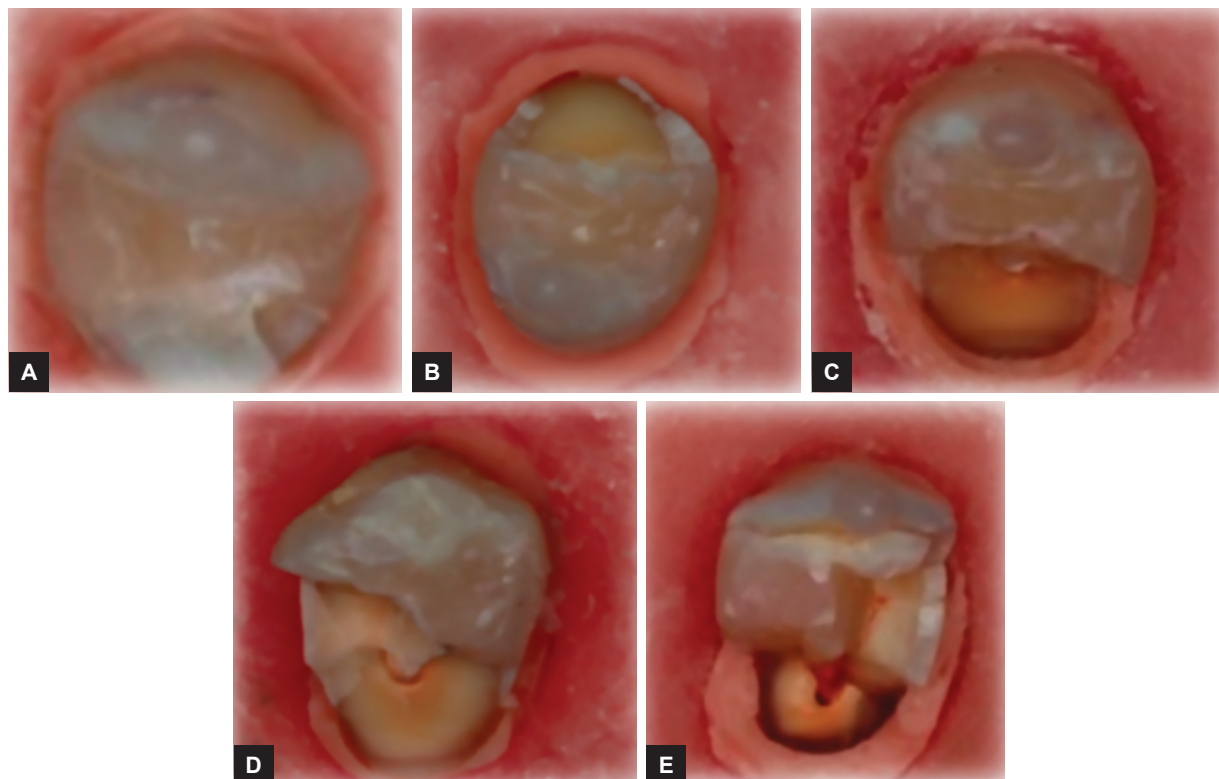
Groups	n	Mean	Std dev
Group I (intact teeth) negative control	12	923.720	5.0460
Group II (MOD prepared) positive control	12	499.892	6.3981
Group III (Tetric n Ceram) bulk-fill condensable	12	703.200	8.3675
Group IV (Beautiful) bulk-fill flowable composite	12	736.558	20.3588
Group V (EverX posterior) bulk-fill fiber-reinforced	12	821.933	19.7842
Group VI (Filtek) conventional resin composite	12	761.208	8.3149



Graph 1: Fracture resistance graph

Table 3: Failure modes among the experimental groups

Restored groups	Mode I	Mode II	Mode III	Mode IV	Mode V
Group I (intact teeth) negative control	9	2	1	–	–
Group II (MOD prepared) positive control	–	–	2	4	6
Group III (Tetric n Ceram) bulk-fill condensable	–	4	3	2	3
Group IV (Beautiful) bulk-fill flowable composite	5	2	2	3	–
Group V (EverX Posterior) bulk-fill fiber-reinforced	–	8	1	–	3
Group VI (Filtek) conventional resin composite	2	1	4	1	4



Figs 1A to E: Images of different fracture modes. (A) Mode I fracture; (B) mode II fracture; (C) mode III fracture; (D) mode IV fracture; (E) mode V fracture

Table 3 illustrates the fracture pattern of the restored groups.

