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Comparative Study on Material Behaviours and Fracture Resistance of Premolars Post-Thermocycling: Evaluating Preheated Thermoviscous, Sonic Fill, and Conventional Resin Composites

Rasha R. Basheer[1,2] , Heba Bahgat Abdel-Maksoud[2,3]

Aim: This research was formulated to investigate the fracture resistance of premolars restored using preheating thermo-viscous, sonic fill, bulk injectable, and incrementally packed nano-hybrid resin composite materials.
Materials and methods: Sixty extracted premolars were selected and standardized class II MOD cavities were prepared. Teeth were distributed randomly into six groups according to restoration techniques used: Group 1 (intact sound teeth; positive control, Group 2 (prepared cavities; negative control), Group 3 (VisCalor Bulk fill; VCB), Group 4 (SonicFill 3; SOF), Group 5 (Herculite™ XRV Ultra™; HXU), and Group 6 (G-aenial bulk injectable; GBI). All prepared teeth were then aged by thermocycling for 5000 cycles and tested for fracture resistance. The mode of fracture was identified using a stereomicroscope and scanning electron microscopy.
Results: All tested MOD restorations failed differently. The resin composite material type had a considerable impact on all specimens' load-bearing capacity ($p<0.05$). A statistically significant difference ($p< 0.05$) in the fracture resistance values of MOD cavities restored with all tested types of resin composites was recorded. No significant difference was reported between SOF and HXU according to one-way ANOVA ($p=0.800$).
Conclusion: GBI represents an acceptable option used for direct restorations without a superficial layer of conventional composite covering layer compared to low or high-viscosity bulk fill materials. Injectable bulk fill composites represent an optimum selection over other nanohybrid packable bulk fill materials in restoring mesio-occluso-distal cavities.

Keywords: Sonic fill, Injectable composite, Bulk fill, Thermoviscous, Pre-heated, Fracture resistance.

1. Conservative Dentistry Department, Faculty of Dentistry, October University for Modern Sciences and Arts, Giza, Egypt.
2. Restorative Dentistry Department, King Abdulaziz University, Jeddah 21589, Saudi Arabia.
3. Conservative Dentistry Department, Faculty of Dentistry, Suez Canal University, Ismailia 41611, Egypt.
Corresponding author: Heba Bahgat Abdel-Maksoud, email: habdalmaksod@kau.edu.sa

Introduction

Throughout the last decade, demand for tooth-colored restorations in dentistry resulted in the introduction of resin-based composite (RBC) filling materials and ceramics, paving the way for a revolution in dentistry. [1] Further generations of RBC were modified to obtain better physical and mechanical properties and convenient handling methods. In addition to this advancement, resin bonding technologies have expanded their uses, making them direct restorations called universal restoration. [2]

Among the critical aspects influencing the clinical achievement of RBC restorations are the degree of polymerization conversion, shrinkage stresses, polymerization shrinkage limited depth of cure, and material mechanical qualities. Adequate polymerization and suitable placement procedures are crucial for optimal clinical performance. [3] RBC should be applied in ≤2 mm increments to reduce shrinkage, increase conversion, prevent restoration margin disintegration, and provide adequate aesthetics. [4] It has been believed that this is a useful strategy for approaching composite layering and can assist in minimizing polymerization shrinkage when combined with an oblique layering methodology. [5]

Moreover, split modeling of consecutive increments done simultaneously can aid in minimizing shrinkage challenges. [6] A split horizontal incremental approach has been demonstrated to produce less microleakage at the gingival border of a cavity. [7] To minimize microleakage at the occlusal margin of a Class II restoration, a centripetal and oblique placement method is used after a split horizontal incremental technique. [8] On the other hand, applying resin composite incrementally demands time. It comes with a higher risk of contamination and can be difficult to restore more conservative cavities.

