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Evaluation of Fracture Resistance of Fiber-Reinforced Resin Composite Restorations in Deep Class I Cavities: A Comparative In Vitro study

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Aim: The research compares the fracture resistance of ultra-polyethylene fiber ribbon, fiber-reinforced resin composite EverX posterior, fiber-reinforced flowable resin composite EverX flow, and bulk fill flow posterior restorative material Tetric N-flow.
Materials and Methods: 60 caries-free human mandibular molars have been utilized. The teeth have been mounted into acrylic blocks 1mm below the CEJ. Class I cavities, which were deep and wide, had been prepared in each tooth, measuring 4x4 millimeters. Teeth have been categorized randomly into 4 equivalent experimental groups (n=15) regarding restorative material. GI was restored with Ribbond®-Ultra with Tetric N-flow, GII, EverX Posterior, GIII, EverX Flow, and GIV, Tetric N-flow. The teeth have been kept in 20 milliliters of distilled water at 37C for 24 hrs. The restored teeth underwent thermocycling and fracture resistance testing utilizing a universal testing machine (Instron). The fracture resistance of groups has been compared utilizing the one-way ANOVA test also post-hoc test using Tukey's test.
Result: The fiber-reinforced bulk fill resin composite (EverX Posterior) showed the greatest fracture resistance, accompanied by the fiber-reinforced bulk fill flowable resin composite (EverX Flow), and the bulk-fill flowable resin composite (Tetric N-flow). The least fracture resistance was observed within teeth restored with polyethylene fiber ribbon and bulk-fill flowable resin composite (Tetric N-flow). Statistical analysis showed significant variance within the groups, excluding EverX Posterior and EverX Flow.
Conclusion: The contemporary fiber-reinforced bulk-fill resin composites are efficient for reinforcing vital teeth against fracture, while utilizing polyethylene fiber ribbon may not hold similar efficacy, regardless of its time-consuming application.

Key word: Compressive load, EverX Flow, Fibre-Reinforced, Tetric N-flow.

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Introduction

The fracture resistance of the tooth is reduced as a result of the cutting of its structure through cavity preparation. Restoring carious cavities, fixing dental trauma may require extensive cavity preparation to achieve functional and aesthetic prerequisites without comprising the support needed for the remaining tooth structure. [1] Composite fillings are commonly used in posterior dental restorations, whose failure is often attributed to bulk fractures and secondary caries. Direct composite resins provide versatility and aesthetic appeal with excellent bond strength but require careful application due to their technique-sensitive nature and susceptibility to shrinkage and microleakage. Although time-consuming and prone to air bubbles and moisture contamination, traditional layering techniques have been standard practice. [2] Bulk-fill composite resins, placable in 4-5-millimeter thick layers and polymerized in a single step, offer improved fracture resistance. [3]

Nano-fillers or polyethylene fibers are aimed at enhancing resin composite strength. [4] Fibers can be included in the resin matrix during the material's production process or placed externally during the application of direct restorations. [5] Ribbond- Ultra® is a polyethylene fiber with a higher degree of fatigue resistance, an ultrahigh elastic modulus, as well as an elastic modulus that is similar to dentin and allows effective force transfer, together with easily adapting to the contours of the teeth. [6] Additionally, Ribbond® excels at stress distributions and energy absorption. [7] Short fibers in the resin composite also make it an ideal substructure for reinforcing any resin composite restoration in large cavities. [8] Fiber-reinforced resin composite restorations serve as fracture stoppers to improve the material's structural qualities. EverX Posterior, premixed fiber-reinforced resin composite of E-glass fibers (nine percent) permeated into the nanohybrid composite. The average fiber size was 140 µm and a 6 µm diameter. It has glass filler particles made of barium silicate that are 700 nm in size. Compared to dentine, its numerous short fibers are firmly integrated into the resin matrix, resulting in superior wear resistance and fracture toughness. [9] Due to the high viscosity and limited aesthetics of EverX Posterior, manufacturers rendered a flowable version for clinical usage that ought to be of superior efficacy. EverX Flow should manifest proper workability as well as improved aesthetical properties, especially regarding the dentine color. Owing to the relatively smaller proportions of the particles of its E-glass fibers component and their sizes (0.006 by 0.14 mm), the flowable product demonstrates higher contents of fibers (approximately 25% by weight).

Additionally, it was shown to have a lower flexural modulus, easier adaptability in large cavities than EverX Posterior, and improved fracture toughness. [10] Tetric N-flow offers superior fracture resistance compared to other intra-orifice barriers with excellent flowability but has limited application in endodontically treated teeth for reducing wear resistance. [11] Therefore, this research compares the fracture resistance of dental restorations using Ribbond-Ultra with Tetric N-flow, EverX Posterior, EverX Flow Bulk, and Tetric N-flow. The null hypothesis of the present research denotes the lack of impact of the fracture resistance upon using diverse dental restorations, such as the utilization of fiber-reinforced composites or ribbons.

