RESEARCH ARTICLE

Comparative Evaluation of Fracture Resistance of Endodontically Treated Teeth Restored with Different Core Build-up Materials: An *In Vitro* Study

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ABSTRACT

The aim is to evaluate the fracture resistance of endodontically treated teeth restored with posterior direct composite (PRC) resin, bulk-fill composite resin, dual-cure composite (DCC) resin, and short fiber-reinforced composite (SFC) resin material.

Materials and methods: Ninety sound maxillary premolar teeth were divided into 6 groups which comprised 15 teeth each. Group I was a negative control group where neither cavity preparation nor root canal treatment was done on the specimen. Group II was named positive control group as it was left unrestored after mesio-occluso-distal (MOD) preparation and root canal treatment. Groups III to VI were filled with PRC, bulk-fill composite, DCC, and SFC, respectively, and subjected to fracture testing in a universal testing machine.

Results: After statistical analysis, it was seen that group VI had increased mean fracture resistance as compared to other groups.

Conclusion: It was concluded that short fiber-reinforced composite proved to have superior properties that other experimental groups and hence can be used as a core build-up material.

Clinical significance: The core build-up is requisite as the residual tooth structure after endodontic procedure decreases and core build-up supplements the resistance and retention of the tooth structure.

Keywords: Core build-up materials, Endodontically treated teeth, Fracture resistance, Premolars.

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INTRODUCTION

Endodontic treatment is routinely used in contemporary dentistry but restoration of endodontically treated teeth and the impact of that restoration on the prognosis of devitalized teeth is becoming an essential part of restorative practice in dentistry nowadays.[1] Due to caries, access cavity preparation, and unavoidable/avoidable flaring of the canal in the cervical area, there is loss of tooth structure which causes endodontically treated weaker than their sound counterparts.[2] Deprivation of moisture in the dentin of endodontically treated teeth leads to consequences like reduced resilience and increased likelihood of fracture.[3] When obturated canals of endodontically treated teeth get contaminated from coronal leakage, it may also lead to lack of success of endodontic treatment.[4] This leakage can be through fracture or cracking of the postendodontic restoration, tooth structure, or delay in the placement of postendodontic restorations.[5]

Core build-up being an integral part, as the residual tooth structure after endodontic procedure decreases and core build-up increases the resistance and retention of the remaining tooth structure, so it could maintain its proper form and function. Morgano and Brackett marked out some of the prudent features of a core build-up material as they should come up with appropriate compressive strength to resist intraoral forces, suitable flexural strength, biocompatibility, resistance to seepage of oral fluids at the core-to-tooth interface, capacity to bond to the tooth structure, dimensional stability and decrease or negate the initiation of caries in the endodontically treated teeth. Long-term lastingness of endodontically treated teeth depends on the success of endodontic treatment, on the amount of dentine thickness, and postendodontic restoration which should be of high strength and acceptable clinical performance.[6]

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Amalgam, composite, and glass ionomer cement commonly are used as core build-up materials. According to Bonilla et al., composites showed better mechanical properties than amalgam core because of mainly two reasons—The micromechanical bonding (monoblock effect) of resins to the tooth structure and[7] curing of composite resin with dual-cure technology.[8] All glass ionomer cements including reinforced GIC are inherently weak because they do not possess the appropriate strength to withstand occlusal forces as compared to composite resin and are not advisable to be used for high stress-bearing applications.[9]

Posterior direct composite (PRC) resins have been introduced for posterior teeth that claim to help the dentist not only by

easily accessible placement but also by the formation of proper interproximal contacts. The material is incrementally placed and the maximum increment thickness is 2.5 mm.[8]

Dual-cure composite (DCC) materials which can be automixed and dispensed with intraoral tips have been introduced recently. They have ideal flow properties, avoiding gaps or air pockets, and are available in different shades.[8]

Bulk-fill resin composites being an ingenious class of dental resin composite materials were developed to simplify the placing of direct composite restorations. They are translucent resins that allow restoration up to 4 mm layer with appropriate curing throughout the bulk of the restoration with a low grade of polymerization shrinkage.[10]

Eskitaşcıoğlu et al. described that root canal treated teeth are prone to fracture and that it can be avoided by using fiber-reinforced composite materials.[11] While Belli et al. reported that positioning of fibers under composite resin restoration significantly augmented the fracture resistance strength of endodontically treated teeth.[12] Recently, silanated E-glass fiber with barium glass filler-reinforced composite resin material was introduced and it was recommended for usage in high stress bearing areas.[13]

The purpose of this study is to compare the strength of fracture resistance of endodontically/root canal treated teeth restored with PRC resin, bulk-fill composite resin, DCC resin, and short fiber-reinforced composite (SFC) resin material.