Another risk associated with the stepwise application process is the entrapment of undesired air between layers, which could lead to adhesive failure between layers. [9] Furthermore, as the number of increments increased, so did the elastic modulus and post-photopolymerization shrinkage. [4] The complexity of incremental layering has resulted in the improvement of bulk-fill composite materials, that have the advantage of taking less time to treat and may result in lower volumetric shrinkage stress and enhanced curing depth while retaining required micromechanical properties. Bulk-fill resin composites are categorized as either high-viscosity (sculptable) or low-viscosity (flowable) because of variations in rheological characteristics and application methods. To achieve a temporary viscosity decrease comparable to that of a flowable composite while preserving the benefits of the higher mechanical qualities associated with densely packed resin composites, pre-heating high-viscosity bulk-fill composites may be an appealing method. [10] Addressing this issue, researchers have investigated numerous tactics for improving the endurance of composite interfaces, with prewarming and sonic applications as potential approaches.

Prewarming composite materials have been demonstrated to improve flowability and reduce viscosity, allowing for better adaption to cavity walls and increased interfacial bond strength. Similarly, the sonic application has been proposed to enhance composite adaptability and reduce void formation at the interface by increasing material flow and seating. According to the manufacturer's documentation, the Sonicfill system is a recent bulk-fill technology consisting of a newly developed composite material in uni-dose tips and a handpiece designed exclusively for this function. The composite incorporates universal and flowable composites, with a special highly filled resin and unique sound-responsive modifiers. When sonic energy is provided to the handpiece with five unique flowability levels, the modifier reduces the viscosity (up to 87%), increasing the composite's flowability. The composite becomes more viscous and non-slumping when the sonic energy is removed, allowing for carving and contouring. Additionally, the business asserts that because of the composite material's increased photoinitiator levels, a complete 5 mm cure may be achieved in 20 seconds when using a 550 mW/cm2 light source. [11] Despite substantial breakthroughs in filler technology, interface optimization, and polymer chemistry, fracture remains the most common failure in posterior direct RBC restorations. [12]

Based on the foregoing issues, this study intended to bridge this gap and provide valuable insights into the performance of these materials in enhancing fracture resistance. In addition, stereo and scanning electron microscopes were used to observe the material's behavior. This study aimed to evaluate the fracture resistance of first premolars restored with different bulk-fill resin composites. The null hypotheses were: first, no significant difference would be between the sound teeth group and the rest of the groups tested in terms of fracture resistance. The second null hypothesis would be no significant difference between all groups of conventional and bulk-fill resin composites in terms of fracture resistance. The third null hypothesis would be no significant difference between all bulk-fill composites tested in terms of fracture resistance.

Materials & Methods

Teeth selection and preparation:

Sixty extracted premolars were collected with no cavities, cracks, restorations, or fractures. They were cleaned and scaled to eliminate plaque before being polished using a spinning brush and pumice. All teeth tested had uniform anatomic crown length and buccolingual and mesiodistal dimensions. The samples were then kept in distilled water at 37°C between the extraction date and the testing to maintain them hydrous and allow for the resin composite restorations to achieve water sorption equilibrium. [13, 14] To replicate periodontium, root surfaces were submerged in molten wax to a depth of 2 mm below the cementoenamel junction, resulting in a 0.2-0.3 layer. Then, they were placed in polyvinyl plastic cylinders with self-cure acrylic resin 2 mm below the C.E.J. The wax spacer was eliminated from the root and acrylic surfaces, and each tooth was isolated from the acrylic. After applying polyether to the remaining space, the teeth were put back into the cylinders. As a result, a partial periodontal ligament replica was achieved. This process made a level foundation for cavity preparation, restoration, and fracture resistance evaluation possible. [15]

Teeth grouping, cavity preparation, and restorations:

Teeth were split into six groups at random (n=10). **Group 1:** Sound teeth were left with no cavity preparation (the positive control), **Group 2:** teeth were prepared with MOD cavities and left unrestored (negative control). **Group 3:** teeth restored with VisCalor Bulk, **Group 4**: teeth restored with Sonic Fill 3 (sonic activated), **Group 5**: teeth were restored with Herculite™ XRV Ultra™ and **Group 6:** teeth were restored with G-aenial bulk injectable resin composite. Materials brands, manufacturers, and compositions are presented in (Table 1).

Table 1: Material brand, manufacturer, resin system, filler type, and filler loading.

