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Comparative evaluation of three restorative materials: Compressive strength, diametral tensile strength and microhardness - An *in vitro* study

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Abstract:
Selecting a restorative material with optimal mechanical performance remains a clinical challenge, as varying compositions yield differing strength and durability. Therefore, it is of interest to compare the compressive strength, diametral tensile strength and microhardness of three restorative materials, namely SDR plus Bulk Fill, Filtek Z250 XT and Zirconomer Improved. Standardized specimens were prepared and tested using a Universal Testing Machine and a Vickers indenter, with data analyzed by one-way ANOVA and Tukey's test. Significant differences were observed among the materials ($p < 0.05$), with Filtek Z250 XT showing the highest values, followed by SDR Plus Bulk Fill, while Zirconomer Improved recorded the lowest. Thus, we report comparative *in vitro* evidence on the mechanical performance of three contemporary restorative materials, guiding clinicians in evidence-based material selection for restorative dentistry.

Keywords: Compressive strength (CS), filtek Z250 XT, zirconomer improved, vicker's microharness, SDR plus bulk fill, diametral tensile strength

Background:
Dental caries and trauma are among the most common reasons why human teeth lose structure. These conditions disrupt the form and function of the affected tooth, which is always restored with the proper restorative material for the following cast repair to be successful and long-lasting **[1]**. Maintaining optimal functioning of systemic activity requires maintaining oral hygiene, a vital contributor to overall physiological health **[2]**. The goal of contemporary dental materials is to replicate the biological compatibility, functional efficiency and esthetic qualities of native tooth structure. Their mechanical properties have a major impact on their clinical performance **[3]**. Restorations are continuously subjected to masticatory forces, causing deformation and potential failure over time. Hardness helps evaluate the extent of polymerization and resistance to surface wear, whereas compressive strength (CS) indicates fracture resistance. Tensile testing is performed to evaluate materials that fracture with little to no permanent deformation. These attributes are important in maintaining the functional lifespan of restorative work **[4]**. With continual innovation in restorative dentistry, more advanced materials have been developed. The pursuit of a restorative material that closely replicates natural tooth structure, along with the increasing need for options that offer strong mechanical performance and protection against caries, has driven the introduction of various innovative restorative products **[5]**. The last few decades have seen a remarkable increase in the use of resin- based composites as materials for restoration. Dental professionals now choose them as their go-to material because of their special qualities, which include simplicity of handling and effective clinical performance **[6]**. Resin based composites have transformed modern operative dentistry by offering outstanding esthetics and long-term clinical performance. They are now considered as widely accepted material restorative option for direct restorations in both anterior and posterior teeth, owing to their enhanced physical and mechanical characteristics, superior cosmetic results and reliable clinical outcomes- benefits that surpass those of earlier restorative materials **[7]**. Because of advancements in their properties, light-cure universal nanohybrid composite resins such as Filtek Z250 XT have gained considerable interest in restorative dentistry due to their excellent esthetics, superior mechanical strength, and minimal abrasivity in posterior regions. However, their incremental placement technique and sequential light-curing process increase chairside time and technique sensitivity. These limitations have led to the development of bulk-fill composite resins, which can be placed in thicker increments while maintaining adequate polymerization, thereby simplifying restorative procedures and reducing clinical time **[8]**. As a result, bulk-fill composite resins were developed. Smart dentin Replacement (SDR) bulk fill flowable resin composite were launched in the dental field in the past decade with the purpose of overcoming the challenges linked to traditional incremental placement in posterior restorations **[9]**. At first, the term bulk-fill referred to resin composites that could be placed in increments of 4-5 mm thickness, making them suitable for both full body and base bulk-fill restorative approaches. Changes in the filler content and/or organic matrix are responsible for the key improvements in bulk-fill materials, which include low shrinkage stress and greater depth of cure, which is likely the result of increased translucency **[10]**. To address the limitations of conventional composites while utilizing the advantages of both glass ionomer cements and composites, zirconia-reinforced GICs known as Zirconomer were developed and introduced into clinical practice in year 2014 **[11]**. Wilson and Kent introduced the first glass ionomer (GI) cement in 1972. Since then, a lot of modifications have been done to enhance their mechanical properties. The constraints of the tooth colored restorative materials that were previously in use may be addressed by the recently developed breakthrough material known as zirconia-reinforced GI (Zirconomer Improved) **[12]**.

Therefore, it is of interest to compare the Filtek Z250 XT, SDR Plus bulk-fill composite and Zirconomer Improved across these critical mechanical properties is needed to inform evidence-based selection of restorative materials.