Materials and Methods

The research protocol was followed and carried out after approval of the ethical committee of Sri Guru Ram Das Institute of Dental Sciences and Research, Amritsar. Freshly extracted 90 non-carious maxillary premolar teeth were collected and split up into 6 groups of 15 teeth each (Fig. 1).

Inclusion criteria included non-carious teeth without any restoration or fracture line and with complete root formation; Exclusion criteria included carious, restored, or fractured teeth (Table 1).

The teeth were cleaned and stored in physiological saline at 4°C for 3 days.

Group I was named as the negative control group where neither cavity preparation nor root canal treatment was done.

Group II–Group VI

In the remaining 75 teeth, mesio-occluso-distal (MOD) cavities were prepared using a straight fissure bur and a high-speed airotor handpiece with water coolant. The buccopalatal dimension and intercuspal distance were measured with the help of a digital caliper. Mesio-occluso-distal cavities were made measuring one-third of the intercuspal distance for the buccopalatal width of the occlusal isthmus. The buccopalatal width of the approximate preparation was one-third of the buccopalatal width of the crown. The buccal

Table 1: Group numbers of samples according to their restorative material

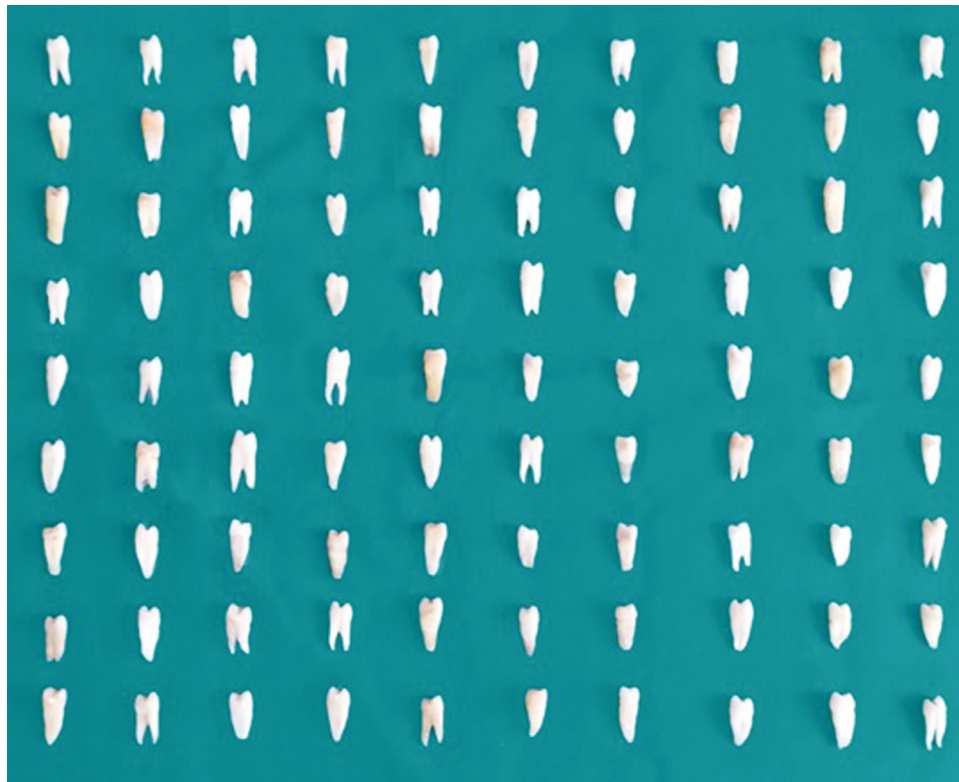| Groups	Number of teeth	Restorative material
Group I	15	Negative control group
Group II	15	Positive control group
Group III	15	Posterior direct composite (FILTEK P60)
Group IV	15	Bulk fill composite (TETRIC-N-CERAM BULK FILL)
Group V	15	Dual cure composite (LUXACORE Z DUAL)
Group VI	15	Short fiber-reinforced composite (EVER X POSTERIOR)