Material	Manufacturer	Resin System	Filler	Filler Loading	Lot number
VisCalor Bulk **VCB**	Voco, Cuxhaven, Germany	Bis-GMA, aliphatic dimethacrylates	Glass-ceramic fillers (average 1 µm), silicon dioxide nanoparticles (20-40 nm)	83 wt%	2020153
SonicFill 3 **SOF**	Kerr, USA	Bis-EMA and TEGDMA	Barium silicon dioxide glass (10-30 nm), Filler loading	81 wt%	8833393
Herculite™ XRV Ultra™ **HXU**	Kerr, Scafati, Italy	Methacrylic monomers, Trimethylolpropane Triacrylate, TiO, benzoyl peroxide, 4-Methoxyphenol, initiators, pigments	Pre-polymerized fller (PPF), Silica nanofllers (20–50 nm), Barium glass (0.4 micron)	78 wt%	7979139
G-aenial bulk injectable **GBI**	GC Corporation, Tokyo, Japan	UDMA, Bis-MEPP, TEGDMA, pigment photo-initiator	barium glass, and silica	69 wt%	220624 A

Abbreviations: BisGMA: bisphenol-A diglycidil ether dimethacrylate; UDMA = urethane dimethacrylate; Bis-MPEPP = 2,2-bis-[4-(2-methacryloyloxyethoxy) phenyl] propane; TEGDMA = triethyleneglycol dimethacrylate; vol%: volume%; wt%: weight%.

Complex class II MOD cavities with pulpal depth of 2 ± 0.2 mm, gingival width of 1.5 ± 0.2 mm, axial height of 2 ± 0.2 mm, parallel proximal walls with buccolingual width of 3 ± 0.2 mm, and occlusal isthmus width one-third of the inter-cuspal distance were produced by a single operator for all specimens. A diamond flat-ended fissure (Brasseler USA Dental, GA, USA) mounted on a high-speed handpiece with enough air-water spray for each specimen was used to prepare the cavity. Every four preparations, the bur was also replaced. In groups 3,4,5, and 6, to imitate the clinical condition, an adjustable circumferential metal matrix (Auto matrix®, MT, Dentsply, Milford, DE, USA) was placed around each tooth's MOD cavity preparation. The cavities were then cleaned of any remaining debris using a moderate air-water spray. Cavities were treated with the etch-and-rinse adhesive procedure, as recommended by the manufacturer. Etching gel with 37% phosphoric acid (Kerr, Orange, CA, USA) was applied to the enamel for 15 seconds, then to the enamel and dentin for another 15 seconds, followed by a 10-second rinse with water, then gentle air drying for 2 seconds. Adhesive optibond™ Universal (Kerr, Orange, CA, USA). Then applied to dentin and etched enamel and light-cured for 20 s, and each increment was light-cured for 20 s (Light Emitting Diode curing unit, 3M ESPE Elipar, Germany, 1,200 mW/cm2, 430-480 nm).

For group 3, VisCalor Bulk (preheated thermos-viscous) was applied after being preheated with the VisCalor Dispenser at 68°C and then light cured for 20 seconds following the manufacturer's instructions. Group 4, Sonic Fill 3 (sonic activated), was applied via the sonic insertion method with a Sonic Fill handpiece. Group 5, Herculite™ XRV Ultra™, was inserted by incremental packing with a maximum of 2 mm thickness, followed by light curing for 20 s. Group 6, G-aenial bulk injectable resin composite, was inserted in a 4 mm thickness increment followed by light curing for 20 s. After restorations were completed, finishing using diamond burs and polishing using a KENDA polishing kit was done. All specimens were kept in distilled water in an incubator at 37°C for 24 hours.

Thermocycling

The teeth were then thermo-cycled for 5000 cycles in a water bath at five °C and 55°C with a transfer time of 5 seconds and a dwell period of 20 seconds (1100 SD Mechatronik thermocycler; Westerham, Germany. The number of cycles recommended by ISO TR was 500 by minimum for dental restoration aging experiments. [16] A total of 10,000 cycles corresponds to approximately one year of functionality. However, 20 to 50 cycles are verified to be comparable to one day of clinical performance. [17] Thus, 5000 cycles were equivalent to a maximum of 250 days of aging.