Materials and Methods:

Following the approval from the Institutional Ethical Committee this *in vitro* comparative study was conducted within the Department of Conservative Dentistry and Endodontics at K.D. Dental College and Hospital, Mathura. All testing procedures were subsequently performed at Elmech Lab Pvt. Ltd., Noida, Uttar Pradesh ensuring standardized environmental conditions and digital calibration throughout the experimental phase. The samples were divided into three groups (n = 15 per group). Group I consisted of SDR plus bulk fill (Dentsply), Group II included Filtek Z-250 XT Nanohybrid composite (3M ESPE) and Group III comprised Zirconomer Improved (Shofu, Japan). Specimens were fabricated in Cylindrical Teflon Molds measuring 4 mm in diameter and 6 mm in height for compressive and diametral tensile strength testing and 3 mm in diameter and 5 mm in height for microhardness evaluation. Mold was positioned on a glass slab during material placement. The nanohybrid composite was packed using the incremental technique, with each increment individually light-cured to ensure adequate polymerization. The bulk-fill composite was inserted using the bulk-fill technique and cured according to the manufacturer's recommendations. Zirconomer improved was mixed and allowed to set as per the manufacturer's instructions. For all materials, the upper surface of the specimens was flattened using Mylar strips; additionally, composite specimens received a final 20-second light-curing cycle to achieve a smooth and completely polymerized surface. The samples were retrieved from the mold and immersed in distilled water for 24h at 37°C. The prepared specimens were subjected to three distinct mechanical tests. Compressive strength testing was performed using a UTM operating at a crosshead speed of 1.0 mm/min. Each specimen was aligned in a vertical orientation, with its flat surfaces in contact with the metal loading platens, ensuring that the compressive force was delivered along the longitudinal axis. The highest load causing mechanical breakdown of the specimen was measured and the corresponding compressive strength was then calculated in megapascals using the standard formula,

$$C = 4P/\pi D2$$

Where P denotes the maximum applied load in Newtons (N), D denotes the measured diameter of the sample in (mm) & π = 3.1416. Diametral Tensile strength was measured at a crosshead speed of 1.0 mm/min using an UTM apparatus. To ensure diametral loading, the specimens were oriented with their flat surfaces positioned perpendicular to the testing platens. The peak force at which structural failure occurred was recorded and DTS values were subsequently calculated in megapascals using the standard formula,

$$T = 2P/\pi DL$$

Where P is the maximum load applied (N), D is the measured mean diameter of the sample (mm), L is the measured length of the sample (mm) & π = 3.1416. For microhardness all specimens were fixed in a holder and test surface was perpendicular to the intender tip with shape of right pyramid with a square base, A Vickers diamond Intender with 150 g load was applied for duration of 20 sec. It included three test material (SDR Plus, Filtek Z-250 XT ,Zirconomer Improved), Cylindrical Teflon Mold of measurement(4mm diameter X 6mm height)(3mm diameter X 5mm Height), a Woodpecker LED curing device, glass slabs for specimen stabilization, Mylar strips for oxygen barrier formation, distilled water, a universal testing machine for strength determinations and a Vickers microhardness tester. The data was tabulated in Microsoft excel and analyzed with SPSS software (Version 20). The continuous variables will be presented with mean and standard deviation. The categorical variables will be presented with frequency and percentage. Statistical analyses will be performed using one way ANOVA and Tukey post hoc test. The p-value ≤0.05 will be considered as statistically significant.

Results:

The study samples were equally distributed among three restorative materials: SDR plus bulk fill, filtek Z250 XT and Zirconomer Improved (n = 15 each). Filtek Z250 XT showed the highest mean compressive strength (307.92 ± 3.05 MPa), diametral tensile strength (47.08 ± 0.85 MPa) and microhardness (92.20 ± 1.92), followed by SDR Plus Bulk Fill, while Zirconomer Improved demonstrated the lowest values for all parameters. One-way ANOVA revealed highly significant differences among the groups for compressive strength, tensile strength and microhardness ($p < 0.001$). **Table 1** illustrates the mean compressive strength of the restorative materials. Filtek Z250 XT recorded the highest mean compressive strength (307.92 ± 3.05 MPa), followed by SDR Plus Bulk Fill (233.88 ± 1.87 MPa), whereas Zirconomer Improved showed the lowest mean compressive strength (217.54 ± 2.29 MPa). **Table 2** displays the mean diametral tensile strength values of the three restorative materials. Filtek Z250 XT exhibited the highest mean tensile strength (47.08 ± 0.85 MPa), followed by SDR Plus Bulk Fill (38.64 ± 0.30 MPa), while Zirconomer Improved showed the lowest mean tensile strength (35.44 ± 0.59 MPa) and **Table 3** presents the mean microhardness values (VHN) of the three restorative materials. Filtek Z250 XT demonstrated the highest mean microhardness (92.20 ± 1.92), followed by SDR Plus Bulk Fill (61.20 ± 1.30), while Zirconomer Improved exhibited the lowest mean value (51.20 ± 1.30).