Fig. 1: Maxillary premolars used in the study

and palatal walls of the occlusal segment were kept parallel to each other. The depth of the preparation was kept up to 1 mm coronal to the level of CEJ (Fig. 2).

Endodontic Procedure

Preoperative radiographs were taken and access cavities were prepared using high-speed round diamond bur. Working length was taken using #15 K-file and confirmed radiographically. Canals were prepared using Rotary Protaper files. The preparation was initiated with the SX file followed by S1, S2, F1, F2, and F3 files. Copious irrigation was done with the help of sodium hypochlorite and normal saline alternatively, throughout the procedure. Root canals were dried completely using paper points and obturation was done with gutta-percha by cold lateral condensation. The gutta-percha was sealed below the level of the CEJ by GC Fuji II. Radiographically, confirmation of the obturation was done.

The access cavities were restored with restorative materials as described below, using the Tofflemire matrix system for creating the proximal contours.

The surface of the cavity of the entire specimen was etched with 37% phosphoric acid etching gel for 30 seconds in enamel and 15 seconds in dentin followed by rinsing with water for 15 seconds. Floor and walls/cavity surfaces were then gently blow-dried. Using

Fig. 2: Cavity design - 1 mm above the cementoenamel junction

microapplicator tips, application of the bonding agent was done at all the cavity surfaces and light-cured for 20 seconds.

Group II was the positive control group as after MOD preparation and endodontic treatment, the specimen of this group were left unrestored.

Group III was filled with Filtek P60 with 2 mm increments up to the occlusal level and light-cured as per the manufacturer's manual suggestion (Fig. 3).

Group IV was filled with Tetric N-Ceram bulk fill with 4 mm increments each up to occlusal level and light-cured as per the manufacturer's manual suggestion (Fig. 4).

Group V was filled with Luxacore Z Dual composite resin. It was injected into the cavities up to the occlusal level through the automix provided and light-cured as per the manufacturer's manual suggestion (Fig. 5).

Group VI was filled with EverX Posterior. It was filled incrementally until it reached an occlusal level and light-cured as per the manufacturer's manual suggestion (Fig. 6).

After restorations were completed, contouring, finishing, and polishing of the restoration were done. The storage of teeth was done in distilled water for 24 hours at 37°C before being subjected to fracture resistance testing. The roots were mounted in a self-cure acrylic resin block of 3 × 2.5 cm up to the level of 1 mm apical to the CEJ.

Fracture Resistance Testing

The prepared specimens were positioned on a holder slot that was previously fixed on the lower arm of a universal testing machine. A metal indenter with a diameter of 0.5 mm was fixed to the upper arm of the machine which was held to deliver increasing loads on the center of the tooth until fracture of restoration occurred. The load applied, was directed vertically along the long axis of the tooth and was applied at a crosshead speed of 1 mm/minute (Fig. 7). The force thus observed, to fracture each tooth, was recorded in Newton. The data compiled were then subjected to statistical analysis using one-way ANOVA and *post hoc* Tukey's test for evaluating fracture resistance of different composite resin materials.