Fracture resistance testing

Each specimen's acrylic block was affixed to the lowest fixed head of the universal testing machine (Instron model 3345, England). Each tooth was subjected to continuous static load with a smooth stainless-steel ball (2 mm in diameter) attached to the testing machine's upper moveable head. Axial compression of force was applied at a crosshead speed of 1.0 mm/min until the specimen failed. The load at the specimen fracture was measured in Newton and assessed and recorded using computer software (BlueHill Universal Instron England). The maximum force needed to break the specimens was the fracture resistance (FR). To ensure consistency, all tests were conducted by the same operator using a standardized procedure.

Failure assessment and analysis

All samples were imaged with a stereomicroscope. For standardization and precision, each tooth was photographed twice using stereomicroscopic techniques: once from the side and once from the occlusal. The failure surfaces of each tooth were studied with a stereomicroscope at 30x magnification (Leica MZ 75, Mannheim, Germany). Two categories of failures were identified: repairable and non-repairable.

Representative samples were selected to determine material behavior. Samples were attached to standard-diameter aluminum stubs with carbon double sticky tape to analyze the fracture topography. The morphological structures and elemental composition of each tested sample were investigated using a scanning electron microscope (SEM) (Model FEI Quanta 3D 200i) attached to an Energy Dispersive X-ray Analyses / thermofisher pathfinder Unit (EDX) under operating conditions of accelerating voltage 30 K.V, resolution 0.1nm, and different magnifications.

Statistical Analysis

Mean and standard deviation (SD) values were computed for all tested groups. When the data was tested for normalcy using the Kolmogorov-Smirnov and Shapiro-Wilk tests, it revealed a parametric (normal) distribution. To compare more than two groups in unrelated samples, one-way ANOVA was performed, followed by the Tukey post-hoc test. The significance level was set to $P < 0.05$. Statistical analysis was carried out using IBM® SPSS® Statistics Version 20 for Windows.

Results

Fracture resistance results

Fracture resistance (FR) values in Newtons (Mean ± SD) for all groups tested are presented in Table 2 and Figure 1. FR of sound teeth (positive control) was significantly higher than the rest of the groups tested ($P < 0.05$), and FR of the unrestored prepared group (negative control) was significantly lower than the rest of all groups tested ($P < 0.05$). According to one-way ANOVA, fracture resistance was significantly affected by the resin composite type (P=0.05). The GBI group had the highest Fracture resistance values (1395.5±92.7), followed by SOF (1164.78±192.4), HXU (1072.4±305.9), and VCB (818.5±104.5). No significant difference was found between the SOF and HXU groups (p=0.800).

Table 2: shows the mean and standard deviation of fracture resistance for all composite resin types.

Groups	*n*	Brand name	Mean ±SD
Group I	10	Sound (Intact) teeth	2008.5710± 86.10847^{a}
Group II	10	Prepared unrestored teeth	371.1980±34.24330^{b}
Group III	10	VisCalor bulk	818.53±104.52^{c}
Group IV	10	SonicFill 3	1164.76±192.37^{d}
Group V	10	Herculite XRV ultra	1072.41±305.86^{d}
Group VI	10	G-aenial Bulk Injectable	1395.55±92.70^{e}

In mean column, different superscript letters indicate statistically significant difference

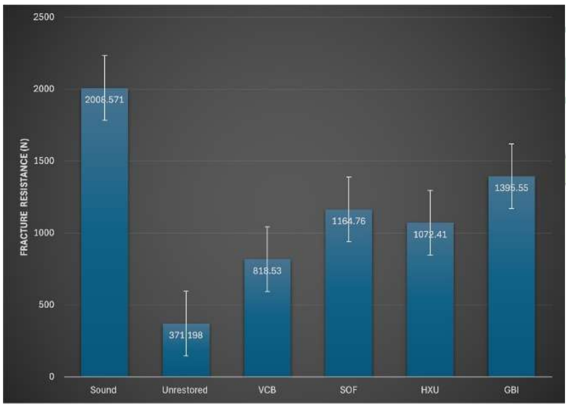

Figure 1: shows the mean fracture load (N) and standard deviation (SD) of the tested restorations following thermocycling. The same letter within the bars denotes a non-statistically significant difference (p>0.05) between the tested materials.