Table 1: Mean compressive strength (MPa) of three different restorative materials

	Mean	Std. Deviation
SDR Plus Bulk Fill	233.88	1.87
Filtek Z250 XT	307.92	3.05
Zirconomer Improved	217.54	2.29

Table 2: Mean tensile strength (MPa) of three different restorative materials

	Mean	Std. Deviation

SDR Plus Bulk Fill	38.64	0.30
Filtek Z250 XT	47.08	0.85
Zirconomer Improved	35.44	0.59

Table 3: Mean microhardness (VHN) of three different restorative materials

	Mean	**Std. Deviation**
SDR Plus Bulk Fill	61.2	1.3
Filtek Z250 XT	92.2	1.92
Zirconomer Improved	51.2	1.3

Discussion:

To evaluate the mechanical performance of the selected materials, three tests were performed. Compressive strength is a key parameter for assessing the mechanical performance of dental restorative materials. As the majority of masticatory forces are compressive in nature, evaluating a material's resistance to these forces is essential for determining its durability in clinical conditions **[11]**. Diametral tensile strength is a critical requirement, because many clinical failures are due to tensile stress. Microhardness testing is employed to evaluate a material's resistance to wear and its susceptibility to surface abrasion. To standardize surface conditions and minimize the effects of an oxygen-inhibited layer, Mylar strips were placed over the uncured specimens during curing. In resin-based materials, Mylar strips limit atmospheric oxygen contact, reducing the formation of the oxygen-inhibited layer and enhancing surface microhardness **[12]**. In addition, studies on glass ionomer and ion-releasing restorative materials have shown that curing or initially finishing against a Mylar strip produces the smoothest surfaces, which is critical for reliable mechanical testing of all material types. Because of its neutral pH and capacity to mimic the moist oral cavity, distilled water was used for both the control and storage media in our investigation **[13]**. Berry *et al.* (2024) **[14]** came to the conclusion that the surface micromorphology of resin-based products was similarly affected by distilled water and artifical saliva. Jafarpour *et al.* (2022) **[15]** reported bulk-fill resin composites demonstrated poorer mechanical properties compared to nano-hybrid composite. Musavinasab and Norouzi (2023) **[16]** evaluated the mechanical properties of various bulk-fill composite resins, including Tetric EvoCeram Bulk Fill (Ivoclar Vivadent), Venus Bulk Fill (Kulzer), Filtek Bulk Fill (3M ESPE), and SDR Flow+ (Dentsply Sirona). They reported that SDR exhibited the lowest compressive and tensile strength among the tested materials, attributing its inferior mechanical performance to its lower filler content, which is intended to reduce viscosity and improve flowability. Similarly, Paul *et al.* (2020) **[17]** compared the compressive strength and hardness of bulk-fill and conventional resin composites and found that conventional nanohybrid composites showed significantly higher compressive strength because of their greater filler loading and optimized nanofiller dimensions. These findings support the superior mechanical performance of conventional resin composites observed in the present study. Guan *et al.* (2025) **[18]** showed that filler composition, particle size, resin matrix formulation, and the quality of filler–matrix bonding are the principal determinants of the mechanical behavior of contemporary restorative materials. Their findings indicate that highly filled nanohybrid composites exhibit superior hardness and wear resistance compared with bulk-fill and glass ionomer–based restorative materials, which is consistent with the present results. The present study showed that Filtek Z250 XT (3M ESPE) exhibited the highest microhardness among all evaluated materials. This superior performance may be attributed to its highly optimized filler system consisting of ultra-fine silica nanoparticles (approximately 20 nm) combined with zirconia–silica fillers ranging from 0.1 to 10 µm. The dense filler packing, high filler loading, and improved filler–matrix interaction contribute to enhanced surface hardness and resistance to indentation compared with the other restorative materials evaluated. França *et al.* (2021) **[19]** reported that flowable bulk-fill composite resins generally exhibit lower hardness than conventional nanohybrid composites because of their reduced filler content and increased resin matrix proportion. These observations corroborate the present findings, where flowable bulk-fill restorative materials demonstrated comparatively lower microhardness than conventional resin composites. The present investigation also demonstrated that Zirconomer Improved exhibited lower mechanical properties than resin-based restorative materials. This may be attributed to its acid–base setting reaction and the incorporation of zirconia particles within the glass ionomer matrix, resulting in a comparatively porous microstructure. Such a structure is more susceptible to plastic deformation under Vickers indentation than the densely packed filler–matrix architecture of resin composites. These findings are consistent with those reported by Sharafeddin and Bahrani (2020) **[20]**, who observed a significant reduction in the hardness of Zirconomer after 24 hours of water storage. The authors attributed this reduction to the material's greater water sorption and solubility, characteristics inherent to chemically cured glass ionomer–based restorative materials. Furthermore, Somani *et al.* (2023) **[21]** compared the mechanical properties of amalgam, resin composite, and Zirconomer and concluded that resin composites showed significantly superior compressive strength and surface hardness, whereas Zirconomer exhibited comparatively lower mechanical performance. Their findings support the results of the present study and reinforce that conventional nanohybrid resin composites remain the material of choice when high mechanical strength and long-term durability are required for stress-bearing posterior restorations.

Conclusion:

Tested restorative materials showed significant variation in mechanical properties. Filtek Z250 XT nanohybrid composite showed superior compressive strength, diametral tensile strength and microhardness, likely due to its higher filler content and enhanced filler–matrix interaction. Thus, SDR Plus bulk-fill composite exhibited acceptable performance, whereas zirconomer improved showed the lowest mechanical properties, reflecting the limitations of its glass ionomer–based composition.

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