Results

The mean fracture resistance values were statistically analyzed using one-way ANOVA and intergroup comparisons were performed using the *post hoc* Tukey's test.
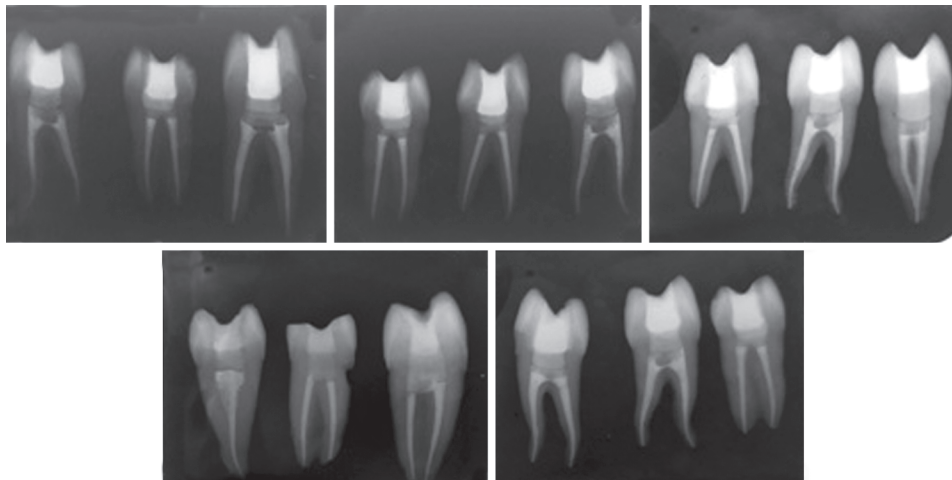

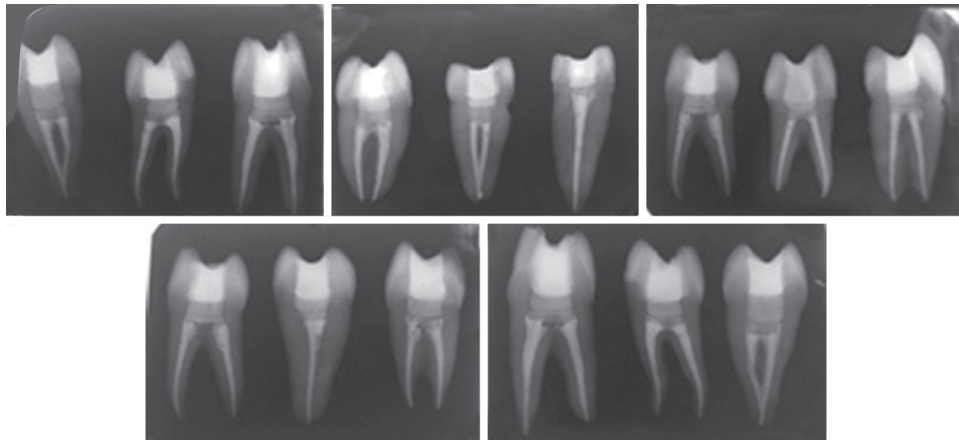**Fig. 3:** Radiographs of Filtek P60 composites

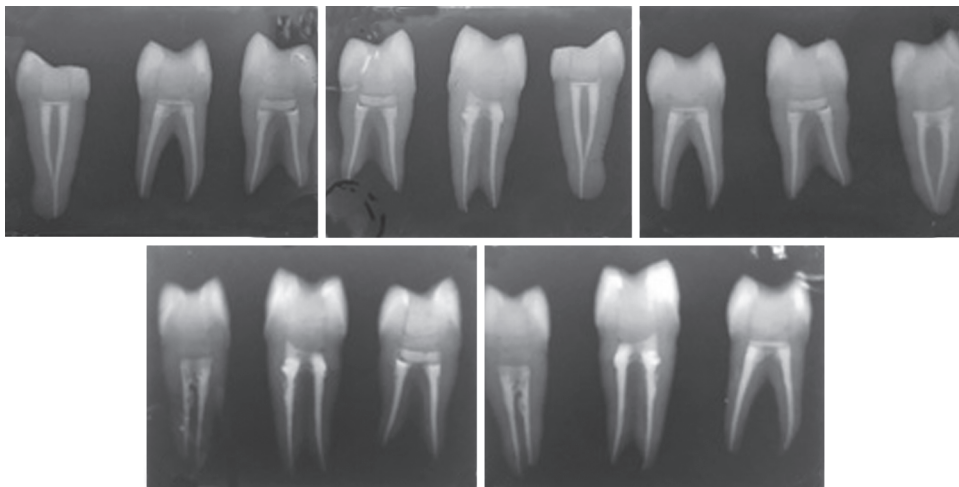**Fig. 4:** Radiographs of Tetric N-Ceram composite

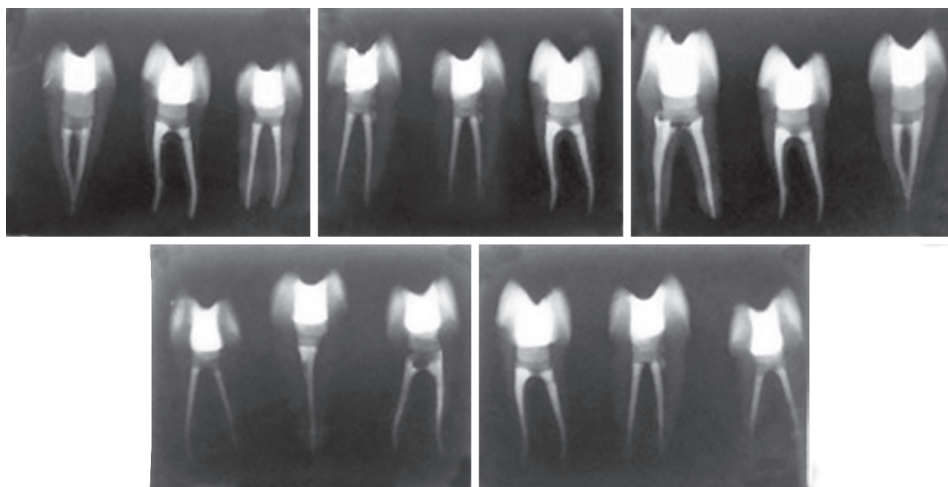**Fig. 5:** Radiographs of Luxacore Z Dual composite

Fig. 6: Radiographs of EverX posterior composite

Table 2 shows the comparison in mean fracture resistance values. Group I had the highest values of mean fracture resistance among all experimental groups, followed by group VI, group V, group IV, group III, and group II.

Table 3 shows the analysis done by one-way ANOVA test, which showed statistically significant differences ($p < 0.0001$).

Table 4 shows Tukey's *post hoc* testing, the *p* value for this difference was computed to be extremely low (< 0.0001).
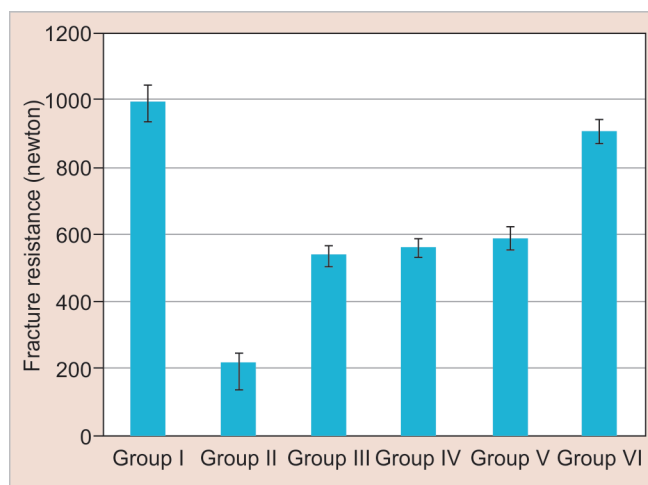
Fig. 7: Instron universal testing machine

Fig. 8: Mean fracture resistance of different groups

Table 2: Mean fracture resistance values

					Confidence interval	
Group	No. of observations	Mean	SD	CV (%)	95%	99%
Group I	15	993.2	54.5	5.5	963.0–1,023.4	951.3–1,035.1
Group II	15	218.9	33.9	15.5	200.1–237.7	192.8–245.0
Group III	15	537.9	33.5	6.2	519.4–556.5	512.2–563.7
Group IV	15	564.0	29.0	5.1	547.9–580.0	541.7–586.3
Group V	15	592.0	36.6	6.2	571.7–612.2	563.9–620.1
Group VI	15	909.2	35.5	3.9	889.6–928.9	882.0–936.5