Fracture analysis results

After visually inspecting the materials, two distinct types of fractures were found. The chipping of only part of the restoration was repairable, and the fracture, including the tooth-restoration complex that extended beyond CEJ into the root, was considered unrepairable. [18] The dominating type of fracture noticed in GBI was repairable, followed by SOF and HXU, both of which showed repairable fractures more than non-repairable ones. The non-repairable fracture was the dominating type in the VCB. Representative samples of the two types of fracture modes are shown in Figures 2 and 3. EDXA was used to ensure tracking cracks by testing the chemical characterization of each substrate qualitatively.

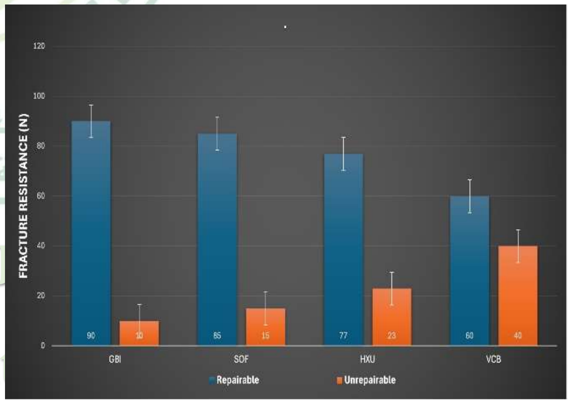

Figure 2: Fracture resistance analysis corresponding to tested groups. Abbreviations: GBI: G-aenial Bulk Injectable; SOF: SonicFill 3; HXU: Herculite XRV ultra; and VCB: VisCalor bulk.

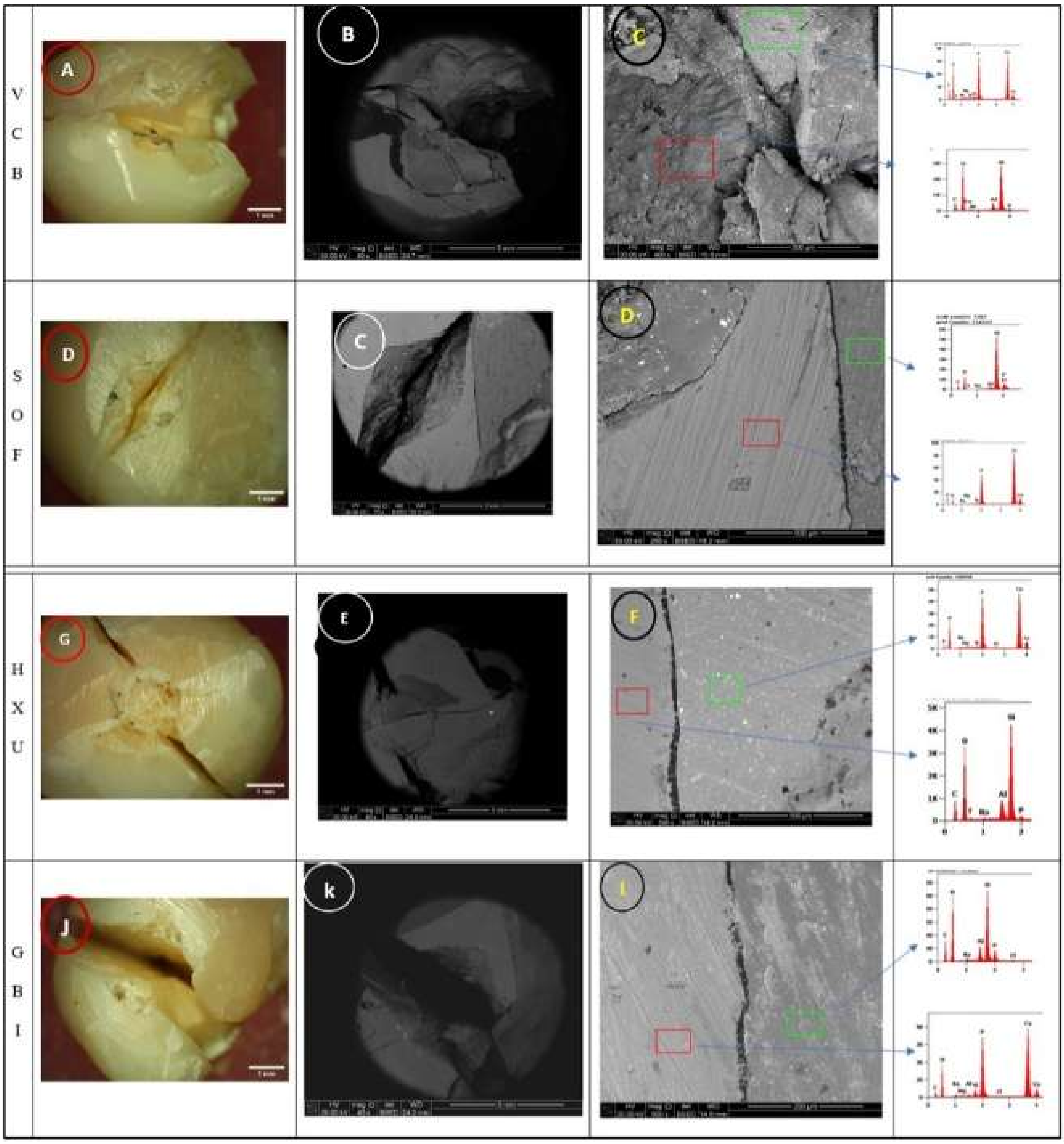

Figure 3: Representative stereomicroscopic pictures were captured for a selected sample from every tested group (A, D, G, J). Cracks were detected propagating within all examined groups on a macro scale. For standardization purposes, the same selected sample was scanned under SEM to confirm the presence of macro and micro-cracks using low magnification (40X), which was like that used by stereomicroscope figures (B, E, H, K). Higher magnification (250-600x) was used to confirm the direction of crack propagation that started from the loading area and extended deeper within substrates (tooth/ restoration/ tooth-restoration unit) (C, F, I, L). EDXA was used to ensure that cracks were tracked by qualitatively testing each substrate's chemical characterization. In the GBI group, cracks were present only on the macro level. However, when using higher magnification, no cracks were detected at all. This goes by the higher percentage of repairable fractures obtained for the same group. Notably, in the VCB group, cracks were reported on both micro and macro levels, which went well with the catastrophic failures recorded. Regarding SOF and HXU, cracks were seen on the macro level with limited propagation on the micro level.

Discussion

The most common failures for resin composite restorations in MOD cavities are secondary caries and material fractures. These are linked to polymerization shrinkage, depth of cure, ease of use, and tooth-restoration interface integrity. [19] The significant loss of tooth structure in MOD cavities compromises strength and integrity, leading to adhesive failure at the gingival aspects and polymerization shrinkage and depth issues. The choice of materials and treatment methods significantly impacts the effectiveness of restorations in preventing these issues. [20] Bulk fill materials have evolved significantly to address some issues related to traditional resin composite restorations. These have passed through many evolutions and advances, including Sonic fill, preheated thermos viscous, injectable, and packable composites. In the present in vitro study, bulk-fill materials that are claimed to restore large cavities subjected to heavy stresses were investigated, and the suitability of different delivery modes in terms of their effect on FR was evaluated. Since MOD cavities are thought to have the lowest fracture resistance, they were selected for this investigation. [21]

A statistically significant difference was reported between the fracture resistance values of all tested groups restored with different types of composites and between the FR values of all tested groups and those of the sound teeth group. Consequently, the study's first and second null hypotheses were disproved.