In most cases, of fiber-reinforced bulk-fill composites mode II (fracture of one cusp, intact restoration) was observed.

Representative images of different fracture modes are shown in Figure 1. In most cases, mode II (fracture of one cusp, intact restoration) was observed for everX posterior fiber-reinforced bulk-fill composite group.

DISCUSSION

In the present study, significant differences were found in fracture resistance among different direct restorative materials. Therefore, the null hypothesis is rejected. Endodontically treated teeth are weakened due to decreased or altered tooth structure attributed to caries and previous restorations, fracture or trauma, endodontic access and instrumentation which leads to reduced moisture.

Earlier schools of thought considered that placement of posts was beneficial to the compromised tooth structure, but postpreparation can significantly weaken the root and ultimately lead to root fracture which leads to patient dissatisfaction.

Hence, selection of the postendodontic restorative material is of prime importance as the material properties of direct restorations influence the fracture toughness.^{17,18}

So, in this study, fracture resistance was taken as a criterion. Filler content plays a significant role in the depth of cure possible with the bulk-fill composites.

The higher the filler content, the greater the depth of cure. An increase in the filler content, in turn, decreases the volume of resin matrix for polymerization¹⁹ and also increases hardness.²⁰ An increase in the filler content would reduce polymerization shrinkage.

Fracture of the restoration mainly depends on the composition and filler content of resin composites and their elastic modulus.²¹ In this experimental study,

negative control group showed highest fracture resistance which is consistent with the studies conducted earlier^{22,23} reporting that restored teeth had significantly lower resistance to fracture.

In Tetric N Ceram bulk-fill, in addition to camphorquinone/amine initiator system, it has introduced an "initiator booster" (Ivocerin) able to polymerize the material in depth. However, not much of literature is available that concerns with the polymerization mechanism or the chemical nature of the initiator.

This might be a reason for the lowest fracture resistance of Tetric N Ceram among the tested groups of bulk-fill composites. The results of the present study show that there was a significant difference in the fracture resistance of endodontically treated teeth restored with flowable bulk-fill resin composite. This may be due to the higher filler load content in them, in spite of their low viscosity characteristics.

The resin-based composites have a higher fracture resistance mean value than the flowable bulk-fill composites, but the values were not statistically different from that of the flowable bulk-fill composites.

These findings are in agreement with those of a previous study,²⁴⁻²⁶ who reported increased fracture resistance of endodontically treated premolars restored with Smart Dentin Replacement flowable bulk-fill composites. Among the tested groups, fiber-reinforced bulk-fill composites showed the highest fracture resistance.

A study conducted by Garoushi et al²⁷ explains that the mere insertion of fibers does not enhance the fracture resistance properties, but its length and diameter play a vital role.²⁸

The fiber length and diameter of everX Posterior using stereomicroscope and scanning electron microscope showed that they have a diameter of 16 μm and a wide range of fiber length, with the average lying between 1 and 2 mm, thus exceeding the fiber length required.²⁷ The fiber length and orientation is in Figure 2. Because of the fiber length and the critical direction of the fibers, they showed highest fracture resistance among the tested groups of this study.

And also, in the present study, the mean fracture resistance values of teeth restored with everX Posterior fiber-reinforced resin were significantly different from those of teeth restored with other restorative materials (Fig. 2).

Microscopic image of everX Posterior showed fiber length extending to the range of 1 mm and up to 2 mm. In the present study, the majority of fractures, with everX Posterior bulk-fill composites were type II, i.e., they were defined as restorable which is in contrast with the study results of Yasa et al¹⁵ and Toz et al.³⁰



Fig. 2: Microscopic image of EverX posterior showing fiber length extending to the length of 1 mm and up to 2 mm

CONCLUSION

Within the limitations of this study, the fracture resistance of teeth restored with everX Posterior, fiber-reinforced bulk-fill composite was the highest. But compared with the intact teeth, the restored teeth had a lower fracture resistance. Further *in vivo* studies may double validate the results.

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