Materials and Method

Study Design:

An in-vitro research has been performed in the Conservative Dentistry Department, Faculty of Dentistry, October 6th University, Egypt, and performed from September 2023 to January 2024. The Council of Conservative Dentistry Department – Faculty of Dentistry – October 6th University accepted the study's protocol, and the Research Ethics Committee – Faculty of Dentistry – October 6th University reviewed & revised the ethical issues on January 9, 2023 (Approval No RECO6U/3-2023).

Calculation of Sample Size:

A power analysis has been conducted for ensuring that the statistical test of the null hypothesis, which posits that the fracture resistance of teeth is unaffected by various reinforcement techniques, like the utilization of fiber-reinforced composite or Ribbond, would have sufficient power. The predicted sample size was a total of Sixty samples, with fifteen samples per group, according to the outcomes of a previous study, a beta of (0.2), an alpha level of (0.05), a power of eighty percent, and an effect size (f) of (0.544). The "Sample Size Calculator" by Georgiev G.Z. was employed to calculate the sample size.

Tested Materials:

The materials used in the present research consisted of various products specifically designed for restorative dental operations, each with its function and composition, as shown in Table 1.

Eligibility Criteria:

The inclusion criteria involved molars with uncommon morphology in the occlusal shape, size, and surface for minimizing probable confounders. Carious teeth were excluded.

Preparation of the teeth:

A total of sixty non-carious molars, freshly extracted human permanent mandibular molars for periodontal reasons, were selected and disinfected by immersion in 0.5 percent sodium hypochlorite solution for fifteen min. Then, it was cleaned for removing any calculus and soft tissue deposits with an ultrasonic cleaner and examined under (X 2.5) magnification. Teeth have been categorized randomly into 4 equal experimental groups, regarding the restorative material to be utilized (Fig. 1). Imbuing into distilled water was followed to maintain normal humidity and cause the smallest changes in dentin over time. Distilled water was changed every 3 days until the restorative procedure following ISO recommendation ISO/TS11405. [12]

Table 1: Summary of distinct functions and compositions of utilized materials.

Utilized Materials	Composition	Manufacturer and LOT no.
Polyethylene fibre (Ribbond®-Ultra)	Ultra-high molecular weight polyethylene, Homopolymer H- (CH2-CH2)n-H	Ribbond Inc., Seattle, WA, USA ribbond@ribbond.com, 98101
Fibre-reinforced bulk fill resin composite (EverX Posterior)	*Organic content:* Bisphenol A-glycidyldimethacryla, triethylene glycol dimethacrylate, polymethyl methacrylate. *Inorganic content:* E-glass fibres, barium borosilicate glass filler. *Filler load:* (wt, vol %) 74.2/53.6	GC Corporation, Tokyo, Japan https://www.gc.dental.com, 2204111
Flowable fibre-reinforced resin composite (EverX Flow™)	*Organic content:* Bisphenol-A-glycidyl dimethacrylate, tri ethylene glycol dimethacrylate, urethane dimethacrylate, *Inorganic content:* micrometer-scale E-glass fibre filler, Barium glass. *Filler load:* (wt, vol %) 70% by weight, 46% by volume	GC Corporation, Tokyo, Japan https://www.gc.dental.com, 2202011
Flowable Bulk Fill resin composite (Tetric N-flow)	*Monomer matrix:* Urethane dimethacrylate, Bis-GMA 27.8% Triethyleneglycol dimethacrylate. *Inorganic fillers*: 7.3 Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide 63.8%. Additives, stabilisers, catalysts, pigments 1.1%	Ivoclar Vivadent www.ivoclar.com Z0417F
Adhesive (OptiBond ™ Extra Universal)	GPDM Monomer.Ternary Solvent System (Water, Acetone, Ethanol). Acidity drop.	KaVo Kerr www.kerrdental.com, 9244546
Enamel and dentin etchant (Meta Biomed)	Phosphoric acid (37%) - H2O -Xanthan gum	Meta Biomed, Chungcheongbuk-do, Republic of Korea.http://www.meta-biomed.com MET2301022

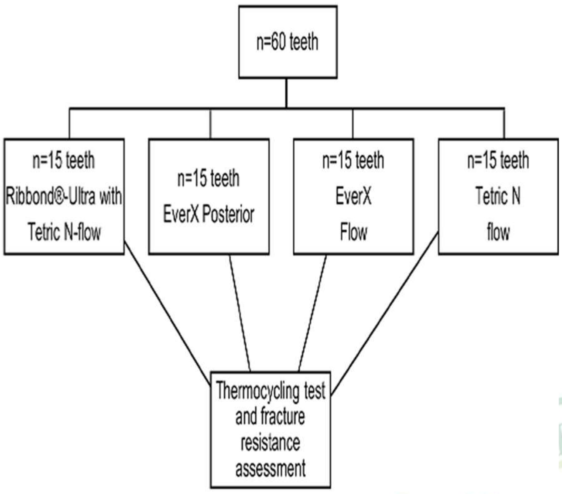

Figure 1: Flowchart of teeth grouping based on used materials

The molars have been mounted in acrylic resin blocks utilizing specially designed cylindrical molds, ensuring uniform embedding while leaving 1 millimeter apical to the CEJ. Class I cavities, which were deep and wide, the design was then prepared in each tooth utilizing a tungsten carbide straight fissure bur (Meisinger, German) and inverted cone bur (Meisinger, German) with high-speed water-cooled handpiece (Dentsply Sirona T4, Sirona Dental Systems GmbH, Fabrikstraße, Germany), standardized to a width of four millimeters and a depth of four millimeters which was confirmed using a William's graduated probe, and restored with the proper restorative materials in compliance with the manufacturer's recommendations.

Following the cavity preparation, each tooth was washed with an air-water syringe, dried, and etched with 37% orthophosphoric acid 30 sec for enamel, 15 sec for dentine. This has been subsequent to the application of OptiBond™ Extra Universal adhesive for priming and bonding. Primer was applied with a micro brush (KaVo Kerr) with agitation motion for 20 sec then air thining for 5 sec with medium air pressure regarding the instructions of manufacturer. Then, the dental adhesive has been applied with a micro brush (KaVo Kerr) for 15 sec with an agitation motion followed by air thinning for 5 sec as instructed, and light curing for 10 sec with a light curing unit (Good Drs - Drs Light CL-AT24 Curing Light, 1200mW/Cm2 light intensity, 490 - 440 nm Wavelength) at zero distance. [13]

Group I has been coated with a 1 mm Tetric N-flow bulk fill and left uncured. The cavities have been restored utilizing Ribbond®-Ultra with Tetric N-flow. Ribbond®-Ultra was cut to the necessary length (3-millimeter-wide and 4-millimeter long) with special scissors (Ribbond® scissors). Ribbond®-Ultra was permeated with an excessive bonding agent removed by gentle air drying. Then, the Ribbond was applied, and the fibers were gently pushed with a hand instrument so that They were laminated in a way that was as close to the dentine floor as possible and cured for 20 seconds for complete processing of the composite resin. Then, the cavities have been restored with Tetric N-flow and cured for 20 sec following the standardized protocol. To further reduce the risk of tooth fracturing, a piece of Ribbond-Ultra is placed in the composite approximately 1.5 mm beneath the occlusal surface of the restoration. Afterward, the 1-mm-thick-restoration with Tetric N-flow was performed. [14]

Group II, a specialized gun was used to apply EverX Posterior resin composite directly into the cavity with a 4-millimeter thickness.

Group III, EverX Flow resin composite has been applied to the cavity as one layer 4 mm thick and cured.

Finally, Group IV administered Tetric N-flow. The composite restoration was applied in a similar manner.

Finishing and polishing of the restoration:

Diamond finishing burs (Bluewhite / Kerr - FG4255-5) and polishing discs (Soflex, 3M ESPE) were used under air/water spray for a smooth and shiny surface. Subsequently, the restored teeth have been reserved within distilled water at 37°C for twenty-four hrs to mimic oral situations.

Thermo-cycling test:

The specimens have been subjected to a thermocycling test (SD Mechatronic Thermocycler, Germany) for 5000 cycles at 5–55 °C, simulating 6 months of oral exposure, to evaluate their resistance to temperature changes. [15] Dwell time was 30 sec, and the bath transition time was 5 seconds.

Fracture resistance assessment:

The fracture resistance analysis was conducted utilizing an Instron universal testing machine model 3345 England[16], where each specimen has been subjected to continuous static load utilizing a stainless-steel ball five-millimeter diameter attached to the upper mobile head of the testing machine. The axial compression mood of force applied at a crosshead speed of 1.0 millimeter/minute up to specimen failure, with the force required for failure (Newton) has been recorded by machine software (Blue Hill Universal Instron England).

By calculating ANOVA analysis and post-hoc Tuckey's testing, the restoration materials associated with higher fracture resistance were compared, assuming a minimal effect of adhesive bonding efficacy, discrepancies among molar morphology, and cavity preparation design, given that all cases were class I. The variations in maximum compressive load among different restorative techniques underscore their varying effectiveness in enhancing fracture resistance. [17]

Statistical analysis:

The Shapiro-Wilk test has been utilized to verify the data's normality. For assessing the homogeneity of differences among groups, Levene's test was utilized. The variance was homogeneous, and the data have been normally distributed. One-way ANOVA has been performed in comparing the maximum compressive loads among groups. Post-hoc test using Tukey's test has been conducted for several comparisons. We established a significance level of $p < 0.05$ for all statistical tests. All statistical analyses were carried out using IBM SPSS, Chicago, IL, USA's statistical software for social studies (SPSS) version 25 for Windows.

Results

For descriptive statistics, Group I, restored with Polyethylene Ribbon Fibre (Ribbond®-Ultra) with Bulk Fill flowable resin composite (Tetric N-flow), exhibited a mean maximum compressive load of 1075.52 ± 31.67 N, with a range between 1026.55 N and 1124.30 N. In comparison, Group II, restored with fiber-reinforced bulk fill resin composite (EverX Posterior), showed a higher mean maximum load of 1984.32 ± 30.24 N, ranging from 1936.15 N to 2032.25 N. Group III, restored with Fibre-reinforced bulk fill flowable resin composite (EverX Flow Bulk), had a mean maximum load of 1951.64 ± 33.36 N, with values ranging between 1898.40 N and 2004.50 N. Finally, Group IV, restored with bulk-fill flowable resin composite (Tetric N-flow), exhibited the lowest mean maximum load of 1479.39 ± 63.11 N, ranging from 1383.60 N to 1575.45 N. These findings highlight variations in fracture resistance among the different restoration materials.

The highest mean of the maximum compressive load was observed in Group II, where EverX Posterior displayed a mean compressive load of 1984.32 ± 30.24 N, followed by Group III, restored with EverX Flow demonstrated a mean load of 1951.64 ± 33.36 N, while Group IV, utilizing Tetric N-flow, displayed a lower mean load of 1479.39 ± 63.11 N. Group I, restored with Polyethylene Ribbon Fibre (Ribbond®-Ultra) with Tetric N-flow, exhibited the least mean fracture resistance at 1075.52 ± 31.67.

One-way ANOVA indicated a significant variance in compressive load within the four groups ($p < 0.001$), except for Groups II and III, where no significant variance was found ($p = 0.36$). Post-hoc analysis utilizing Tukey's test has been performed for the following several comparisons. The mean difference in maximum compressive load between groups I and II was -908.8 N. A significant rise was found in the maximum compressive load of Group II compared with Group I ($p < 0.001$). The average variance in maximum compressive load among groups I & III was -876.12 N. A significant rise was found in the maximum compressive load of Group III compared with Group I ($p < 0.001$). The average variance in maximum compressive load among groups I and IV was -403.87 N. A significant rise has been observed in the maximum compressive load of group IV than in group I ($p < 0.001$). The mean variance in maximum compressive load among groups II and III was 32.68 N. Insignificant variance was found in the maximum compressive load among groups II and III ($p = 0.36$). The mean variance in maximum compressive load among groups II and IV was 504.93 N. A significant rise was found in the maximum compressive load of group II compared to group IV ($p < 0.001$). The mean variance in maximum compressive load within groups III and IV was 472.25 N. A significant rise was found in the maximum compressive load of group III compared to group IV ($p = 0.001$). As established within (Table 2), (Fig. 2).

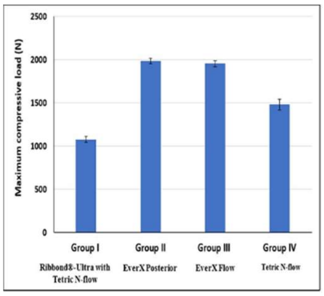

Figure 2: Maximum compressive load of studied groups

Table 2: Comparison of maximum compressive load between the studied groups

Maximum compressive load (N)				F-value	p-value
$\overline{X}$±SD					
Group I (n=9)	Group II (n=9)	Group III (n=9)	Group IV (n=9)		
1075.52±31.67	1984.32±30.24	1951.64±33.36	1479.39±63.11	956.28	0.001
Multiple comparisons (Tukey's test)					
	MD	95% CI		p-value	Significance
		Lower bound	Upper bound		
Group I vs Group II	-908.8	-962.29	-855.32	0.001	S
Group I vs Group III	-876.12	-929.60	-822.64	0.001	S
Group I vs Group IV	-403.87	-457.35	-350.39	0.001	S
Group II vs Group III	32.68	-20.80	86.17	0.36	NS
Group II vs Group IV	504.93	451.45	558.42	0.001	S
Group III vs Group IV	472.25	418.77	525.73	0.001	S

Discussion

Tooth fractures, particularly prevalent in restorations involving a substantial portion of the intercuspal distance, highlight the necessity of robust restorative solutions. [2] Fracture resistance determines a material's ability to withstand predetermined loads, influencing its suitability for different masticatory load areas. [18] This is evaluated by measuring the maximum compressive load of the resins. [17] Because polymerization shrinkage remains a concern, which results in contraction stresses and lowers fracture resistance as well as restoration failure[19], selecting appropriate materials that can compensate for the loss of tooth structure, improving treatment outcomes. [20] Various fiber-reinforced resin composites are some of the greatest alterations in resin composites because of their ability to strengthen teeth. [21]

Therefore, the fracture resistance of teeth that have been restored with fiber-reinforced composites (EverX posterior, EverX flow), ultra-polyethylene fiber ribbon, and bulk-fill posterior restorative material was assessed in this study.

The cusps and ridges of posterior teeth are especially vulnerable to fracture because of their anatomical form, which causes them to deflect under occlusal force during mastication. [1] In the present research, We utilized extracted natural mandibular molars. These teeth have an elevated risk of dental caries, which requires restorative intervention. Additionally, these teeth are more liable to fracture because of the heavy occlusal forces they endure. [12] The teeth have been embedded in acrylic resin for stabilization. [12]

In previous studies, cavity depth and design affected stress generation in enamel. Larger restoration volumes correlate with increased stress on the remaining dental structure, with cusp deflection amplifying with cavity depth, especially with a high C-factor that implies the ratio among the bonded to the free surfaces. [22] Class I cavities were prepared for the current investigation due to the fact that they exhibited the greatest C-factor when filled with resin composite. [23] Bulk-filling offers a convenient approach to cavity restoration, allowing for single-layer filling of cavities up to 4 mm thick. Injectable resin composites, accessible in low-viscosity (flowable) and high-viscosity forms, are beneficial in clinical settings due to their ease of handling and shorter working times. [24] Optibond eXTRa Universal[25], a 2-component bonding agent, boasts unique smart pH technology, a patented formula enriched with the GPDM monomer and ternary solvent system, providing deeper penetration, improved etching, rewetting capabilities, and a uniform adhesive layer. Polyethylene fibre ribbons[11,26], such as Ribbond®-ULTRA, have emerged as premium dental fibers, it is only 0.12 mm thick and offers enhanced strength and reinforcement capabilities. Cold gas plasma is utilized to improve the chemical connection between polyethylene fibers and applied restorative materials. [27] These fibers are placed either under or over composite restorations to absorb stresses and support the composite in multiple directions to enhance fracture resistance, particularly in the occlusal third of the restored tooth. [28] In this study a thin layer of Tetric N-flow, measuring 1 mm, has been applied to the cavity surfaces before embedding polyethylene fiber ribbons to help reinforce the tooth by raising the elastic modulus and preventing fracture. [7] After that, Polyethylene fiber ribbons with a length of 4 millimeters and a width of 3 millimeters have been prepared[29], followed by impregnation with adhesive bonding resin and kept uncured. OptiBond™ Extra Universal, as a wetting agent, facilitated chemical bonding among the fibers and the flowable resin, forming a single combined structure. [4]

Fiber reinforcement Resin composites are materials that are utilized in dentistry for a variety of applications due to their exceptional strength and toughness. [30] It's made of short E-glass fibers inserted in a polymer network matrix along with inorganic fillers. Glass fibers have been categorized into A, C, D, E, R, and S types based on their chemical composition, which differ in their chemical and mechanical properties. Type E-glass fibers, characterized by their electric properties, boast mechanical attributes such as tensile and compressive strength, elastic modulus, and density, contributing to enhanced fracture resistance. [31] Stress transfer from the matrix to fibers, influenced by fiber length and diameter, coupled with the fibres' ability to impede crack propagation is often accountable for the enhanced qualities of the fiber-reinforced composite. [32]

This research assessed the fracture resistance of two distinct commercially available short fiber reinforced composites, specifically utilized in stress-bearing areas, EverX posterior[29], is a light-cured fiber-reinforced composite that is radio-opaque. This material consists of a semi-interpenetrating polymer network matrix composed of bis-GMA, TEGDMA, and PMMA compounds, with randomly oriented short E-glass and inorganic particle fillers. The second material was EverX Flow[33], an injectable composite with short fibers introduced to raise dental composite restoration toughness and fracture resistance. It simplified handling and operative steps, thereby improving the treatment's efficacy. Low-viscosity composite resins, Tetric N-flow[34], is a light-curing, radiopaque, flowable nano-hybrid composite. Compared to traditional composites, they provide higher flow, improved adaptability to the interior cavity wall, simpler insertion, and increased elasticity for routine anterior and posterior restorations, providing the best overall combination of good material qualities and clinical efficacy.

Thermal cycling has been a widely utilized method in dentistry research. It involves repeatedly exposing restorative materials to hot and cold temperatures to mimic the aging process that occurs in vivo, in water baths in a bid to reproduce thermal variations happening in the oral cavity. In this study, the number of cycles applied was 5000, which corresponds to six months of clinical function. [15]

Fracture resistance is studied for in vitro research to evaluate the variant materials strength. Numerous variables may impact the results of fracture resistance research. This includes the crosshead speed, load application device type, and tooth mounting technique. [35] In this investigation, a 5-millimeter stainless steel sphere has been utilized for testing the fracture resistance of the material utilizing a universal testing machine. An axial compressive force has been applied to the center of the occlusal surface. According to numerous research, the usage of a 5-millimeter stainless steel sphere is perfect for measuring the fracture resistance of molars since it makes uniform contact with functional and non-functional cusps. [36]

The outcomes of this research showed that the null hypothesis was excluded as the statistical analysis demonstrated a significant variance within the four groups ($p < 0.001$), except for G II EverX Posterior and G III EverX Flow, where there was no significant difference.

Consistent with previous work, Gürel et al.[37] found that restoration of severely compromised premolar teeth using EverX Posterior may have advantages over G-aenial Posterior or polyethylene woven fiber-reinforced composite methods. Ozsevik et al.[29] showed that EverX Posterior gives higher fracture resistance than G–aenial posterior and Polyethylene fiber ribbons in root-filled teeth. Also, Garlapati et al.[7] concluded that endodontically managed teeth restored with EverX Posterior resin composite demonstrated increased resistance to fracture than Te-Econom Plus and Ribbond with 3M-ESPE. Farahanny et al.[5] showed that resin composite EverX bulk-fill has a greater fracture resistance than other groups, Sonicfill bulk-fill, and Filtek bulk-fill with no significant differences. Taher et al.[32] concluded that the utilization of EverX posterior short fiber reinforced resin composite as restoration significantly elevated the fracture resistance of the teeth with MOD restorations compared to sonic fill bulk fill composite and Ceram-x-SpherTEC.
For EverX Flow being a barrier to crack propagation, this was also consistent with Garoushi et al.[38] These authors traced similar compressing loads with restorations on intermingling EverX Flow and a surface

dental composite layer. Similarly, Gamal et al.[30] stated that the teeth restored with EverX Flow conveyed higher significant fracture resistance than Alert fiber-reinforced resin composite and Z350 nano-filled resin composite. Magne et al.[10] stated that statistically insignificant variance among EverX posterior and EverX Flow groups. Also, it is agreed with Ranka et al.[9] who detected no statistically significant variation in the clinical outcome between EverX posterior and EverX Flow. Aboobaker et al.[34] stated that the TetricN-flow group showed higher fracture resistance than FUJI GC resin-modified GIC and bonded amalgam.

In contrast to our results, Goda et al.[39] showed that EverX Flow has a non-significantly greater fracture resistance than Tetric N-flow. This difference is probably attributed to external confounders concerning the composite restorations' placement and smaller effect sizes. Loading parameters (rate, direction, toolkit, ..etc) and changes in mechanic-physical attributes secondary to flowability/consistency could affect empirical measuring of structural flaws or defects (e.g. microcracks and voids detectable ultrastructurally) if the effect size is too small. Also, Rahman et al.[40] demonstrated that the fracture resistance of teeth treated with root canal therapy has been much enhanced by the use of polyethylene fiber placed over or under the restoration, highest fracture resistance was noted when the cavity was rebuilt utilizing a dual-fiber approach rather than base fiber group, occlusal fiber group, and (Filtek Z250). Balkaya et al.[8] concluded that the utilization of Ribbond® with Filtek Bulk Fill Restorative and Ribbond® with SDR and Filtek Z550 enhanced the fracture resistance of teeth more than Filtek Z550, Filtek bulk fill restorative, SDR with Filtek Z550, and EverX Posterior with Filtek Z550. Agrawal et al.[19] stated that the greatest fracture resistance was exhibited by Ribbond® fiber placed horizontally on the pulpal and gingival floor, EverX Posterior showed lesser fracture resistance than the Ribbond® fiber groups. This controversy might be attributed to variances in aging time in thermocycling tests in simulating the aging of biomaterials, differences in resin composite material used with Ribbond® fiber, differences in the direction of the force applied, type of tooth, and many other confounders that can affect the results. Choosing direct resin composites in restoring teeth with a moderate amount of remaining tooth structure depends on several factors as fiber-reinforced resin composite restorations (Ribbond®) need more operator skills, patient cooperation, longer intra-oral time, more procedural steps, and are expensive. The direct bulk fill fiber reinforced resin composite (EverX posterior) restorations offer less patient cooperation, ease of use, less intra-oral time, fewer procedural steps, and cost-effective.

Among the limitations of the current in vitro research is that it has been performed under a static load without simulation of an in vivo condition. further, in vivo, studies should identify the mechanical properties of fiber-reinforced bulk fill resin composite (EverX posterior, EverX Flow) and polyethylene fiber ribbon (Ribbond®) materials. Also, Future research will incorporate cyclic fatigue testing, exploring diverse cavity configurations, and integrating simulated periodontal ligaments to well simulate clinical situations.

Conclusion

Within the constraints of this investigation, it is possible to conclude that the contemporary fiber-reinforced bulk fill resin composite restoration for deep and wide class I cavities reinforces vital teeth against fracture. Application of polyethylene fiber ribbon to reinforce prepared teeth is doubtful and time-consuming.

Clinical significance

In severely weakened teeth, bulk-fill fiber-reinforced resin composite may be employed as a reliable option for such large posterior restorations, as it can strengthen the remaining sound tooth structure and raise the tooth's resistance to fracture.

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Data Availability Statement: Not applicable.

Conflicts of Interest: None.

Ethics approval and consent to participate: Obtained on January 9, 2023 (Approval No RECO6U/3-2023).

Authors' contributions:
Conceptualization, HMHN.; methodology, HMHN; validation, HMHN, And HH.; formal analysis, HMHN, and HH.; investigation, HMHN, and HH.; resources, HMHN and AF.; data curation, HMHN and RROOT.; writing—original draft preparation, HMHN ; writing—review and editing, HMHN, And HH.; visualization, HMHN, and HH.; supervision, HMHN; project administration, HH. All authors have read and agreed to the published version of the manuscript.

References

1. Rajaraman G, Senthil Eagappan AR, Bhavani S, Vijayaraghavan R, Harishma S, Jeyapreetha P. Comparative evaluation of fracture resistance of fiber-reinforced composite and alkasite restoration in class I cavity. Contemp Clin Dent 2022;13(1):56–60.
2. Rosatto CMP, Bicalho AA, Veríssimo C, et al. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. J Dent 2015;43(12):1519–1528.
3. Papadogiannis D, Tolidis K, Gerasimou P, Lakes R, Papadogiannis Y. Viscoelastic properties, creep behavior and degree of conversion of bulk fill composite resins. Dental materials 2015;31(12):1533–1541.
4. Albar NHM, Khayat WF. Evaluation of Fracture Strength of Fiber-Reinforced Direct Composite Resin Restorations: An In Vitro Study. Polymers (Basel) 2022;14(20).
5. Farahanny W, Dennis D, Sihombing D. Fracture resistance of various bulk-fill composite resins in class II MOD cavity on premolars: An In Vitro study. World Journal of Dentistry 2019;10(3):166–169.
6. abed yasser, Abdelwahed A. Effect of Using Fiber Reinforcement Ribbond® System on Marginal Adaptation of Fluoride Releasing Restorations: An In Vitro Study. Egypt Dent J 2024;70(1):611–623.
7. Garlapati TG, Krithikadatta J, Natanasabapathy V. Fracture resistance of endodontically treated teeth restored with short fiber composite used as a core material—An in vitro study. J Prosthodont Res 2017;61(4):464–470.
8. Balkaya H, Topçuoğlu HS, Demirbuga S, Kafdağ Ö, Topçuoğlu G. Effect of different coronal restorations on the fracture resistance of teeth with simulated regenerative endodontic treatment: An in vitro study. Australian Endodontic Journal 2022;48(2):331–337.
9. Ranka S, Rao AS, Shah U, et al. Comparative Evaluation of Two Different Fiber-Reinforced Composite Materials in Class 1 Post-Endodontic Restorations in Molars—A Randomized Clinical Study. Materials 2022;15(21).
10. Magne P, Carvalho MA, Milani T. Shrinkage-induced cuspal deformation and strength of three different short fiber-reinforced composite resins. Journal of Esthetic and Restorative Dentistry 2023;35(1):56–63.
11. Foek DLS, Yetkiner E, Özcan M. Fatigue resistance, debonding force, and failure type of fiber-reinforced composite, polyethylene ribbon-reinforced, and braided stainless steel wire lingual retainers in vitro. Korean J Orthod 2013;43(4):186.
12. Jain A, Parvez S, Likhyani L, Aggarwal MK, Binawra KK, Khatri S. Comparative Evaluation of Fracture Resistance of Endodontically Treated Mandibular First Molar Restored with Fibre Reinforced Composite, Nanohybrid Composite and Bulkfill Composite–An In-vitro Study. List of Articles Pages No
13. Goda et al.2020.
14. Tekçe N, Pala K, Tuncer S, Demirci M, Serim ME. Influence of polymerisation method and type of fibre on fracture strength of endodontically treated teeth. Australian Endodontic Journal 2017;43(3):115–122.
15. Morresi AL, D'Amario M, Capogreco M, et al. Thermal cycling for restorative materials: Does a standardized protocol exist in laboratory testing? A literature review. J Mech Behav Biomed Mater. 2014;29:295–308.
16. Elfatih Mansour M, Hamdy Wahba A, Abdellatif A, Hassan El-kalla I. AIN SHAMS DENTAL JOURNAL Official Publication of Ain Shams Dental School Evaluation of Different Post and Core Systems

for Restoring Pulpectomized Primary Incisors: An In-Vitro Study.
17. Kamath AK, Kudva AR, Eram A, Sreekantan PM, Kini S. Comparative Evaluation of Fracture Resistance of Posterior Teeth Restored Using Three New Composite Materials: An In Vitro Study. World Journal of Dentistry 2023;14(7):608–612.
18. Battancs E, Sáry T, Molnár J, et al. Fracture resistance and microleakage around direct restorations in high c-factor cavities. Polymers (Basel) 2022;14(17):3463.
19. Agrawal V, Shah A, Kapoor S. Effect of fiber orientation and placement on fracture resistance of large class II mesio-occluso-distal cavities in maxillary premolars: An in vitro study. Journal of Conservative Dentistry 2022;25(2):122–127.
20. Sengun A, Cobankara FK, Orucoglu H. Effect of a new restoration technique on fracture resistance of endodontically treated teeth. Dental Traumatology 2008;24(2):214–219.
21. Albar N, Khayat W. Fracture Load of Mesio–Occluso–Distal Composite Restorations Performed with Different Reinforcement Techniques: An In Vitro Study. Polymers (Basel) 2023;15(6).
22. Tang C, Ahmed MH, Yao C, et al. Experimental two-step universal adhesives bond durably in a challenging high C-factor cavity model. Dental Materials 2023;39(1):70–85.
23. Sfeikos T, Dionysopoulos D, Kouros P, Naka O, Tolidis K. Effect of a fiber-reinforcing technique for direct composite restorations of structurally compromised teeth on marginal microleakage. Journal of Esthetic and Restorative Dentistry 2022;34(4):650–660.
24. Elgammal YA, Temirek MM, Hassanein OE, Abdelaziz MM. The Effect of Different Finishing and Polishing Systems on Surface Properties of New Flowable Bulk-fill Resin Composite. J Contemp Dent Pract 2023;24:587–594.
25. Siddarth B, Aileni KR, Rachala MR, et al. Comparative evaluation and influence of new Optibond eXTRa self-etch Universal adhesive and conventional Transbond XT on shear bond strength of orthodontic brackets - An in vitro study. J Orthod Sci 2022;11(1):43.
26. Abdulamir SW, Majeed MA. Fracture Resistance of Endodontically Treated Maxillary Premolar Teeth Restored with Wallpapering Technique: A Comparative in Vitro Study. Int J Dent 2023;2023.
27. Mangoush E, Garoushi S, Lassila L, Vallittu PK, Säilynoja E. Effect of fiber reinforcement type on the performance of large posterior restorations: A review of in vitro studies. Polymers (Basel). 2021;13(21).
28. Yeniçeri Özata M, Adıgüzel Ö, Falakaloğlu S. Evaluation of stress distribution in maxillary central incisor restored with different post materials: A three-dimensional finite element analysis based on micro-CT data. 2021;
29. Ozsevik AS, Yildirim C, Aydin U, Culha E, Surmelioglu D. Effect of fibre-reinforced composite on the fracture resistance of endodontically treated teeth. Aust Endod J 2016;42(2):82–87.
30. Gamal W, Abdou A, Salem GA. Fracture resistance and flexural strength of endodontically treated teeth restored by different short fiber resin composites: a preclinical study. Bull Natl Res Cent 2022;46(1).
31. Liu J, Chen M, Yang J, Wu Z. Study on mechanical properties of basalt fibers superior to E-glass fibers. Journal of Natural Fibers 2022;19(3):882–894.
32.Taher HM, Haridy M, Haridy EDJ Vol M. FRACTURE RESISTANCE OF MAXILLARY PREMOLARS RESTORED WITH DIFFERENT FIBER-REINFORCED COMPOSITES: AN IN VITRO STUDY [Homepage on the Internet]. 2019; Available from: www.eda-egypt.org
33. Ferrari M, Lettieri E, Pontoriero DIK, Vallittu P, Ferrari Cagidiaco E. Particulate Filler and Discontinuous Fiber Filler Resin Composite's Adaptation and Bonding to Intra-Radicular Dentin. Polymers (Basel) 2023;15(15).
34. Aboobaker S, Nair BG, Gopal R, Jituri S, Veetil FRP. Effect of intra-orifice barriers on the fracture resistance of endodontically treated teeth – An ex-vivo study. Journal of Clinical and Diagnostic Research 2015;9(2):ZC17–ZC20.
35. Al-Makramani BMA, Razak AAA, Ng MY, Ying SY, Al-Sanabani FA. Effect of restorative techniques on fracture resistance of endodontically treated premolars. Open J Stomatol 2013;3(07):379.
36. Belli S, Cobankara FK, Eraslan O, Eskitascioglu G, Karbhari V. The effect of fiber insertion on fracture resistance of endodontically treated molars with MOD cavity and reattached fractured lingual cusps. J Biomed Mater Res B Appl Biomater 2006;79(1):35–41.
37. Gürel MA, Helvacioğlu Kivanç B, Ekıcı A, Alaçam T. Fracture Resistance of Premolars Restored Either with Short Fiber or Polyethylene Woven Fiber-Reinforced Composite. Journal of Esthetic and Restorative Dentistry 2016;28(6):412–418.
38. Garoushi S, Akbaşak-Sungur A, Erkut S, Vallittu PK, Uctasli S, Lassila L. Evaluation of fracture behavior in short fiber–reinforced direct and indirect overlay restorations. Clin Oral Investig 2023;27(9):5449–5458.
39. Abogabal A, Goda A. Efficacy of Bulk Fill Flowable Composite Reinforced with Short Fibers in Fracture Resistance of Restored Extensive Premolars Cavities. Al-Azhar Assiut Dental Journal 2020;3(2).

40. Rahman H, Singh S, Chandra A, Chandra R, Tripathi S. Evaluation of fracture resistance of endodontically treated teeth restored with composite resin along with fibre insertion in different positions in vitro. Aust Endod J 2016;42(2):60–65.