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Comparative Evaluation of Fracture Resistance of Class Ii Cavities Restored with Three Different Classes of Composite Resins – An in Vitro Study

Dr Mohit Kumar[1](Corresponding author), Dr Garima Singh[2], Dr Nikita Sharma[2], Dr Pulkit Arora[2], Dr Ayushi Jain[1]

[1]Department of Dentistry, Kalyan Singh Government Medical College, Bulandshahr, Uttar Pradesh,

[2]Department of Conservative Dentistry and Endodontics, Shree Bankey Bihari Dental College, Ghaziabad, Uttar Pradesh

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KEYWORDS

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ABSTRACT:

Objectives: This study aimed to evaluate and compare the fracture resistance of Class II dental cavities restored with three different composite systems: Fibrafil, Filtek Bulk Fill, and Estelite Sigma Quick.

Methods: Fifty-five intact mandibular molars were divided into: positive control (unprepared, n=5), negative control (unrestored, n=5), and three experimental groups (n=15 each) restored with Filtek Bulk Fill (Group C), Estelite Sigma Quick (Group D), or Fibrafil (Group E). Standardized Class II cavities were prepared, restored, and stored in distilled water (37°C, 24 hours). Fracture resistance was measured using an INSTRON machine (load in Newtons) and analyzed via one-way ANOVA and Bonferroni post-hoc tests ($\alpha=0.05$).

Results: The highest mean fracture resistance was observed in Group A (positive control: 218.40±8.20 N), followed by Fibrafil (Group E: 657.07±7.41 N), Estelite Sigma Quick (Group D: 446.80±8.03 N), and Filtek Bulk Fill (Group C: 438.27±4.92 N). The negative control (Group B: 676.80 ± 4.32 N) exhibited the lowest resistance. Fibrafil's performance was statistically superior to other composites ($p<0.001$).

Conclusions: Fibrafil demonstrated significantly higher fracture resistance, likely due to its fiber-reinforced structure, which mimics the dentino-enamel junction.

1. Introduction

Restoration of extensively decayed posterior teeth remains one of the foremost challenges in contemporary restorative dentistry. Significant loss of tooth structure due to dental caries, traumatic injury, or extensive cavity preparation often compromises the biomechanical strength of the remaining tooth, making it more susceptible to fracture under functional loads.[1] The primary objective of restorative dentistry is therefore not only to replace the lost tissue but also to restore the structural integrity, function, and esthetics of the tooth while preventing recurrent decay and secondary complications.[2]

Class II cavities, which involve the proximal surfaces of posterior teeth, account for a significant proportion of restorative procedures in daily clinical practice. These restorations are inherently more complex because cavity preparation often necessitates removal of one or both marginal ridges and proximal contacts, which are critical for distributing occlusal forces. Studies have demonstrated that the loss of marginal ridges can reduce the stiffness of the tooth by up to 46%, significantly increasing cuspal flexure and the risk of fracture during mastication.[3] Despite advances in material science, fracture and secondary caries remain the primary causes of failure for Class II composite restorations, with reported survival rates ranging from 55% to 100% over ten years, depending on the material used, cavity size, and clinical technique.[4]

Resin-based composite materials have become the preferred choice for direct posterior restorations due to their superior esthetics, adhesive bonding capability, and the potential for conservative tooth preparation.[5] However, polymerization shrinkage remains a persistent limitation that can generate contraction stresses at the tooth-restoration interface. These stresses can result in

marginal gaps, interfacial debonding, postoperative sensitivity, and microcracks within the adjacent tooth structure, ultimately compromising the restoration's longevity.[6]

To address this, incremental layering techniques were historically recommended to minimize the effects of polymerization stress. However, this method is time-consuming and technique-sensitive. In response, bulk-fill resin composites have been developed to simplify placement by allowing thicker increments of up to 4 mm to be cured effectively with lower shrinkage stress.[3] Filtek™ Bulk Fill (3M ESPE) is one such material that incorporates advanced monomers, including aromatic urethane dimethacrylate (AUDMA) and addition-fragmentation monomers (AFM). These components work synergistically to reduce polymerization shrinkage and internal stress by promoting stress relaxation during the formation of the polymer network.[7]

Simultaneously, advances in filler technology have led to the development of nanohybrid composites such as Estelite Sigma Quick (Tokuyama Dental). This material employs uniform supra-nanofillers with a high filler loading of approximately 82% by weight. This spherical filler technology enhances polishability, shade matching, and wear resistance, making it suitable for both anterior and posterior restorations where esthetics and durability are critical.[8]

Despite these improvements, conventional composites may still lack sufficient fracture resistance when used to restore teeth with extensive structural loss, especially in large Class II cavities subjected to high occlusal forces. In recent years, fiber-reinforced composites have emerged as a promising biomimetic solution to strengthen weakened teeth. Short fiber-reinforced composites, such as Fibrafil, incorporate a network of microfibers within the resin matrix, mimicking the reinforcing effect of the natural dentino-enamel junction. These fibers act as crack stoppers, enhancing the material's load-bearing capacity and resistance to catastrophic fracture propagation.[9]

The longevity of a posterior restoration is closely linked to the material's ability to withstand repetitive masticatory forces without significant deformation or failure.[10] As restorative techniques evolve, it becomes crucial to evaluate whether modern fiber-reinforced composites can outperform conventional bulk-fill and nanohybrid resins in reinforcing weakened tooth structure and preventing fractures under functional loading.

Although individual studies have reported on the mechanical properties of various composite systems, there remains a paucity of comparative data specifically evaluating fiber-reinforced composites in large Class II restorations. Understanding how these materials perform relative to each other under standardized conditions can guide clinicians in material selection for cases with high biomechanical demands.

Therefore, the present in vitro study was designed to compare the fracture resistance of standardized Class II cavities restored using a bulk-fill composite (Filtek Bulk Fill), a nanohybrid composite (Estelite Sigma Quick), and a short fiber-reinforced composite (Fibrafil).

2. Methods

SAMPLE SELECTION

A total of fifty-five freshly extracted, intact human mandibular molars were collected for this in vitro study. All teeth were extracted for periodontal reasons and stored in distilled water at room temperature until use. The inclusion criteria required that all teeth be fully erupted, with mature apices, intact enamel and dentin, and free from carious lesions, restorations, cracks, or developmental defects. Teeth exhibiting open apices, signs of root resorption, previous restorations, or any anatomical abnormalities were excluded from the study.

GROUPING

The selected teeth were randomly divided into five groups:

- Group A (Positive Control, n = 5): Intact teeth with no cavity preparation.
- Group B (Negative Control, n = 5): Teeth with prepared Class II cavities left unrestored.
- Group C (n = 15): Teeth with Class II cavities restored using Filtek™ Bulk Fill Posterior composite (3M ESPE).
- Group D (n = 15): Teeth with Class II cavities restored using Estelite Sigma Quick composite (Tokuyama Dental).
- Group E (n = 15): Teeth with Class II cavities restored using Fibrafil composite resin.

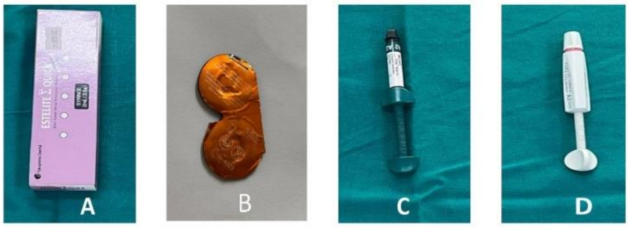

Figure 1. Representative images of the restorative materials used in this study: A. Estelite Sigma Quick composite resin; B. Fibrafil composite; C. Filtek Bulk-Fill posterior composite resin; D. Neospectra Composite.

CAVITY PREPARATION

Standardized wide Class II mesio-occlusal or disto-occlusal cavities were prepared in fifty teeth using a high-speed handpiece with water cooling and tungsten carbide straight fissure burs under constant replacement after every five preparations to maintain cutting efficiency. The dimensions were standardized as follows:

- Occlusal width equal to half of the intercuspal distance.
- Pulpal depth of 2.5 mm.
- Proximal box width equal to half of the buccolingual dimension.
- Axial depth of 1.5 mm.

The gingival floor was positioned 1 mm coronal to the cemento-enamel junction (CEJ). The buccal and lingual walls of each cavity were prepared parallel to the long axis of the tooth, with all cavosurface margins maintained at a 90° angle and internal line angles rounded to reduce stress concentration. The cavity dimensions were verified using a digital caliper with an accuracy of 0.2 mm to ensure consistency across all samples.

RESTORATIVE PROCEDURES

Following cavity preparation, each tooth was thoroughly rinsed with an air-water spray and dried gently. A Tofflemire matrix system was used to achieve proper proximal contours during restoration.

All prepared cavities were etched with 37% phosphoric acid gel for 30 seconds on enamel margins, rinsed for 20 seconds with water, and gently air-dried. A universal dental adhesive (Prime and Bond, Dentsply) was then applied with a disposable applicator brush, rubbed for 10 seconds, and gently air-thinned according to the manufacturer's instructions.

Restoration protocols were as follows:

- Group C: The conditioned cavities were filled with Filtek™ Bulk Fill Posterior composite (Figure 1) in a single increment up to 2.5 mm and light cured for 20 seconds using an LED curing unit at an intensity of 1000 mW/cm².
- Group D: The cavities were restored incrementally using Estelite Sigma Quick composite (Figure 1) resin, applied in 1 mm horizontal layers. Each increment was individually light-cured for 20 seconds to ensure adequate polymerization.
- Group E: After adhesive application, the proximal wall was first built using Neospectra composite (Dentsply) (Figure 1) to convert the Class II cavity into a Class I configuration. The core was then restored using Fibrafil composite in bulk and light-cured for 20 seconds. A final 1 mm occlusal capping layer of Neospectra was placed and light-cured to complete the restoration.

Finishing and polishing of all restorations were performed using the Super Snap polishing system (Shofu, Japan) under constant water cooling. All restored teeth were then stored in distilled water at 37°C for 24 hours to allow for post-polymerization before fracture testing.

All restorative procedures were carried out following the manufacturer's instructions by a single operator to eliminate inter-operator variability. Specimens were loaded to failure using an INSTRON 5944 universal testing machine. Maximum load at fracture was recorded in Newtons. Data were analyzed using SPSS v26. One-way ANOVA with Bonferroni post-hoc tests was performed (α=0.05)

3. Results

	N	Mean	Std. Deviation	Lower Bound	Upper Bound
Gr A: Positive Control	5	218.4	8.20366	208.2138	228.5862
Gr B: Negative Control	5	676.8	4.32435	671.4306	682.1694

Gr C: Filtek Bulk fill	15	438.26	4.92032	435.5419	440.9914
Gr D: Estelite Sigma Quick	15	446.8	8.0252	442.3540	451.2460
Gr E: Fibrafil	15	657.06	7.41106	652.9626	661.1708

Table 1: Mean fracture resistance observed in all groups taken in the study

Table 1 summarizes the mean fracture resistance values (in Newtons) observed for all five groups included in this study. The positive control group (Group A, unprepared teeth) recorded a mean fracture resistance of 218.40 ± 8.20 N, while the negative control group (Group B) showed the highest overall mean fracture resistance of 676.80 ± 4.32 N due to the absence of restorative material. Among the restored groups, the fiber-reinforced composite (Group E, Fibrafil) demonstrated the highest mean fracture resistance (657.07 ± 7.41 N), followed by the nanohybrid composite (Group D, Estelite Sigma Quick) at 446.80 ± 8.03 N, and the bulk-fill composite (Group C, Filtek Bulk Fill) at 438.27 ± 4.92 N. Figure 2 represents the boxplot showing fracture resistance in all the above mentioned groups.

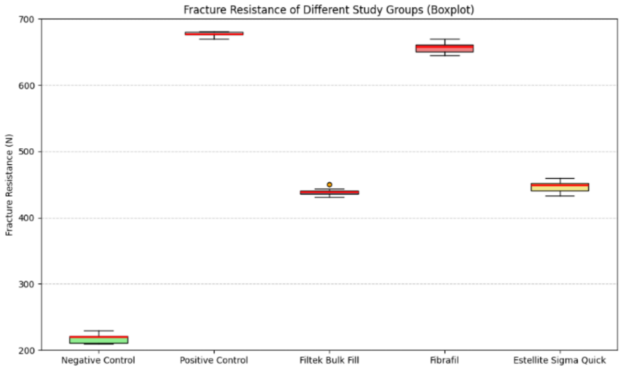

Figure 2. Boxplot illustrating the fracture resistance (in Newtons) of five groups: Negative Control (unprepared teeth), Positive Control (prepared but unrestored cavities), Filtek Bulk Fill, Fibrafil, and Estelite Sigma Quick. The boxes represent the interquartile range (IQR), the horizontal line inside each box indicates the median, whiskers show the minimum and maximum values within 1.5 × IQR, and outliers are displayed as individual dots.

Table 2 presents the results of the one-way ANOVA, which revealed a statistically significant difference in mean fracture resistance among all groups ($p < 0.001$).

	Sum of Squares	df	Mean Square	F	P value
Between Groups	1022239.661	4	255559.915	5427.591	<0.001
Within Groups	2354.267	50	47.085		
Total	1024593.927	54			

Table 2: One-way ANOVA output table for intergroup comparison of fracture resistance

To identify where these differences occurred, Table 3 shows the post hoc Bonferroni pairwise comparisons. The analysis confirmed that all pairwise group comparisons were statistically significant ($p < 0.05$). The mean fracture resistance of the negative control (Group B) was significantly higher than that of all restored groups. Among the restored groups, Fibrafil (Group E) exhibited significantly higher fracture resistance than both Estelite Sigma Quick (Group D) and Filtek Bulk Fill (Group C) ($p < 0.001$). Estelite Sigma Quick (Group D) demonstrated significantly higher mean fracture resistance than Filtek Bulk Fill (Group C) ($p < 0.001$).

	Mean Difference	P value
Gr A* Gr B	-458.40000	<0.001 , S
Gr A * Gr C	-219.86667	<0.001, S
Gr A * Gr D	-228.40000	<0.001 , S
Gr A * Gr E	-438.66667	<0.001, S
Gr B* Gr C	238.53333	<0.001 , S
Gr B * Gr D	230.00000*	<0.001 , S
Gr B * Gr E	19.73333*	<0.001, S
Gr C * Gr D	-218.80000	<0.001 , S
Gr C * Gr E	-8.53333	0.013, S
Gr D * Gr E	210.26667	<0.001, S

Table 3: post hoc pairwise comparison by using the Bonferroni test

These results indicate that the choice of restorative material has a significant impact on the fracture resistance of Class II cavities. Teeth restored with the fiber-reinforced composite Fibrafil showed the greatest reinforcement effect, while the nanohybrid composite performed better than the bulk-fill system. All restored groups provided substantially higher fracture resistance than the positive control (intact, unprepared teeth) but lower than the negative control (unrestored cavities).

4. Discussion

The longevity of posterior composite restorations is influenced not only by the material's inherent properties but also by its ability to reinforce weakened tooth structure under functional loads. Loss of substantial tooth tissue, such as that associated with large Class II cavities, significantly compromises the tooth's structural integrity and resistance to fracture.[11] This underlines the importance of using restorative materials that restore stiffness and help distribute occlusal stresses effectively.

In the present study, the fiber-reinforced composite (Fibrafil) exhibited the highest mean fracture resistance among the tested materials. This is consistent with the reported performance of short fiber-reinforced composites, which have demonstrated the capacity to enhance load-bearing capacity and fracture toughness by acting as internal crack arrestors.[12] The incorporation of short fibers within the resin matrix helps mimic the function of the dentino-enamel junction, where crack propagation is naturally resisted by changes in tissue structure.[13]

Although direct studies on Fibrafil are limited, similar behavior has been extensively documented for EverX Posterior and other glass fiber-based systems, which have shown promising results in reinforcing structurally compromised teeth, including large MOD cavities and endodontically treated teeth.[14,15] Compared to conventional particulate-filled composites, fiber-reinforced materials better distribute functional loads and reduce stress concentration within the residual tooth structure.

Estelite Sigma Quick, a supra-nanofilled composite resin, demonstrated higher fracture resistance than Filtek Bulk Fill Posterior. This result aligns with previous reports showing that composites with higher filler content and optimized filler morphology display improved mechanical strength and wear resistance.[16] The advanced spherical filler technology of Estelite Sigma Quick enhances filler packing and reduces resin matrix content, thereby improving stress distribution and limiting polymerization shrinkage stress.[17] Moreover, its radical-amplified photopolymerization initiator enables rapid curing while achieving sufficient depth of cure, which contributes to its robust mechanical performance.

In contrast, bulk-fill composites such as Filtek Bulk Fill Posterior are engineered to allow placement in thicker increments and to simplify restorative procedures. While the addition–fragmentation monomer (AFM) and AUDMA technology reduce shrinkage stress, the comparatively lower filler content and differences in filler particle size distribution may explain its lower fracture resistance compared to nanohybrid or fiber-reinforced systems.[18,19]

This study supports the principle that material selection should be tailored to cavity configuration and anticipated functional demands. For large Class II cavities where structural support is critically reduced, fiber-reinforced systems offer a meaningful advantage in fracture resistance over conventional and bulk-fill composites. However, it is important to recognize the limitations of this study. It was conducted under static load conditions and did not simulate intraoral factors such as cyclic loading, thermal cycling, or fatigue, all of which influence long-term clinical performance.[20]

Therefore, while fiber-reinforced composites show promise for restoring structurally compromised teeth, further long-term clinical trials and fatigue studies are needed to validate these results under functional conditions.

5. Conclusion

Within the limitations of this in vitro study, it can be concluded that the choice of restorative material has a significant impact on the fracture resistance of Class II cavities. Among the three composite systems evaluated, the short fiber-reinforced composite (Fibrafil) demonstrated the highest mean fracture resistance, likely due to its integrated fiber network that mimics the natural dentino-enamel junction and acts as an internal crack-arrestor, effectively distributing occlusal stresses throughout the tooth structure. The nanohybrid composite Estelite Sigma Quick also showed higher fracture resistance than the bulk-fill composite, which may be attributed to its high filler loading, spherical supra-nanofiller technology, and advanced photopolymerization system that enhances its mechanical performance and reduces polymerization stress. Although the bulk-fill composite Filtek Bulk Fill simplifies placement and allows for thicker increments, its lower filler content and material characteristics resulted in comparatively lower fracture resistance,

indicating that it may be more suitable for moderate restorations rather than large cavities where substantial reinforcement is needed. Overall, the findings suggest that fiber-reinforced composites can offer significant biomechanical benefits when restoring large Class II cavities in posterior teeth subjected to high functional loads. However, as this was an in vitro study conducted under controlled conditions, further long-term clinical research and in vivo studies are necessary to confirm these results and develop reliable protocols for the routine use of fiber-reinforced composites in demanding clinical scenarios.

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