Table 3: One-way ANOVA analysis

		Results of ANOVA		
Group	Mean	$F_{5, 84\ d.f.}$	p value	Remark
Group I	993.2	814.3	<0.0001	***
Group II	218.9			
Group III	537.9			
Group IV	564.0			
Group V	592.0			
Group VI	909.2			

***Significant at 0.1% probability level

Table 4: Tukey's *post hoc* analysis

Paired comparison b/w study groups	Observed difference	p value	Remark
Group II–Group I	−774.3	<0.0001	***
Group III–Group I	−455.3	<0.0001	***
Group IV–Group I	−429.2	<0.0001	***
Group V–Group I	−401.2	<0.0001	***
Group VI–Group I	−84.0	<0.0001	***
Group III–Group II	319.1	<0.0001	***
Group IV–Group II	345.1	<0.0001	***
Group V–Group II	373.1	<0.0001	***
Group VI–Group II	690.4	<0.0001	***
Group IV–Group III	26.0	0.4251	NS
Group V–Group III	54.0	0.0027	**
Group VI–Group III	371.3	<0.0001	***
Group V–Group IV	28.0	0.3431	NS
Group VI–Group IV	345.2	<0.0001	***
Group VI–Group V	317.3	<0.0001	***

***Significant at 0.1% probability level
**Significant at 1.0% probability level
NS, non-significant

The difference in fracture resistance between group I and each of the remaining four groups turned out to be highly significant.

Each of group III, group IV, group V, and group VI had significantly higher fracture resistance values as compared to group II. Although a significant difference could not be detected between group III and group IV and similarly between group IV and group V, group VI had highly significant fracture resistance values in comparison to each of group III, group IV, and group V (Figs 8 and 9).

DISCUSSION

Endodontic treatment is an important aspect of treatment procedures in dentistry. Some of the important prerequisites for endodontic treatment are irreversible pulpitis and necrosis of pulp, which are caused by dental caries or dental trauma.[14] Successful endodontic treatment is marked by the absence of symptoms and clinical signs of infection in a tooth, without radiographic evidence of periodontal involvement.[15] The success of treatment depends on the preoperative condition of the tooth, the endodontic procedure, and postendodontic restoration.[16] A properly sealed coronal restoration is required after obturation of root canal as it would prevent the ingress of any microorganisms, which are present in the oral environment.[17]
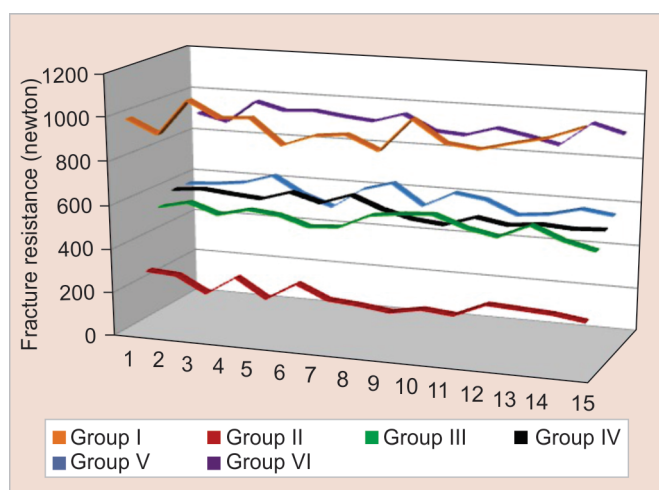
Fig. 9: Comparative pattern of fracture resistance, which was observed in different study groups

Tooth fractures being the most frequent cause of tooth loss, together with dental caries and periodontal disease.[18] Some studies assert that fractures are more common in endodontically treated teeth. According to Ellis et al., excessive damage to coronal and radicular dentin during the endodontic treatment and decreased residual moisture content reduces the strength and increases the tooth's fragility.[19] Cavity preparations cause loss of dental tissue, reducing the fracture resistance of the remaining dental structure. According to Geistfeld, an occlusal cavity preparation reduces tooth strength by 14–44% and a MOD cavity by 20–63%.[20] Moreover, an access cavity preparation further weakens a tooth's integrity. According to Belli et al., the MOD cavity with the dimension of half of the intercuspal distance and specifications of rounded internal angles and convergent or divergent angulation of internal walls further reduces the strength of the remaining tooth structure.[21] Due to the limited amount of residual tooth structure, planning a restoration is an important aspect for the long-term survival of teeth. Dentist's main goal should be to preserve the sound tooth structure and a conventional approach to be taken to protect the remaining dental tissue.

Packable resin composites were brought into being in the late 1990s for dentists who wanted to use a tooth-colored posterior restorative material that had more properties like dental amalgam. These packable resin composites were stiffer and less tenacious than traditional composites and allowed for easier positioning.[22] Their handling properties are the same as those of dental amalgam in that they permit easier placement and compacted interproximal contact with Class II restorations than traditional posterior resin-based composites.[23] Filtek P60 used in our study, is a thoroughly filled packable posterior composite resin, which has a filler volume of 60–70% and a compressive strength of 360–380 MPa with decreased polymerization shrinkage. Its resin matrix consists of BisGMA, BisEMA, UDMA, TEGDMA, and ZrO_2/SiO_2 as fillers, with the size of 0.01–3.5 μm. The material is incrementally placed and the maximum increment thickness is 2.5 mm.[24]

The incremental layering technique advocates placement of resins up to 2 mm thickness, which is a time-consuming technique. The other significant disadvantage of this technique includes increased risk of contamination through oral fluids in-between layers, polymerization shrinkage, and the inclusion of voids in the restoration. Some of the factors of polymerization shrinkage include marginal discrepancies, marginal staining, white lines around the restoration, cusps fractures, microleakage, debonding, recurrent caries, postoperative sensitivity, and pain.[25]

Bulk-fill resin composites are an ingenious class of dental resin composite materials, which were introduced for the ease of the placement of direct composite restorations. Clinical recommendations report that these resin composites have a greater depth of cure, can be seated in a 4-mm bulk increment, and will have appropriate polymerization.[26] The stress-decreasing resin technology was designed to decrease the shrinkage stress and allow bulk placement of composite. Clinically, this would eradicate the requirement for incremental placement and curing and thus reduce the need for material manipulation and time required during insertion, thereby improving patient compliance.[27] Manufacturers introduced this new technology by modifying the Bowen monomer (Bis-GMA: 2,2-bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl] propane) to create monomers with lower viscosity. The bulk-fill composite used in this study was Tetric N-Ceram Bulk fill. Its matrix consists of Bis-GMA, UDMA (15 wt%), and ethoxylated Bis-EMA (3.8 wt%). Its filler particles constitute barium glass, ytterbium trifluoride, mixed oxide, and silicon dioxide (63.5 wt%).[24]

According to the literature, bulk placement of traditional composite resin restorative materials may result in poor polymerization in the more apical aspects of a restoration. This is due to the inability of the light from the light-curing unit to penetrate these regions.[28]

Dual curing eliminates the limitation of light attenuation and also the need for incremental placement for curing. Dual-cure composite resins are recommended for core build-ups and luting of all-ceramic restorations. The benefit of dual-cure resin materials is the ability to bulk fill the core build-up material and lute an opaque restoration while minimizing the risk of light attenuation that would disrupt the setting of the deepest portions of the resin material.[29] They have ideal flow properties, avoiding gaps or air pockets, and are available in different shades. The DCC used in this study is the Luxacore Z Dual composite. The nanotechnology which is been used in Luxacore dual eliminates particle agglomeration. This is attained by incorporating a proprietary coating process during particle manufacture. According to manufacturer's, they possesses similar strength, flexibility and insulation properties to that of dentin, cuts, and trims like dentin and is not too hard as many other core restorative composites. Their monomer matrix consists of dimethacrylate (base: 28.1 wt% and catalyst: 28.4 wt%) and the type of fillers are aluminoborosilicate glass, fumed silica, and titanium oxide, which could be the reason for their high strength.[8]

Literature suggests that dual-cure resins which are not exposed to the appropriate amount of light may not obtain maximum mechanical properties. It is because the monomer does not achieve a high degree of conversion. When limited to chemical curing, it has been observed that dual-cure resin cements have lower mechanical properties due to a lower degree of conversion.[30]

