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Review Article

Balancing Efficiency and Longevity in Bulk-Fill Resin Composites: A Narrative Review

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Abstract

Background and Aim: Resin-based composites are among the most widely used restorative materials in dentistry today, primarily due to their superior esthetic qualities and their ability to preserve tooth structure. However, conventional composites pose several clinical challenges, including limited depth of cure, polymerization shrinkage, and the need for incremental layering, which can be time-consuming and technique-sensitive. In response to these limitations, bulk-fill resin composites have been developed to allow placement in increments up to 4 mm without compromising polymerization quality or mechanical properties. The aim of this study is to investigate the properties of bulk-fill composites and compare them with those of other restorative materials.

Findings: Recent studies have shown that bulk-fill composites can provide clinical outcomes comparable to, or in some cases better than, traditional composites in terms of marginal adaptation, fracture resistance, and postoperative sensitivity. Moreover, they significantly reduce the time required for direct restorations, thereby enhancing both patient comfort and clinical efficiency. Newer generations of bulk-fill composites, such as self-adhesive, dual-cure, and thermos-viscous formulations, have been introduced to further simplify application procedures and address specific drawbacks, including polymerization depth, handling properties, and shade matching.

Conclusion: Bulk-fill composites offer promising clinical efficiency, but their long-term durability remains to be fully validated.
Key Words: Bulk-Fill; Composite Resins; Flowable Bulk-Fill

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Introduction

Dental caries has been a primary cause of dental pain and tooth loss throughout history, affecting billions of individuals worldwide. According to a 2025 report by the World Health Organization (WHO), the global prevalence of dental caries has reached approximately 3.7 billion people, highlighting the serious nature of this condition for public health (1).

The standard treatment for dental caries involves the removal of decayed tooth structure followed by the restoration of the cavity using appropriate filling materials. Over the years, a wide range of restorative materials has been employed for this purpose, ranging from gold to glass ionomer cements.

Currently, light-cured resin-based composites are among the most widely used restorative materials worldwide. This widespread adoption can be attributed to their close resemblance to natural tooth structure and their ability to preserve more sound tooth tissue compared to traditional restorative materials such as dental amalgam and gold alloys (2).

However, resin-based composites are not without challenges, which can complicate their clinical use. Notable limitations include the need for strict moisture control, polymerization shrinkage, and a limited depth of cure of approximately 2 mm. Due to these constraints, conventional composites must be applied in increments no greater than 2 mm, following a protocol known as the incremental technique. This approach increases chair time and also elevates the risk of air entrapment between layers, potentially compromising the integrity of the final restoration (3-5).

In response to these limitations, a new class of resin-based composites known as bulk-fill composites has been developed. These materials are designed to be placed in thicker increments (up to 4–5 mm) without compromising depth of cure or physical properties, offering a simplified and more efficient restorative technique.

Bulk-Fill Composites: Enhanced Usability and Efficiency

To address the limitations of conventional composite placement techniques, manufacturers have introduced significant modifications in the formulation of bulk-fill resin composites. One such advancement involves the incorporation of high molecular weight monomers, such as urethane dimethacrylate (UDMA), into the resin matrix (6). Additionally, the filler particle size and distribution have been optimized (7). These changes facilitate more efficient light transmission and allow for uniform polymerization of composite layers up to 4 mm in depth.

A key challenge in curing thicker layers of composite resin is the increase in polymerization shrinkage and associated stress, which can lead to gap formation and increased risk of microleakage. To mitigate this issue, polymerization modulators have been incorporated into bulk-fill composites. These agents help to moderate the rate of polymerization, effectively reducing shrinkage and stress on the adhesive interfaces (8-10).

In addition, placing composite in thicker layers minimizes the number of increments needed for the restoration process. This simplification not only shortens chairside time but also lowers the risk of air entrapment between layers, promoting the formation of a more homogeneous and structurally stable restoration (9, 10).

Clinically, three main techniques are recommended for the optimal use of bulk-fill composites:

1. **Two-step technique:** A flowable bulk-fill composite is placed at the base of the cavity and light-cured, followed by placement of a conventional nanohybrid or microhybrid composite as the final occlusal layer.
2. **Sonic-activated technique:** In this method, a sonic-activated flowable bulk-fill composite is applied using sonic energy, which enhances flow and adaptation to cavity walls.
3. **Single-step technique:** This approach involves the exclusive use of bulk-fill composites for the entire restoration, without additional layering of conventional composites (3).

Despite these innovations, a critical question persists: To what extent have bulk-fill composites succeeded in achieving clinical outcomes comparable to or superior to those of traditional restorative materials? Ongoing research continues to evaluate their long-term performance, marginal integrity, mechanical durability, and esthetic stability under various clinical conditions.

Therefore, the aim of this review is to critically evaluate the clinical performance, mechanical properties, and esthetic outcomes of bulk-fill resin composites in comparison with other restorative materials, drawing on current evidence to determine whether bulk-fill systems genuinely provide comparable or superior restorative results in clinical practice.

Bulk-Fill vs. Conventional Composites: A Comparative Review of Clinical Performance

To assess the clinical efficacy of bulk-fill composites, it is crucial to compare their performance with that of conventional resin composites.

Polymerization and Depth of Cure

The most critical factor in bulk-fill composite restorations is the depth of polymerization. It is well established that the degree of polymerization decreases as the depth of the material increases. However, studies have demonstrated that bulk-fill composites maintain a degree of polymerization similar to that of conventional composites up to a depth of 2 mm. Beyond this point, although the polymerization degree declines, it still surpasses that of conventional composites at equivalent depths. This may result in reduced mechanical properties at increased thicknesses. Nevertheless, this reduction is not uniform across all bulk-fill materials; greater translucency is often associated with improved polymerization at deeper layers. For example, Filtek™ Bulk Fill Flowable Restorative (3M ESPE) achieves nearly uniform polymerization due to its high translucency, leading to more consistent mechanical behavior throughout the restoration (11).

Surface Hardness and Roughness

Another important factor is surface hardness. The surface layers of bulk-fill composites are generally harder than deeper regions. Notably, Cieplik et al. reported that Filtek™ One Bulk Fill Restorative exhibits surface roughness comparable to that of intact enamel (12).

Additionally, multiple studies have demonstrated comparable or even superior surface hardness in bulk-fill composites relative to conventional materials. For instance, Dindaroğlu et al. found no significant difference in surface hardness between Admira Fusion x-tra (VOCO GmbH, Cuxhaven, Germany), a bulk-fill composite, and Grandio (VOCO GmbH), its conventional counterpart (13). Similarly, Correia et al. reported equivalent hardness between Filtek™ Bulk Fill Posterior Restorative and Filtek™ Z350 XT Universal Restorative (3M ESPE) (14). Caroline Sekundo et al. compared Filtek™ Bulk Fill Posterior Restorative and Tetric EvoCeram® Bulk Fill (Ivoclar Vivadent) to the conventional Filtek™ Z250 Universal Restorative (3M ESPE) and also reported similar outcomes (15).

Furthermore, Yazici et al. noted no significant short-term difference in roughness between Tetric EvoCeram® Bulk Fill and Filtek™ Ultimate Universal Restorative (3M ESPE) but emphasized that, over time, conventional composites tend to develop rougher surfaces than bulk-fill alternatives (16, 17). Canali et al. confirmed this finding by showing that Filtek™ Supreme Ultra Universal Restorative (3M ESPE), a conventional composite, exhibited greater surface roughness compared to Filtek™ Bulk Fill Flowable Restorative, a bulk-fill material (18).

While all studies confirmed a reduction in hardness following simulated oral environment exposure, this decline was generally less severe in bulk-fill composites than in conventional ones. Such properties may contribute to reduced bacterial adhesion and potentially enhanced restoration longevity (19). However, since larger filler particles can facilitate microbial accumulation, this potential benefit may be negated in some bulk-fill materials (20).

Although differences in results may be attributed to variations in brands, follow-up durations, clinical protocols, or bonding systems, Goda et al. found no statistically significant differences among four different bulk-fill composites: Filtek™ Bulk Fill, Heated Filtek™ Bulk Fill, G-ænial™ BULK Injectable (GC Corporation), and SonicFill™ 3 (Kerr Corporation) (21).

Most studies report comparable surface hardness between bulk-fill and conventional composites, with some suggesting superior performance in bulk-fill materials (13-15). However, variations exist depending on brand and testing protocols.

Fracture Resistance and Shrinkage Stress

Bulk-fill composites have also demonstrated greater fracture resistance than conventional composites (22).

Polymerization shrinkage, associated stress, and microleakage remain significant drawbacks of conventional composites, particularly with increased increment thickness. Therefore, these parameters are critical when assessing bulk-fill materials. Oliveira Schliebe et al. found that flowable bulk-fill composites exerted less polymerization stress, especially in endodontically treated teeth, suggesting they may be more suitable as core build-up materials in such cases (23).

These mechanical differences can influence several clinical outcomes, including poor marginal adaptation, microleakage, marginal discoloration, postoperative sensitivity, and the occurrence of secondary caries (24-26).

Marginal Integrity and Discoloration

Different studies have produced varying results regarding marginal discoloration. Balkaya et al. and Yazici et al. reported that bulk-fill composites performed better than conventional composites over the long term (16, 17, 27). In contrast, Dindaroğlu et al., Correia et al., and Barceleiro et al. observed no significant difference between the two groups (13, 14, 28). Nevertheless, all studies noted a statistically significant increase in marginal discoloration over time, regardless of the composite type used (13, 16, 17).

Similar discrepancies exist regarding marginal integrity. While some studies favor bulk-fill composites, others report comparable performance between the two categories (13, 14, 16, 17, 22, 27, 28). Only Heck et al. found superior marginal adaptation with Tetric Ceram (Ivoclar Vivadent) compared to QuiXfil (Dentsply DeTrey), a bulk-fill composite (29). It is important to note that QuiXfil is among the earliest commercial bulk-fill materials and may lack the optimized physical properties of more recent formulations.

Overall, current evidence shows no consistent superiority between bulk-fill and conventional composites regarding marginal discoloration and integrity. Both materials exhibit progressive marginal deterioration over time, and differences appear largely dependent on specific formulations.

Postoperative Sensitivity and Secondary Caries

Most studies reported no statistically significant difference in postoperative sensitivity between bulk-fill and conventional composites (12-14, 16, 17, 27, 28, 30-33).

Similarly, no significant differences in secondary caries rates were observed between the two composite types across multiple studies (13, 14, 17, 18, 28, 30, 34-36).

Clinical Efficiency and Retention

Although several studies have shown higher retention rates for bulk-fill restorations compared to conventional ones, these differences have not consistently reached statistical significance (12, 14, 17, 18, 30, 32, 35).

In addition to the aforementioned considerations, comparative studies on the time required to complete composite restorations have demonstrated that bulk-fill composites significantly reduce operative time. This reduction in clinical working time not only enhances efficiency but also contributes to improved comfort for both the patient and the clinician during the restorative procedure (22, 33).

Esthetic Performance: Shade Match and Color Stability of Bulk-Fill Composites

Given that a primary advantage of resin composites is their ability to replicate natural tooth color, initial shade match and color stability are critical esthetic parameters.

Initial Shade Match

Barceleiro et al. found that Filtek™ One Bulk Fill Restorative exhibited superior initial shade matching compared to Filtek™ Supreme Ultra Universal Restorative (3M ESPE). While some studies favor bulk-fill composites for initial shade match, long-term color stability remains inconsistent across brands and formulations (28).

Material Composition and Discoloration

Although all studies reported some degree of discoloration over time, the comparison between bulk-fill and conventional materials yielded contradictory results. Two key factors influencing discoloration are the type of monomer used and the organic matrix content. Higher concentrations of Bis-GMA, TEGDMA, or UDMA, together with a high proportion of the resin matrix, tend to increase pigment uptake, thereby contributing to greater discoloration in bulk-fill resin composites. In contrast, monomers such as Bis-EMA possess more pronounced hydrophobic characteristics, which reduce water sorption (37-39).

This difference originates from the molecular structure of these organic monomers: TEGDMA and UDMA exhibit hydroxyl and urethane functional groups, and Bis-GMA contains ethylene oxide linkages, all of which impart significant hydrophilicity (39). This hydrophilic behavior promotes water sorption and subsequently leads to structural degradation and staining. Nevertheless, Bis-GMA has been shown to exhibit higher water sorption and staining susceptibility compared with the other two monomers (40). Consequently, bulk-fill composites with a high Bis-GMA content—such as VisCalor Bulk Fill (thermoviscous nano-hybrid bulk-fill composite; VOCO GmbH, Cuxhaven, Germany)—tend to demonstrate greater water sorption compared with other commercial bulk-fill materials (41, 42). Conversely, the dual phenyl rings of Bis-EMA introduce substantial steric hindrance around its ethoxylated moieties, effectively limiting water interaction and resulting in a more hydrophobic monomeric profile (39).

Color Stability Over Time

Bilgili Can et al. concluded that the color stability of three bulk-fill composites—VisCalor (VOCO GmbH), Tetric PowerFill (Ivoclar Vivadent), and Fill-Up! (Coltène/Whaledent)—fell below the clinically acceptable threshold (43).

Balkaya et al. also found that the conventional Charisma® Smart Composite (Kulzer) showed better color stability than Filtek™ Bulk Fill Posterior Restorative (3M ESPE) (27). In contrast, Yazici et al. reported no significant color change difference over six years between Filtek™ Ultimate and Tetric EvoCeram® Bulk Fill (16, 17). Colak et al. also found no meaningful difference between Tetric EvoCeram® Bulk Fill and Tetric EvoCeram® conventional composite (30).

Conversely, Dindaroğlu et al. found that Admira Fusion x-tra (VOCO GmbH) outperformed Grandio (VOCO GmbH) in terms of color stability (13). These conflicting outcomes may stem from brand-specific differences. Moda et al. compared two different flowable bulk-fill composites—SDR®+TPH3 (Dentsply Sirona) and Filtek™ Bulk Fill Flowable + Filtek™ Z350XT (3M ESPE)—against a conventional microhybrid composite (Amelogen Plus + Peak Universal Bond, Ultradent). Results showed that one flowable bulk-fill had better color stability than the conventional composite, while the other performed worse (35).

Given the variability in color stability, clinicians should consider brand-specific performance and patient esthetic expectations when selecting bulk-fill composites.

Bulk-Fill Composites vs. Other Direct Restorative Materials

After comparing different types of composite resins, it is essential to examine how bulk-fill composites perform in relation to other direct restorative materials. The following sections evaluate their advantages and limitations relative to amalgam and glass-ionomer cements.

Clinical Comparison of Bulk-Fill Composites and Dental Amalgam

Dental amalgam remains one of the most debated restorative materials today. On one hand, concerns persist regarding its biocompatibility—particularly due to mercury content—while on the other, its low cost, ease of use, and outstanding mechanical properties make it a popular option, especially in developing countries (44). Therefore, a comparative analysis with bulk-fill composites is both logical and necessary.

The most apparent disadvantage of dental amalgam is its poor esthetics, as its metallic color starkly contrasts with natural tooth structure. This mismatch severely limits its use in anterior restorations, where esthetic outcomes are paramount. In this regard, bulk-fill composites clearly outperform amalgam due to their tooth-colored appearance.

Additionally, bulk-fill composites chemically bond to dental structures, allowing for more conservative cavity preparations compared to amalgam, which relies on mechanical retention. However, because bulk-fill composites are commonly used in deep cavities, the overall cavity preparation may end up being similar for both materials (45).

From a mechanical perspective, despite advancements in the mechanical properties of bulk-fill composites, studies have consistently shown that amalgam still outperforms them in terms of fracture resistance and stress distribution on the tooth structure (46, 47). Nonetheless, amalgam does not reinforce surrounding dental tissues, which remains a notable disadvantage.

The biocompatibility of dental amalgam can be evaluated in two primary contexts: its interaction with oral tissues and its potential systemic effects due to mercury content.

Regarding local tissue compatibility, amalgam has been shown to perform better in protecting the pulp, particularly in deep cavities with remaining dentin thickness less than 1 mm (48). Moreover, teeth restored with amalgam demonstrate lower incidences of secondary caries, which contributes to reduced pulp inflammation (49). However, no significant difference has been found between amalgam and bulk-fill composites concerning periapical inflammation (50).

In subgingival restorations, amalgam is generally favored due to its lower sensitivity to moisture contamination and its greater resistance to degradation in the presence of oral fluids. It has also been associated with reduced bone resorption (50). Additionally, amalgam restorations have shown lower bacterial adhesion compared to composites, indicating superior local biocompatibility (51).

A significant advantage of amalgam is its cost-effectiveness, especially relevant in low-resource settings where access to advanced adhesive systems or light-curing equipment may be limited.

However, concerns about the systemic effects of mercury exposure remain. It has been reported that blood and urine mercury levels increase following multiple amalgam restorations, potentially affecting the immune system, nervous system, and renal function (52). These concerns have led to regulatory bans on dental amalgam in several countries, including India, Indonesia, Nigeria, and across the European Union. The emergence of initiatives like the World Alliance for Mercury-Free Dentistry reflects global efforts to phase out amalgam usage (53).

Nevertheless, many studies suggest that the amount of mercury exposure from dental amalgam remains below toxic thresholds, and no significant systemic adverse effects have been reported in patients with amalgam restorations (52). Therefore, amalgam can still be considered a viable material, particularly for posterior restorations that are not in the esthetic zone.

Taken together, these findings suggest that while amalgam offers superior pulpal protection and microbial resistance, its esthetic and environmental limitations reduce its appeal in modern restorative practice.

Bulk-Fill Composites vs. Glass-Ionomer Materials

Glass-ionomer cements (GICs) have also been employed as direct restorative materials, particularly valued for their chemical bonding to dental tissue, fluoride release, and elimination of the need for adhesive systems (54, 55). These properties made GICs especially useful in managing rampant caries, particularly in pediatric and geriatric populations. However, the poor physical properties of conventional GICs—such as low fracture strength and high wear—have limited their broader clinical application (56).

To overcome these shortcomings, various modified versions have been developed, including:

- Glass-hybrid materials (e.g., Equia Forte® HT)
- High-viscosity GICs
- Zirconia-reinforced GICs
- Glass carbomers (57)

Glass-Hybrid GICs

In comparing Equia Forte® HT (GC Corporation), a glass-hybrid GIC, with bulk-fill composites, studies found no significant differences in color stability, marginal discoloration, anatomic form, or secondary caries incidence. However, bulk-fill composites demonstrated superior retention (58-60).

Regarding postoperative sensitivity and marginal integrity, while Uyumaz et al. and Akman et al. reported no significant differences, Atmaca et al. found lower postoperative sensitivity with glass-hybrid materials and better marginal adaptation with bulk-fill composites (58-60).

Zirconia-Reinforced GIC

Zirconia-reinforced GICs performed worse than bulk-fill composites in shade matching and retention, but studies reported comparable results in marginal integrity, marginal discoloration, secondary caries, and anatomic form. Similar to glass-hybrids, Atmaca et al. found lower postoperative sensitivity in zirconia-reinforced GICs, though Akman et al. and Bayazıt et al. did not observe statistically significant differences (59-61).

Glass Carbomer

Bayazıt et al. compared glass carbomer with bulk-fill composites and found no significant differences in secondary caries, retention, or postoperative sensitivity; however, bulk-fill composites performed better in maintaining anatomic form (61).

High-Viscosity GIC

In comparing high-viscosity GICs with bulk-fill composites, Bayazıt et al. reported similar performance in secondary caries prevention, anatomic form retention, overall retention, and postoperative sensitivity (61). Although Olegário et al. did not report significant clinical differences, they concluded that high-viscosity GICs were more cost-effective than bulk-fill composites (62).

Overall, while modified GICs show comparable clinical outcomes in several parameters, bulk-fill composites consistently outperform them in retention and anatomic form

Recent Innovations in Bulk-Fill Composite Formulations and Protocols

Despite current improvements in bulk-fill composites, continuous innovation in both formulation and clinical protocols aims to further enhance their properties, simplify restorative procedures, and increase longevity. Recent advancements have introduced several new approaches and materials, discussed as follows:

1. Veneering Bulk-Fill with Conventional Composite

A novel clinical approach involves layering bulk-fill composite from the cavity floor up to 2 mm below the occlusal surface, followed by veneering with a conventional composite in the final 2 mm. This technique combines the advantages of both materials. While no significant differences were observed in terms of marginal integrity, marginal discoloration, or postoperative sensitivity, veneered restorations demonstrated superior anatomic form and fracture resistance compared to bulk-fill alone (63).

2. Self-Adhesive and Dual-Cure Bulk-Fill Composites

This new generation eliminates the need for separate adhesive application and can polymerize through both light and chemical activation. Two prominent examples are Surefil One™ (Dentsply Sirona) and Self-Adhesive Dual-Curing Bulk-Fill (3M).

Although these materials showed inferior shade matching and higher marginal discoloration compared to traditional bulk-fill composites, no significant differences were observed in surface roughness, retention, or secondary caries (12, 34, 64-66). Postoperative sensitivity was similar long-term, though Maghaireh et al. reported lower short-term sensitivity with Surefil One™ compared to Filtek™ Bulk Fill Posterior (67). Regarding fracture resistance and anatomical preservation, studies showed no significant differences (12, 34, 64).

3. Thermo-Viscous Bulk-Fill Composites

Designed to merge the handling benefits of flowable and packable composites, these materials are preheated to 68°C using devices such as Caps Warmer or VisCalor Dispenser, becoming flowable for easy placement. Upon cooling, they regain a packable consistency for better adaptation and condensation.

Morsy et al. demonstrated superior marginal discoloration resistance and adaptation in VisCalor Bulk (Voco GmbH) compared to Filtek Bulk Fill, despite similar mechanical properties (41). Furthermore, Favoreto et al. noted that the heating method had no significant effect on composite properties (68, 69).

Interestingly, heating conventional bulk-fill composites also improved handling and reduced immediate postoperative sensitivity, without compromising material properties (70, 71).

4. Self-Cure Bulk-Fill Composites

These materials were introduced to overcome depth-of-cure limitations. While traditional bulk-fill composites effectively cure up to 4 mm, self-cure versions claim to cure at any depth.

Stela Automix and Stela Capsule (SDI), which rely solely on chemical polymerization, showed superior shade adaptation and reduced short-term sensitivity compared to Filtek One in a study by Loguercio et al. (72). However, no differences were found in other clinical parameters.

Another self-cure option, Fill-Up! (Coltene Whaledent AG), employs dual-curing, where the top layer is light-cured and deeper layers continue curing chemically. Elawsya et al. found no significant difference in aesthetics or function when compared to QuiXfil (Dentsply) and Tetric N-Ceram Bulk Fill (Ivoclar) (73).

Conclusion

Recent studies indicate that bulk-fill composites, in addition to demonstrating comparable or even superior clinical performance in several parameters relative to conventional composites, also significantly reduce restoration time. This makes their use a pragmatic and efficient alternative. Furthermore, newer generations of bulk-fill composites are being introduced, aiming to address and minimize the remaining limitations of earlier formulations. However, despite these promising developments, further research is required to draw definitive and generalizable conclusions.

Declarations

Ethical Considerations

This article is a narrative review and does not contain any studies with human participants or animals performed by any of the authors. Therefore, ethical approval and informed consent were not required.

Availability of Data and Materials

The data supporting this narrative review are available from the cited references. Further inquiries can be directed to the corresponding author.

Competing Interests

The authors declare that they have no conflict of interest related to this study.

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Authors' Contributions

Farid Merrikhi (FM) contributed to the conception and design of the review, literature search and acquisition of data, analysis and interpretation of the literature, and drafting of the manuscript. **Soroush Mirdehghan (SM)** contributed to the conception and design of the review, literature search and data extraction, critical revision of the manuscript for important intellectual content, and final approval of the version to be published. Served as the corresponding author and supervised all aspects of the work. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Declaration of Generative Artificial Intelligence (AI) Utilization

The authors declare that generative AI and AI-assisted technologies were used exclusively for language polishing and grammatical correction during the preparation of this manuscript. The following tools were employed:

- ChatGPT-4 (OpenAI): Used for reviewing text fluency, grammar, and spelling
- Grammarly: Used for additional proofreading

These tools were not used to generate scientific content, analyze data, or produce intellectual contributions. All AI-assisted output was carefully reviewed and edited by the authors, who assume full responsibility for the accuracy, integrity, and originality of the final manuscript. No AI tools were listed as authors, as they cannot be accountable for the work.

References

1. World Health Organization. Oral health [Internet]. Geneva: WHO; 2025 [cited 2025 Jan 15]. Available from: https://www.who.int/news-room/fact-sheets/detail/oral-health.

2. Malhotra N, Mala K, Acharya S. Resin-based composite as a direct esthetic restorative material. Compend Contin Educ Dent. 2011;32(5):58-63.

3. Corral-Núñez C, Vildósola-Grez P, Bersezio-Miranda C, Alves-Dos Campos E, Fernández Godoy E. State of the art of bulk-fill resin-based composites: a review. Rev Fac Odontol Univ Antioq. 2015;27(1):177-96.

4. Malhotra N, Mala K, Acharya S. Strategies to overcome polymerization shrinkage– materials and techniques: a review. Dent Update. 2010;37(2):115-25.

5. Moore BK, Platt JA, Borges G, Chu TG, Katsilieri I. Depth of cure of dental resin composites: ISO 4049 depth and microhardness of types of materials and shades. Oper Dent. 2008;33(4):408-12.

6. Chen Z, Zhang L. Clinical application and research progress of bulk-fill resin-based composites. J Prev Treat Stomatol Dis. 2017;25(4):205-10.

7. Habib E, Wang R, Wang Y, Zhu M, Zhu X. Inorganic fillers for dental resin composites: present and future. ACS Biomater Sci Eng. 2016;2(1):1-11.

8. El-Damanhoury H, Platt J. Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. Oper Dent. 2014;39(4):374-82.

9. El-Safty S, Akhtar R, Silikas N, Watts D. Nanomechanical properties of dental resin-composites. Dent Mater. 2012; 28(12):1292-300.

10. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LES, Martin AA, et al. Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. Dent Mater. 2015;31(12):1542-51.

11. Son SA, Park JK, Seo DG, Ko CC, Kwon YH. How light attenuation and filler content affect the microhardness and polymerization shrinkage and translucency of bulk-fill composites? Clin Oral Investig. 2017;21(2):559-65.

12. Cieplik F, Scholz KJ, Anthony JC, Tabenski I, Ettenberger S, Hiller KA, et al. One-year results of a novel self-adhesive bulk-fill restorative and a conventional bulk-fill composite in class II cavities—a randomized clinical split-mouth study. Clin Oral Investig. 2022; 26(1): 449-61.

13. Çağırır Dindaroğlu F, Yılmaz E. Two-year evaluation of a nano-hybrid and a bulk-fill resin composite: a randomized, double-blind split-mouth clinical study. Clin Oral Investig. 2024;28(4):208.

14. Correia A, Jurema A, