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Fracture Resistance of Endodontically Treated Teeth Restored with Fiber-Reinforced and Stress-Decreasing Composites: A Comparative In-Vitro Analysis

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ABSTRACT

Background: Endodontically treated teeth often suffer from diminished fracture resistance due to structural alterations such as moisture loss, dentin dehydration, and access cavity preparation. Selecting suitable core build-up materials is crucial for restoring their strength and ensuring long-term functionality.

Objective: This study aimed to compare the fracture resistance of endodontically treated premolars restored with fiber-reinforced composite (GC EverX Flow) and stress-decreasing resin composite (Dentsply SDR), using both occlusal and mesio-occluso-distal (MOD) cavity preparations.

Methodology: Forty-nine freshly extracted maxillary premolars were divided into seven groups based on cavity design and restorative material. After standardized endodontic treatment, core build-up was done using either GC EverX Flow or SDR. Fracture resistance testing was performed using a universal testing machine, and data were analysed using ANOVA and post hoc comparisons.

Results: The highest mean fracture resistance was observed in the control group (721.14 N), followed by Dentsply SDR in MOD preparations (613.21 N), and GC EverX Flow in MOD (583.86 N). MOD groups with no restorative material showed the lowest resistance (337.29 N). Statistical analysis confirmed that both GC EverX and SDR composites significantly enhanced fracture resistance compared to unrestored controls, especially in MOD cavities.

Conclusion: Fiber-reinforced and stress-decreasing composites effectively reinforce endodontically treated teeth, especially in structurally compromised MOD designs. SDR exhibited slightly superior performance, suggesting its clinical advantage in restoring weakened teeth. These findings guide clinicians in selecting optimal restorative materials to enhance durability and reduce the risk of post-treatment fracture.

1. INTRODUCTION

Endodontic therapy is an indispensable intervention in modern restorative dentistry, allowing clinicians to preserve teeth affected by pulpal pathology, deep caries, or trauma.[1] While effective in eliminating infection and maintaining oral function, the procedure intrinsically weakens tooth structure. Removal of pulp tissue, canal flaring, and access cavity preparation deplete the biomechanical integrity of the tooth, rendering it susceptible to fracture under functional load.[2]

One of the major concerns post-endodontic treatment is the structural stability of the treated tooth. Factors such as dehydration of dentin, loss of marginal ridges, and occlusal contact significantly elevate the risk of fracture.[3] Hence, an appropriate post-endodontic restoration is vital. Traditional full-coverage crowns have long been the gold standard, but evolving material science and conservative philosophies now favor direct restorative techniques with core build-up materials that combine strength, aesthetics, and minimal invasiveness.[4-5]

Core build-up materials restore missing tooth structure and act as a foundation for the final restoration. Their efficacy depends on their ability to distribute stresses, bond with tooth structure, and resist fracture. Among various materials, fiber-reinforced composites (e.g., GC EverX Flow) and stress-decreasing flowable composites (e.g., Dentsply SDR) have gained prominence. Fiber-reinforced composites incorporate short fibers to deflect and arrest crack propagation, while SDR technology reduces polymerization stress, enhancing marginal integrity and stress tolerance.[6-7]

Access cavity design plays a synergistic role in tooth strength. MOD cavities, characterized by the removal of both marginal ridges, represent the most structurally vulnerable design. In contrast, occlusal cavities preserve more of the pericervical dentin, resulting in comparatively better fracture resistance. Thus, evaluating the combined effect of access design and material choice offers valuable clinical insight.[8-9]

In-vitro studies provide a controlled environment to simulate oral forces and compare material performance. Despite limitations in replicating the exact oral environment, these models offer standardized, reproducible assessments. This study utilizes universal testing machines and consistent protocols to ensure scientific rigor and relevance to clinical conditions.[10]

The present study aims to compare the fracture resistance of endodontically treated teeth restored with fiber-reinforced (GC EverX Flow) and stress-decreasing (Dentsply SDR) resin composites in occlusal and MOD access cavity designs. It seeks to determine which material provides superior reinforcement under compressive loads and guide clinicians in selecting appropriate restorative strategies based on cavity morphology and material behavior.

2. MATERIALS AND METHODS

This in-vitro experimental study was conducted to evaluate the fracture resistance of endodontically treated maxillary premolars restored with different core build-up materials and access cavity designs. Ethical approval for the study was obtained from the Institutional Ethics Committee of Bharati Vidyapeeth Dental College and Hospital, Pune. The experiment was performed under controlled laboratory conditions to ensure standardization and reproducibility of results.

A total of 49 freshly extracted, non-carious human maxillary premolars were collected. These teeth were extracted for orthodontic purposes and were selected based on strict inclusion criteria, which required intact marginal ridges, fully formed roots, and no history of restorative procedures or structural defects. Teeth with caries, cracks, previous restorations, anatomical abnormalities, or hypoplastic defects were excluded to maintain uniformity. After extraction, the teeth were cleaned and stored in normal saline at room temperature until further processing.

The teeth were randomly assigned into seven groups of seven samples each. Group 1 consisted of intact, untreated teeth and served as the negative control. Groups 2 and 3 underwent standardized endodontic treatment but were not restored with any core build-up material; Group 2 received an occlusal cavity preparation, while Group 3 was prepared with a mesio-occluso-distal (MOD) design. The remaining groups were restored using one of two core build-up materials: a fiber-reinforced composite (GC EverX Flow) or a stress-decreasing resin composite (Dentsply Smart Dentin Replacement, SDR). Specifically, Group 4 received an occlusal cavity restored with GC EverX Flow, while Group 5 had an MOD cavity restored with the same material. Groups 6 and 7 received occlusal and MOD restorations, respectively, using Dentsply SDR

	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6	GROUP 7
Access Cavity Opening	**No access opening (NEGATIVE**	**Occlusal . (POSITIVE**	**Mesio-Occluso-distal (POSITIVE**	**Occlusal**	**Mesio-Occluso-distal**	**Occlusal**	**Mesio-Occluso-distal**

	CONTROL) n=7	CONTROL) n=7	CONTROL) n=7	n=7	n=7	n=7	n=7
Material Used For Core Build-Up	**No material used**	**No material used**	**No material used**	**Gc EverX flow**	**DENTSPLY smart dentin replacement (SDR)**	**Gc EverX flow**	**DENTSPLY smart dentin replacement (SDR)**

Endodontic treatment was performed on all groups except the negative control. Access cavity preparation was followed by canal instrumentation using rotary nickel-titanium files, with copious irrigation using 5.25% sodium hypochlorite. Following drying, canals were obturated with gutta-percha cones and AH Plus sealer. In experimental groups, core build-up materials were placed in 4 mm increments and light-cured according to the manufacturer's guidelines. Packable composite resin was used to restore the enamel portion and finalize the occlusal anatomy.

Fig.1 Endodontic Procedure

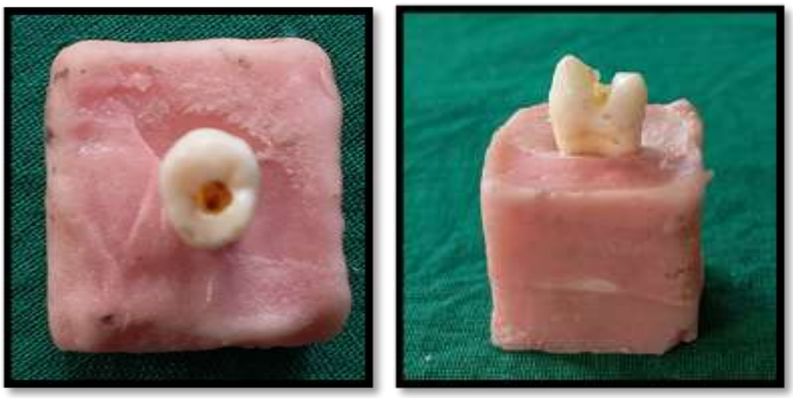

Fig2 : Occlusal & MOD Cavity Preparation

To simulate periodontal ligament conditions, each tooth was coated with a thin layer of polyvinyl siloxane impression material. This step aimed to mimic physiological load distribution during mechanical testing. All specimens were vertically embedded in self-curing acrylic resin blocks with their long axes perpendicular to the base, ensuring consistent positioning and stress application during testing.

Fig 3: All prepared samples – according to group

Fracture resistance was assessed using a universal testing machine (UTM). A compressive force was applied via a 4 mm diameter steel rod at a crosshead speed of 1 mm/min until fracture occurred. The point of load application varied based on cavity design: the central fossa for occlusal preparations and the central groove for MOD preparations. The maximum force required to fracture each sample was recorded in Newtons (N).

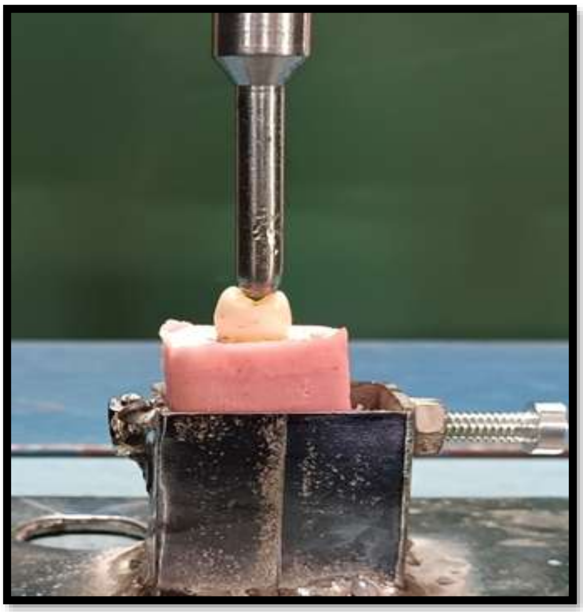

Fig 4. Fracture resistance test under UTM in lab

All data were collected and subjected to statistical analysis using the SPSS software package. A one-way analysis of variance (ANOVA) was employed to identify statistically significant differences in mean fracture resistance among the groups. Post hoc analysis was performed using Tukey's test for pairwise comparisons, and a p-value of less than 0.05 was considered indicative of statistical significance.

3. RESULTS

Table 1: Descriptive statistics of fracture resistance of all groups.

Groups	Mean	SD	SE	Minimum	Maximum
Group 1 [n=7] (Negative)	721.14	164.88	62.32	438.5	873.5
Group 2 [n=7] (Positive Control + Occlusal)	404.79	173.99	65.76	214.0	662.5
Group 3 [n=7] (Positive Control + MOD)	337.29	83.92	31.72	241.0	506.0
Group 4 [n=7] (GC EverXFlow+ Occlusal)	358.71	171.94	64.98	200.0	701.0
Group 5 [n=7] (GC EverXFlow + MOD).	583.86	152.57	57.66	341.0	808.0
Group 6 [n=7] (Dentsply + Occlusal)	568.36	90.92	34.36	459.0	685.0
Group 7 [n=7] (Dentsply + MOD)	613.21	195.48	73.88	302.0	840.5

Table 1 presents the descriptive statistics of fracture resistance values across all study groups, each containing 7 specimens. The Negative Control (Group 1) exhibited the highest mean fracture resistance at 721.14 N, with a standard deviation (SD) of 164.88 N and a standard error (SE) of 62.32 N, ranging from 438.5 N to 873.5 N. In contrast, Group 3 (Positive Control + MOD) demonstrated the lowest mean fracture resistance at 337.29 N, indicating a substantial reduction compared to the negative control.

Among the occlusal restoration groups, Group 2 (Positive Control + Occlusal) had a mean of 404.79 N, while Group 4 (GC EverXFlow + Occlusal) and Group 6 (Dentsply + Occlusal) had means of 358.71 N and 568.36 N, respectively. Notably, Group 6 showed improved fracture resistance among the occlusal restorative materials.

For MOD restoration groups, Group 5 (GC EverXFlow + MOD) and Group 7 (Dentsply + MOD) had higher mean fracture resistance values (583.86 N and 613.21 N, respectively) compared to Group 3, suggesting better performance of these restorative materials in compromised tooth structures.

Table 2: Comparative statistics of fracture resistance between Occlusal Groups.

Group	Mean	SD	F-test value	p-value
Group 1 (Negative)	**721.14**	**164.88**	**F = 8.022**	**p = 0.001**
Group 2 (Positive Control + Occlusal)	**404.79**	**173.99**		
Group 4 (GC EverXFlow + Occlusal)	**358.71**	**171.94**		
Group 6 (Dentsply + Occlusal)	**568.36**	**90.92**		

***p<0.05 – significant difference**

Table 2 presents the comparative analysis of fracture resistance among different Occlusal groups, using a one-way ANOVA test. The results demonstrate a statistically significant difference between the groups, as indicated by the F-test value of 8.022 and a p-value of 0.001 ($p < 0.05$).

Among the groups, the Negative Control (Group 1) had the highest mean fracture resistance (721.14 N), serving as a benchmark for comparison. In contrast, Group 2 (Positive Control + Occlusal) and Group 4 (GC EverXFlow + Occlusal) showed considerably lower fracture resistance values, 404.79 N and 358.71 N, respectively. However, Group 6 (Dentsply + Occlusal) demonstrated a relatively higher mean resistance (568.36 N) among the treated groups, indicating a better performance in restoring occlusal strength.

The statistically significant p-value suggests that the type of restorative material used for occlusal restorations has a notable impact on the fracture resistance of teeth, with Dentsply performing more favorably compared to GC EverXFlow and the positive control.

Table 3: Pairwise comparative statistics of fracture resistance Occlusal groups.

Group Comparison	Mean Difference	P-value
Group 1 (Negative) vs Group 2 (Positive Control +Occlusal)	316.35	p = 0.004
Group 1 (Negative) vs Group 4 (GC EverXFlow + Occlusal)	362.42	p = 0.001
Group 1 (Negative) vs Group 6 (Dentsply + Occlusal)	152.78	p = 0.275
Group 2 (Positive Control + Occlusal) vs Group 4 (GC EverXFlow + Occlusal)	46.07	p = 0.943
Group 2 (Positive Control + Occlusal) vs Group 6 (Dentsply + Occlusal)	163.57	p = 0.222
Group 4 (GC EverXFlow + Occlusal) vs Group 6 (Dentsply + Occlusal)	209.64	p = 0.079

***p<0.05 – significant difference**

Table 3 presents the pairwise comparisons of fracture resistance between the occlusal restoration groups, offering detailed insights into how each group differs from the others. The most notable findings emerge when comparing the Negative Control group (Group 1) with the others.

Group 1 showed significantly higher fracture resistance compared to both Group 2 (Positive Control + Occlusal) and Group 4 (GC EverXFlow + Occlusal), with mean differences of 316.35 N (p = 0.004) and 362.42 N (p = 0.001) respectively, indicating statistically significant differences (p < 0.05). However, when Group 1 was compared to Group 6 (Dentsply + Occlusal), the mean difference was 152.78 N, but this was not statistically significant (p = 0.275), suggesting that Dentsply performed closer to the negative control in preserving fracture resistance.

No statistically significant differences were observed among the experimental occlusal groups themselves. The differences between Group 2 vs Group 4 (46.07 N; p = 0.943), Group 2 vs Group 6 (163.57 N; p = 0.222), and Group 4 vs Group 6 (209.64 N; p = 0.079) did not reach significance, although the last comparison approached borderline relevance.

Table 4: Comparative statistics of fracture resistance in MOD Groups.

Group	Mean	SD	F-test Value	P-value
Group 1 (Negative)	**721.14**	**164.88**		
Group 3 (Positive Control + MOD)	**337.29**	**83.92**	**F = 7.694**	**p = 0.001**
Group 5 (GC EverXFlow + MOD)	**583.86**	**152.57**		
Group 7 (Dentsply + MOD)	**613.21**	**195.48**		

***p<0.05 – significant difference**

Table 4 shows the comparative statistics of fracture resistance in MOD (mesio-occluso-distal) groups, assessed using one-way ANOVA. A significant difference was observed among the groups, as indicated by the F-test value of 7.694 and a p-value of 0.001, which is below the significance threshold of 0.05.

The Negative Control group (Group 1) once again had the highest mean fracture resistance at 721.14 N, establishing the baseline. Among the MOD-restored groups, Group 7 (Dentsply + MOD) and Group 5 (GC EverXFlow + MOD) demonstrated relatively high mean values of 613.21 N and 583.86 N, respectively, indicating effective reinforcement of the tooth structure despite the extensive cavity preparation. In contrast, Group 3 (Positive Control + MOD) recorded the lowest mean fracture resistance at 337.29 N, reflecting the negative impact of MOD cavity preparation without additional restorative support.

Table 5: Pairwise comparative statistics of fracture resistance MOD groups.

Group Comparison	Mean Difference	P-value
Group 1 (Negative) vs Group 3 (Positive Control + MOD)	383.35	p = 0.001
Group 1 (Negative) vs Group 5 (GC EverXFlow + MOD)	137.28	p = 0.366
Group 1 (Negative) vs Group 7 (Dentsply + MOD)	107.92	p = 0.569
Group 3 (Positive Control + MOD) vs Group 5 (GC EverXFlow + MOD)	246.57	p = 0.031
Group 3 (Positive Control + MOD) vs Group 7 (Dentsply + MOD)	257.92	p = 0.014
Group 5 (GC EverXFlow + MOD) vs Group 7 (Dentsply + MOD)	29.35	p = 0.984

Table 5 presents the pairwise comparative analysis of fracture resistance among the MOD restoration groups. The comparisons reveal that Group 1 (Negative Control) had a significantly higher fracture resistance than Group 3 (Positive Control + MOD), with a mean difference of 383.35 N and a highly significant p-value of 0.001. This indicates that MOD cavity preparation without appropriate reinforcement (Group 3) drastically reduces fracture resistance.

However, when the Negative Control was compared with Group 5 (GC EverXFlow + MOD) and Group 7 (Dentsply + MOD), the differences were not statistically significant (mean differences of 137.28 N, $p = 0.366$ and 107.92 N, $p = 0.569$, respectively). This suggests that the use of GC EverXFlow and Dentsply materials in MOD cavities helps restore fracture resistance to levels closer to the natural tooth.

Furthermore, significant differences were observed when Group 3 was compared with Group 5 (mean difference = 246.57 N, $p = 0.031$) and with Group 7 (mean difference = 257.92 N, $p = 0.014$), reinforcing the superior performance of both GC EverXFlow and Dentsply over the untreated MOD group.

No significant difference was found between Group 5 and Group 7 (mean difference = 29.35 N, $p = 0.984$), indicating that both materials performed similarly in reinforcing MOD cavities. Overall, the findings highlight the importance of restorative material selection, as both EverXFlow and Dentsply significantly enhance fracture resistance in structurally compromised MOD teeth.

4. DISCUSSION

Endodontically treated teeth (ETT) are prone to structural failure due to the cumulative loss of dentin during endodontic access, canal shaping, and caries removal. These interventions compromise the biomechanical integrity of the tooth, making it more susceptible to fracture under functional loads. Thus, post-endodontic restorative techniques play a critical role in re-establishing strength and longevity. The present in-vitro study evaluated the fracture resistance of ETT restored using different core build-up materials—GC EverX Flow (fiber-reinforced composite) and DENTSPLY Smart Dentin Replacement (SDR, a stress-decreasing bulk-fill resin)—under occlusal and mesio-occluso-distal (MOD) access cavity preparations.

The findings of this study revealed that both the type of access cavity and the restorative material significantly influenced fracture resistance. Among all experimental groups, the highest fracture resistance was noted in Group 7 (MOD cavity restored with SDR), followed closely by Group 5 (MOD cavity restored with GC EverX Flow). This supports the hypothesis that both GC EverX and SDR can effectively reinforce ETT and approximate the structural performance of intact teeth.[11]

Interestingly, the negative control group (intact teeth) naturally demonstrated the highest resistance to fracture, as expected. However, when MOD-prepared teeth were restored with SDR or GC EverX Flow, the resulting fracture resistance was statistically comparable to that of intact teeth ($p > 0.05$). This suggests that these materials can compensate for the structural deficits caused by aggressive cavity preparation.[12-13]

In contrast, the positive control groups (Groups 2 and 3), where no core build-up was used, showed significantly lower fracture resistance, underscoring the critical importance of using appropriate restorative materials post-endodontically. Group

3, which represented MOD preparations without reinforcement, had the lowest fracture resistance, highlighting how extensive tooth structure loss without restoration severely weakens the tooth.[14-15]

Among the occlusal groups, Group 6 (occlusal access + SDR) demonstrated better performance than Group 4 (occlusal access + EverX Flow), although the difference was not statistically significant. Notably, the occlusal group restored with SDR (Group 6) showed no significant difference from intact teeth (Group 1), further confirming the favourable stress-distributing properties of SDR[16].

The performance of SDR may be attributed to its low modulus of elasticity and stress-decreasing properties that reduce polymerization shrinkage and cuspal deflection. Conversely, GC EverX Flow, being a short-fiber-reinforced composite, benefits from fiber reinforcement that aids in crack propagation resistance, especially in structurally compromised MOD designs.[17-18]

These observations align with studies by **Selvaraj et al.**[19] and **Clark et al.**[20], who reported superior fracture resistance for fiber-reinforced and nano-enhanced composites compared to conventional resins. Similarly, studies by **Yang et al.**[11] and **Forster et al.**[15] emphasized the significance of material compatibility with tooth biomechanics in enhancing durability.

This study further reinforces the findings of previous research **Plotino et al.**[12]; **Silva et al.**[17] regarding the impact of cavity design on tooth strength. MOD preparations consistently showed lower fracture resistance when left unreinforced, but their performance significantly improved with proper core material placement.

Additional evidence from **Gher et al.**[23] and **Akkayan et al.**[24] also demonstrated that fiber-reinforced composites significantly enhance the load-bearing capacity of ETT, likely due to better distribution of masticatory forces and increased flexibility. **Naumann et al**.[25] and **Cheung et al.**[26] further corroborated these results, emphasizing that fiber-reinforced materials align more closely with the modulus of elasticity of natural dentin, thus reducing the risk of catastrophic failures. These studies collectively support the rationale behind selecting materials that mimic natural tooth properties to improve long-term restorative outcomes.

Although this study was conducted under in-vitro conditions using a universal testing machine and controlled loading forces, clinical outcomes may vary due to factors such as cyclic fatigue, thermal variations, occlusal dynamics, and patient habits like bruxism. Furthermore, only two restorative materials were evaluated; additional research with other materials and techniques (e.g., endocrowns, 3D-printed cores) could offer broader insights.[19-22.]

Clinical implications of the current findings are significant. When restoring ETT, especially those with extensive MOD preparations, fiber-reinforced and stress-decreasing composites like GC EverX Flow and SDR should be strongly considered for their ability to restore strength near to natural tooth levels. This is crucial for long-term success and resistance to catastrophic failures.

Conclusion: In this in-vitro study, it can be concluded that the use of core build-up materials significantly enhances the fracture resistance of endodontically treated teeth. Among the materials tested, DENTSPLY SDR showed the highest fracture resistance, followed closely by GC EverX Flow, especially in MOD cavity preparations. MOD cavity designs, when left unrestored, demonstrated the lowest resistance to fracture, highlighting the importance of reinforcement. Overall, both fiber-reinforced and stress-decreasing resin composites proved effective in restoring strength to structurally compromised teeth, with DENTSPLY SDR offering performance closest to that of intact, unrestored teeth.

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