Comparison of fracture resistance of endodontically treated mandibular first molars restored with different reinforcing materials with and without cusp capping

Vaishnavi J Singh, Shivkumar P Mantri, Bonny Paul, Kavita A Dube, Nishikumari Gupta, Sayantani Ghosh

Department of Conservative Dentistry and Endodontics, Hitkarini Dental College, Jabalpur, Madhya Pradesh, India

ABSTRACT

Aim: This study aims to estimate and compare the fracture resistance of endodontically treated mandibular first molar restored with reinforced composite resin or cusp capping.

Materials and Methods: Seventy-five freshly extracted intact mandibular molars were randomly divided into five groups. The teeth were embedded vertically into the self-cure acrylic lined with elastomeric impression material to a level 1 mm apical to the cement-enamel junction. Group 1 included intact teeth. After access preparation in Groups 2–5, canals were negotiated with 10 K file, cleaned shaped using K3XF NiTi rotary files, 17% Ethylenediaminetetraacetic acid, and 3% sodium hypochlorite. After drying, the canals were obturated with gutta-percha and Sealapex sealer. Group 2 teeth were restored using Cavit. In Groups 3–5, the access cavity floor was lined by resin-modified glass-ionomer cement. After etching, rinsing, and bonding, teeth were restored. Group 3 teeth with everX posterior as a base and 1.5 mm of occlusal nanohybrid composite. Group 4 teeth were restored with nanohybrid composite after bonding Interlig fiber circumferentially in the access cavity. In Group 5, after 2 mm cusp reduction, etching, and bonding, teeth were restored by cusp capping using nanohybrid composite. All specimens were subjected to a fracture test. The peak-load fracture value in Newton was recorded.

Results: One-way analysis of variance test for intergroup comparison revealed a statistically significant difference between the groups ($P = 0.011$). *Post hoc* Tukey's test showed a significant difference ($P = 0.005$) between everX posterior and Cavit specimens. The Chi-square test results revealed that there is a significant difference ($P = 0.0276$) in the fracture pattern between the groups.

Conclusion: It is concluded that restoration using short fiber-reinforced composite improved the fracture resistance of endodontically treated mandibular molars. Cusp-capped teeth exhibited more favorable fractures. The combined use of fiber-reinforced composite and capping the cusps using nanohybrid composite could be a viable option to restore molar favorably.

Keywords: Composite resin, endodontically treated teeth, fracture resistance, mandibular molar

INTRODUCTION

Endodontically treated teeth are weakened due to loss of tooth structure, cusps, ridges, and the pulp chamber's arched roof. This structural loss is often a consequence of caries, trauma, access cavity preparation, and radicular preparation. Root canal-treated teeth have impaired normal protective reflex as a result of a reduced level of proprioception.[1,2] When pulp is removed during routine endodontic therapy, there is a loss of positive feedback mechanism, which contributes to fracture of teeth.[2]

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Address for correspondence: Dr. Shivkumar P Mantri, Department of Conservative Dentistry and Endodontics, Hitkarini Dental College, Dumna Airport Road, Jabalpur - 482 005, Madhya Pradesh, India.
E-mail: shivmantri24@gmail.com

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Root canal-treated teeth's long-term survival is determined not only by the endodontic treatment's effectiveness but also by the amount of residual dentin thickness and postendodontic reconstruction.[3]

Restoring endodontically treated teeth with suitable material that can resist fracture is a crucial consideration during postendodontic restoration. Drawbacks of the complex and indirect restorations include more treatment time and high cost.[4] However, with advances in adhesive technology, conventional materials are being replaced by resin-based materials.[5]

With advances in composite resin as minimally invasive preparation and maximal conservation of tooth structure, it is widely used in endodontically treated teeth.[6] The fracture strength of composite resin restoration reinforced with polyethylene and glass fibers shows significant improvements. Improvement is also achieved by the application of a fiber layer beneath the restoration.[7,8] EverX posterior (GC Company, Tokyo, Japan), a short fiber-reinforced composite (SFC) resin, has gained attention as a restorative material and is recommended to be used in high stress-bearing areas.[9,10]

The restoration of endodontically treated teeth has been extensively investigated. Despite extensive research, it has been not easy to arrive at a particular solution as to what type of restorative procedure gives the greatest success.[11]

The robust occlusion of the pointed, projecting maxillary molar palatal cusp into the mandibular molar central grooves[12] makes mandibular molars more prone to vertical fractures[13] and more likely to be extracted. The question of whether full cast crowns are required after endodontic treatment, particularly in the posterior teeth, has been disputed.[14]

The present study aims to evaluate and compare the fracture resistance of endodontically treated mandibular molar restored with Cavit, with fiber-reinforced composite, by using bonded braided glass fiber and nanohybrid composite, and by cusp-capping with nanohybrid composite.

MATERIALS AND METHODS

Seventy-five freshly extracted intact human mandibular first molars with complete root formation and similar dimensions were collected. The teeth were extracted for a periodontal reason. Any calculus, soft deposits, and soft tissue remnants were removed using a hand scaler, rinsed, and stored in 0.2% thymol. All the teeth were caries-free, without any previous restoration or cracks when observed under magnification and transillumination. All the teeth were used within 1 month from the time of extraction. The sample size was calculated considering the α value 0.05, $1-\beta$ value 0.8, and large effect size using G Power 3.1 software.

Specimen preparation

The teeth were dipped in molten wax to 1 mm apical to the cement-enamel junction (CEJ), which resulted in the formation of a wax layer. The self-curing polymethyl-methacrylate resin was mixed in a jar and poured into the custom-made mold. All the teeth were embedded vertically into the mold to a level 1 mm apical to the CEJ. After the resin had been set, the teeth were removed from the block, and wax was eliminated from the teeth and the base block. Elastomeric impression material was loaded in the resin block cavity, and the teeth were re-seated in position. The flash paste was trimmed with a blade.

Samples were randomly divided into five groups, one positive control (intact tooth without root canal procedure – Group 1) and four experimental groups (2–5). Each group had 15 samples.

Root canal procedure (Groups 2–5)

Standard endodontic access cavities were prepared in 60 teeth using a high-speed airotor handpiece (NSK Nakanishi Inc., Japan) with coolant and Endo Access Bur (Dentsply Maillefer, Switzerland). Access cavities were prepared such that 1.5 mm of tooth structure remained throughout the circumference. The coronal pulp tissue was removed with a spoon excavator, and canal patency was confirmed with 10 size k-file (Mani Inc., Tochigi, Japan). The canals were negotiated with 15 k-file till the apical foramen and working length is determined by subtracting 1 mm from this length. Root canals were prepared by K3XF NiTi rotary files (Sybron Endo, Canada) using Endomate DT Endomotor (NSK, Japan). Mesial canals were shaped till 25 (4%) and distal canals till 30 (4%). Seventeen percent ethylenediaminetetraacetic acid gel (RC-Help, Prime Dental Products; Thane, India) was used as a lubricant. Three percent sodium hypochlorite (Vishal Dentocare Pvt. Ltd. Ahmedabad, India) was used for irrigation. Final irrigation was done with distilled water. Canals were dried with paper points and obturated with gutta-percha cones and Sealapex sealer using cold lateral compaction technique. Access cavity was cleaned with cotton.

Postendodontic restoration

Access cavity in experimental groups was restored in the following way:

Group 2: The access cavities of the teeth in this control group were restored with temporary restorative material using Cavit, as clinically, teeth are not left open.

Group 3: Pulp chamber floor was layered with resin-modified glass-ionomer cement (GC Fuji II LC Capsule, GC Corporation). The surface of the cavity was etched with 37% phosphoric acid etching gel (Prime Dental Products; Thane, India) for 15 s and rinsed with water for 15s. The floor and walls of the cavity were gently blow-dried. The bonding agent G-bond (GC, India) was applied to all the cavity surfaces using a micro applicator tip and light-cured for 20 s. The cavity was restored with fiber-reinforced composite (everX Posterior, GC, India) as a base and occlusal 1.5 mm layer of Herculite précis (Kerr, Asia). Each layer was cured for 40 s.

Group 4: Pulp chamber floor was layered with resin-modified glass-ionomer cement (GC Fuji II LC Capsule, GC Corporation). The surface of the cavity was etched and bonded as described in Group 3. A strip of premeasured glass fiber Interlig® (Angelus) was bonded against the circumference of access cavity tooth structure with the help of a thin layer of flowable posterior composite (G-anial Universal Flo, GC India) and then, the entire access cavity was restored with nanohybrid composite (Kerr Herculite précis, Asia) using the incremental technique. Interlig® consists of glass fibers pre-impregnated with light-curable composite resin arranged in a braided design.

Group 5: Pulp chamber floor was layered with resin-modified glass-ionomer cement (GC Fuji II LC Capsule, GC Corporation). Teeth were prepared for cusp capping by 2 mm cusp reduction. The cavity and prepared tooth surface were etched and bonded as described in Group 3 and restored with nanohybrid composite (Herculite précis, Kerr) using the incremental technique.

Fracture resistance testing

All the samples were fixed with the help of a clamp and positioned in a universal testing machine. A 5 mm diameter round tip stainless steel metal rod was positioned over the occlusal surface parallel to the teeth' long axis. The compressive force was applied to the center of the sample at a crosshead speed of 1 mm/min. The peak-load fracture was recorded in Newtons (N) for each sample.

The data were tabulated and entered in spreadsheet Microsoft Excel 2007, which was then exported to the data editor page of SPSS version 20.0 (SPSS Inc., Chicago, Illinois, USA).

RESULTS

The test of normality showed data to be normal. Hence, parametric tests such as one-way analysis of variance (ANOVA) and Tukey's *post hoc* test were applied. The level of significance was set at 0.05.

The one-way ANOVA test for intergroup comparison revealed a statistically significant difference between the experimental groups ($P = 0.011$). *Post hoc* Tukey's test for intragroup comparison showed a significant difference ($P = 0.005$) between the everX posterior and Cavit interim restoration group. There was no significant difference among Interlig®, everX posterior group, and cusp capping group [Table 1 and Figure 1].

The Chi-square test results revealed that there is a significant difference ($P = 0.027605$) between the groups [Table 2 and Figure 2].

DISCUSSION

Despite advancements in material sciences and with the concept of minimally invasive procedures, composite resins are still not commonly used for extensive restorations or in high stress-bearing areas. Composite resins are reinforced with microglass fibers, a fiber-reinforced substructure, whiskers, and particulate ceramic fillers to improve their mechanical properties.[15] It acts as crack stoppers and enhances the property of composite.[16] Kevlar, carbon, glass, ultra-high-molecular-weight polyethylene (UHMWPE), and silane-treated glass have been used to provide fiber reinforcement.[17] Currently, the most popular fiber types are UHMWPE and glass.

EverX posterior, a SFC resin, has been recommended to be used in high stress-bearing areas.[10] It is designed to replace dentine in large cavities. The transfer of stresses from the polymer matrix to the fibers is vital for the optimal reinforcement of the polymers. This, in turn, is a function of the critical fiber length. Multidirectional and discontinuous short glass fibers prevent crack propagation in the material and provide an isotropic reinforcement effect.[18] In the

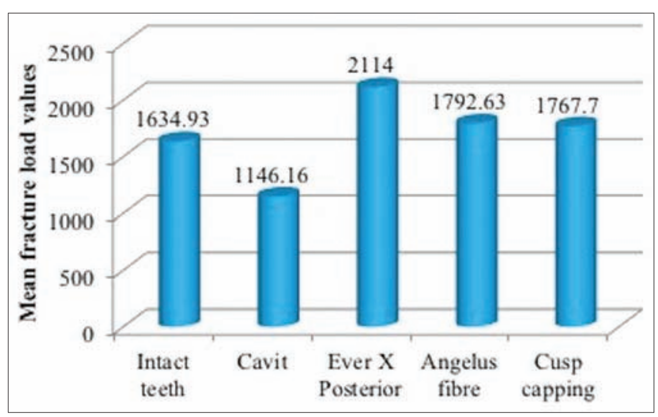

Figure 1: EverX posterior group exhibits highest fracture resistance followed by angelus fiber and then cusp capping group, whereas Group 2 Cavit showed the least resistance to fracture