The periodontal ligament attaches to the alveolar bone of the tooth and prevents breakage by distributing occlusal forces. [22] Studies show that a 90-degree load on premolars distributes force evenly when applied in a parallel direction to the teeth’s long axis, affecting both cusps equally. This study used that method to ensure equal cusp loading. Fracture resistance is linked to stopping crack growth, and chewing forces can cause cusp deflection. Cusp deformations under chewing power are lessened by composite resins. Differences in size, distribution, filler content, and matrix composition all affect how long they last. [23] Determining a restoration’s fracture susceptibility involves many factors, including cavity size, tooth structure integrity, bonding effectiveness, and material properties. [24, 25] Bulk-fill composite resins have been shown in studies to reduce cusp deformation and increase fracture resistance. [26, 27]

The fracture resistance values of teeth restored using bulk-fill and conventional composite resin differed statistically significantly from those of intact teeth in this investigation. This outcome could be explained by the dental crown's superior strength characteristics, which include mesial, distal, buccal, and lingual walls, entire marginal ridges, and an intact occlusal surface. [28] On the other hand, mutilation is indicated by the ratio of the quantity of tooth loss in premolars to the amount of remaining tooth structure in the MOD cavities. As a result, the amount of remaining tooth substance resistance to fracture was reduced. This follows studies that reported a significant difference between the fracture resistance of intact, prepared, and restored cavities, with the intact teeth showing the highest fracture resistance values. [29 30] A recent study in 2024 reported a non-significant difference between the fracture resistance values of intact teeth and teeth restored with bulk-fill composites. [31] This contradiction might be due to the difference in the type of bulk fill materials used in that study and those used in the present research. Although they investigated high-viscosity bulk fill composites, they did not test the fracture resistance after thermocycling used in the present study. This is crucial as it mimics the temperature variation the materials experience intraorally. It evaluates long-term durability by repeating thermal cycles, causing expansion and contraction of the materials, and it affects the tooth-restoration bond. Therefore, testing after thermocycling ensures that this bond remains strong and intact under thermal stresses.[24, 32, 33, 34]

In this study, there was a statistically significant difference found between the fracture resistance values of teeth restored using G-aenial bulk injectable (GBI) and the rest of all tested groups restored with VisCalor Bulk (VCB), SonicFill 3 (SOF), and Herculite™ XRV Ultra™ (HXU). GBI reported the significantly highest FR values among all restored tested groups. The addition of components to the material may be responsible for improved fracture resistance in teeth rebuilt using GBI. GC utilizes Full-Coverage Silane Coating (FSC) technology to create barium glass fillers, which are extremely small particles (approximately 150 nm) that are firmly attached to the resin matrix. [35] According to research, the presence of extremely small and reactive glass particles in the material may have a beneficial effect on the fracture resistance value.[36]

Different from other composites investigated, GBI contains a rigid monomer Bis-MEPP in its resin matrix that improves the adhesion between the fillers and resin matrix along with advanced silane coupling agents. It also contributes to the hydrophobic nature of composites, reducing the risk of hydrolysis and degradation over time. [37] The results of the present study come by *Rajabi et al. in 2024,* who reported that the wear resistance and flexural strength of highly filled flowable composite resins containing nanofiller particles were superior to those of traditional flowable and paste composite resins, and these resins may find application in occlusal, load-bearing regions. [37] Contradicting the results of the present study, *Sarica et al. in 2024* concluded that G-aenial universal injectable showed similar clinical properties with other bulk fill and traditional composites after one year of clinical performance. The contradiction might be due to the difference in the methodology and types of composites used in their study. Besides, they evaluated the clinical performance of restorations according to FDI criteria but did not specifically test the fracture resistance value. [37]