According to Belli et al., using polyethylene fiber beneath composite restorations in endodontically treated teeth with MOD preparations, significantly increased their fracture strength, reduced the microleakage in class II cavities, and increased microtensile bonding to the dentin.[31] Fiber reinforcement between the restorative resin and dentin changes the fracture line, causing repairable fractures which lead to saving of the remaining tooth structure and increasing the restorability of teeth after failure.[32]

According to Garoushi et al., randomly oriented glass fibers significantly affect the mechanical properties of the material and serve as a crack stopper layer. The load-bearing capacity may be increased by adding a continuous bidirectional or short random fiber-reinforced composite substructure under the particulate filler composite resin.[33] Short fiber-reinforced composite resin used in this study was EverX Posterior composite; GC, Europe. This is composed of randomly oriented short glass fiber fillers made of a combination of barium glass and silanated E-glass fibers and is claimed to provide an isotropic reinforcement effect in multiple directions instead of 1 or 2 directions.[34]

Maxillary premolars were selected in this study since they are appropriate for the evaluation of the efficacy of materials for their fracture resistance. Their anatomy, function, crown size, and crown/root ratio make them more prone to fracture than other posterior teeth.

Moreover, considering their location in the dental arch, they are subjected to both compressive and shear forces[35] and during mastication, the anatomic shape of premolars creates a tendency for the separation of cusps. Post-placement in these teeth is also not usually recommended because of their delicate root morphology.[36]

The consequence of poor mechanical resistance is a cuspal fracture. Since tooth fracture is a common occurrence in clinics and is more frequent in premolars, selection of the postendodontic restorative material is of prime importance as the properties of direct restorative materials influence the fracture toughness. So, in this study, fracture resistance was taken as a criterion, and the study of this pathology remains relevant.[35]

Burke and Watts proved that when the cylindric indenter makes contact with the tooth, it acts as a wedge between the buccal and lingual cusps and decreases the mean fracture resistance values while promoting more catastrophic types of fracture.[37] Similarly, in our study, the application of force was applied on the center of the tooth vertically because it was found to be appropriate to simulate the clinical intraoral conditions.

The highest resistance to fracture was observed in group I as compared to other experimental groups, proving the deleterious effects of the loss of vital tooth structure because of MOD and access cavity preparations.[24]

According to Bahsi et al., the lowest fracture resistance of Filtek P60 could be attributed to its lower filler content. It has a filler volume of 60–70% which is the least among the experimental groups. Reduced filler content leads to higher polymerization shrinkage, which leads to reduced fracture resistance.[38]

In this study, the values of fracture resistance of Filtek P60, Tetric N-Ceram bulk fill, and Luxacore Z Dual are not statistically significant. According to Fonseca et al.[39] and Panitiwat and Salimee,[40] this could be attributed to their lower filler volume, which are 61, 63.5, and 70%, respectively.

Higher mean fracture resistance was seen in EverX Posterior which was 909.2 N as compared to Tetric N-Ceram and Luxacore Z Dual which was 564 N and 592 N, respectively. According to Kumar and Sarthaj, this difference could be attributed to the reason that filler content plays a significant role in the depth of cure with the bulk-fill composites. The increase in the filler content causes a greater depth of cure. An increase in the filler content, in turn, decreases the volume of the resin matrix for polymerization and also increases hardness. An increase in the filler content also reduces polymerization shrinkage. Fracture of the restoration mainly depends on the composition and filler content of resin

composites and their elastic modulus.[25] This highest mean fracture resistance may also be attributed to the support provided by bulk short fiber composite substructure by transferring the stresses from the polymer matrix to the fibers, where these individual fibers act as crack stoppers.[24]

Conclusion

The lowest fracture resistance was observed in Filtek P60 composite resin and higher mean fracture resistance was seen in EverX Posterior. This difference could be attributed to the reason that filler content plays a significant role in the depth of cure with the bulk-fill composites.

It was concluded that EverX Posterior composite resin is considered to be a desirable core build-up material to be used as a long-lasting postendodontic restoration for the long-term survivability of endodontically treated teeth.

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