Table 1: Inter- and intragroup comparison

One-way ANOVA for intergroup comparison					
Serial number	**Group**	**Mean fracture load**	**SD**	***F***	***P***
1	Intact teeth	1634.93	819.89	3.508	0.011*
2	Cavit	1146.16	750.61		
3	EverX posterior	2114	656.17		
4	Angelus fiber	1792.63	734.03		
5	Cusp capping	1767.7	664.33		

Post hoc Tukey's test for intragroup comparison						
Group (I)	**Group (J)**	**Mean difference (I-J)**	**SE**	**Significant**	**95% CI**	
					Lower bound	**Upper bound**
Intact teeth	Cavit	488.76	265.65	0.359	−255.09	1232.62
	EverX posterior	−479.06	265.65	0.380	−1222.92	264.79
	Angelus fiber	−157.7	265.65	0.976	−901.55	586.15
	Cusp capping	−132.76	265.65	0.987	−876.62	611.09
Cavit	Intact teeth	−488.76	265.65	0.359	−1232.62	255.09
	EverX posterior	−967.83	265.65	0.005*	−1711.69	−223.97
	Angelus fiber	−646.46	265.65	0.119	−1390.32	97.39
	Cusp capping	−621.53	265.65	0.145	−1365.39	122.32
EverX Posterior	Intact teeth	479.06	265.65	0.380	−264.79	1222.92
	Cavit	967.83	265.65	0.005*	223.97	1711.69
	Angelus fiber	321.36	265.65	0.746	−422.49	1065.22
	Cusp capping	346.3	265.65	0.690	−397.55	1090.15
Angelus fiber	Intact teeth	157.7	265.65	0.976	−586.15	901.55
	Cavit	646.46	265.65	0.119	−97.39	1390.32
	EverX posterior	−321.36	265.65	0.746	−1065.22	422.49
	Cusp capping	24.93	265.65	1.000	−718.92	768.79
Cusp capping	Intact teeth	132.76	265.65	0.987	−611.09	876.62
	Cavit	621.53	265.65	0.145	−122.32	1365.39
	EverX posterior	−346.3	265.65	0.690	−1090.15	397.55
	Angelus fiber	−24.93	265.65	1.000	−768.79	718.92

*Significant $P<0.05$. SD: Standard deviation; SE: Standard error; CI: Confidence interval

Table 2: Chi-square test for favorable and unfavorable fracture

Groups	Favorable fractures, *n* (%)	Unfavorable fractures, *n* (%)	Total, *n* (%)	χ^2	*P*
Intact teeth	3 (20)	12 (80)	15 (100)	10.9091	0.027605*
Cavit	2 (13.3)	13 (86.7)	15 (100)		
EverX posterior	3 (20)	12 (80)	15 (100)		
Angelus fiber	3 (20)	12 (80)	15 (100)		
Cusp capping	9 (60)	6 (40)	15 (100)		
Total	20	55	75		

*Significant

present study, everX posterior group exhibited the highest fracture strength (2114 N) among the experimental groups.

In recent years, fiber reinforcement in the form of ribbons has been introduced.[19] Garoushi *et al.* in a study reported that the use of fiber in the deepest part of composite restorations could increase fracture strength of restoration.[9] Composite resin reinforced with polyethylene fibers (Ribbond) or glass fibers (Interlig) creates a discontinuous phase with the continuous polymer resin matrix leading to delamination and thus failure at the interface.[20] Embedding fiber into the bed of flowable composite under a composite restoration helps reinforce the tooth by increasing the elastic modulus and preventing fracture. Adhesive restorations permit a more efficient transfer and distribution of functional stresses across the bonding interface to the tooth structure.[21]

Braun *et al*. reported that the mean bite force in the molar region to be 490N in males and 402N in females.[22] In the present study, all the teeth in experimental groups have fracture resistance values well above the mean bite force. There is a statistically significant difference ($P = 0.011$) between groups. Fracture resistance of molars restored with everX posterior was better ($P = 0.005$) than teeth restored

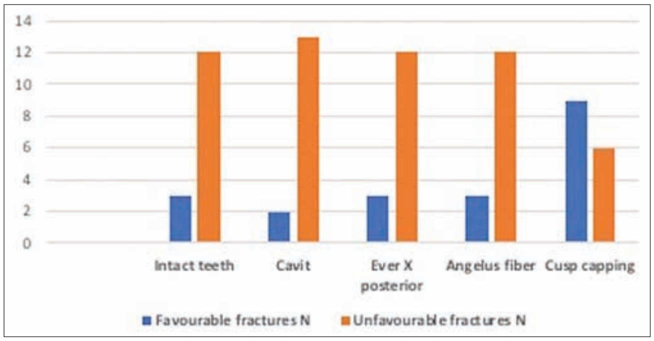

Figure 2: Shows no of teeth exhibiting favorable and unfavorable fracture pattern of Group 1 intact teeth, Group 2 Cavit, Group 3 everX posterior, Group 4 Angelus fiber, and Group 5 cusp capping

using Cavit intermediate restoration. Ozsevik *et al*.[23] and Hiremath *et al*.[24] reported similar findings. Ozsevi kept the access cavity empty in the control group, whereas Hiremath used Biodentine as a postobturation restoration.

There is a statistically significant difference ($P = 0.027605$) in the failure mode of teeth. Teeth restored by cusp capping using nanohybrid composite resin showed more favorable fractures than other experimental groups. The tendency of onlay restoration to receive a higher load might be attributed to the dispersion of compressive stresses on onlays.[25]

In our study, we chose mandibular first molars because they have a high incidence of dental caries that need restorative care. These teeth are often exposed to strong occlusal forces, rendering them more vulnerable to fracturing.[26] Each tooth was embedded in self-cure acrylic resin held perpendicular to the base of the block up to the level of CEJ. A thin layer of elastomeric impression material was used to imitate the periodontal ligament. This helps in dampening of the occlusal forces' incident on the samples. The thermocycling of samples replicated the aging of the restoration as seen in a clinical situation.

In the present study, the fracture resistance was tested using a universal testing machine by applying axial static compressive load with the help of a 5 mm stainless steel round end rod to the center of the occlusal surface. The ball's diameter has been shown to have an impact on the tooth's fracture resistance. As compared to a smaller ball, a larger diameter ball is known to cause an increased fracture rate.[27]

The results of the present study exhibit higher fracture strength for the everX posterior group, Interlig fiber group, and cusp-capped group than the intact teeth, indicating that the bonded adhesive restoration reinforces the endodontically treated molar teeth. The transfer and distribution of functional stresses across the bonding surface to the tooth structure is more efficient with adhesive restorations.[21] The distribution of compressive loads on onlay may account for the tendency of onlay restoration to receive a higher load.[25] This could be one of the reasons for cusp capped group. Nanocomposites display improved performance due to their dense filler loading. The smaller size of the fillers allows them to have excellent optical properties along with good mechanical properties.[28] In the Interlig group, the circumferential placement of the fiber strip increased the fracture resistance, as the presence of fiber creates a change in the stress dynamics at the restoration/adhesive resin interface. The higher modulus of elasticity and lower flexural modulus of the fiber might have a modifying effect on how the interfacial stresses are developed along the restoration/tooth interface.[29]

The present study was carried out under *in vitro* conditions that do not simulate the dynamic oral conditions in which the forces regularly change their rate, magnitude, and direction. The influence of dynamic loading and clinical performance needs to be further investigated.

CONCLUSION

Within the limitations of the study, it is concluded that restoration with everX posterior composite improved the fracture resistance of endodontically treated mandibular first molars. Teeth restored by cusp capping using nanohybrid composite resin exhibited more favorable fractures.

The combined use of SFC in an access cavity and capping the cusps with nanohybrid composite could be a viable option to restore endodontically treated mandibular first molar.

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Conflicts of interest
There are no conflicts of interest.

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