Teeth restored with SOF composite recorded higher values of FR than the HXU group, but the difference was non-significant. This finding might be explained by the similarities in the resin matrix (BIS-GMA and TEGDMA) and the high filler content between both composites that contribute to their comparable fracture resistance properties. Both materials are designed to provide high strength and durability, making them suitable for use in high-stress areas such as posterior restorations. Some research reported that sonic fill was slightly but non-significantly higher than conventional resin composites in terms of fracture resistance and fracture strength. [38 39] Other studies found that teeth restored with SonicFill 3 exhibited the highest fracture resistance compared to other bulk-fill and incrementally-filled composites tested. [40] On the contrary, Colak et al. results were partially following the records of the present study. They concluded a non-significant difference between bond strength values of teeth restored with HXU and sonic fill composites but with the HXU group recording the higher FR value. [37] These results might be due to the type of composite used in the current study, which differs from the (SonicFill Bulk-Fill) used in their study. SonicFill 3, used in the present study, utilizes a refined filler system with nano-scale zirconium oxide and silica oxide, which enhances the mechanical properties and fracture resistance. [40]

The fracture resistance values of teeth restored with Viscalor Bulk were found to be significantly the lowest among all types of composite tested. An explanation might be differences in microstructural characteristics between VCB and other tested materials. Since VCB is designed to be processed at high temperatures, it should not be surprising that performance is poorer at room temperature and even at 37 °C intraoral temperature, [40] although the exact causes are unclear. A study reported that VCB is noticeably better than competing condensable materials at 54◦C. By micromorphological SEM characterization in the same study, continuous cracks that negatively affected the fracture toughness were noticed in VCB specimens. This might be the reason behind the inferior behavior of the material in the present study.

Additionally, higher temperatures may promote the co-polymerization of the materials due to the increased segmental mobility of the top layer's C–C double bonds and the radicals they produce. Furthermore, after 5000 thermocycling cycles, the VisCalor Bulk composite may have less fracture resistance due to a combination of thermal stress, polymerization shrinkage, hydrolytic degradation, and viscosity changes. [32] This comes against Hassan et al., [41] who reported statistically significantly higher fracture resistance and functional properties of VCB than self-adhesive composite. The contradiction might be explained by the different methodologies utilized, as they used restored class II cavities in comparison to MOD cavities used in the present study. Besides, the tested materials were not exposed to any aging, such as thermocycling, used in the present study. Among all tested composites, the presence of Ivocerin, the photoinitiator found in the composite matrix, was supposed to enhance the curing efficiency of VisCalor Bulk and directly influence the material's fracture resistance. However, the material's overall fracture resistance can still be compromised under thermal cycling conditions, highlighting the importance of considering the specific clinical scenario when selecting restorative materials.

Regarding the mode of failure, all fractures above the cementoenamel junction were recorded as repairable, and the opposite (irreparable) was recorded for fractures below it. Some studies also considered the fractures in the coronal third of the root to be repairable. [42] The repairable mode of failure frequency for GBI was 75%, 70% for SOF, 65% for HXU, and 60% for VCB. Previous studies reported the domination of the repairable type of fracture over the irreparable one. [43, 44, 45] In the GBI group, cracks were present only on the macro level. However, under higher magnification, no cracks were detected at all. This goes by the higher percentage of repairable fractures obtained for the same group. Notably, in the VCB group, cracks were reported on both micro and macro levels, which went well with the catastrophic failures recorded. Regarding SOF and HXU, cracks were seen on the macro level with limited propagation on the micro level.

This study involved a laboratory-based, standardized assessment of the static fracture resistance of teeth repaired using various materials and procedures. This in-vitro research does not, however, accurately replicate dynamic oral circumstances. Clinically, several factors contribute to restorative clinical performance that is more effective. The absence of periodontal ligament simulation was another drawback.

Conclusions

Within the limitations of this study:

1- Because bulk-fill composite resin may affect fracture resistance, clinicians should exercise caution when using it to restore teeth with MOD cavities.

2- It may be said that there is no discernible variation in the kinds of tooth fractures that occur, even though the restorative material may have varying impacts on teeth's resistance to fracture.

3- When compared with low—or high-viscosity bulk-fill materials, the GBI represents an excellent option within the class of light-cured restorative materials used for direct restorations without a superficial layer of conventional composite covering.

Declarations

Ethics approval and consent to participate

The study was approved by the Research Ethics Committee Faculty of Dentistry, King Abdulaziz University—with approval number 80-04-23.

Competing interests

The authors declare no potential conflicts of interest.

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Data Availability

The data are available from the corresponding author upon appropriate request.

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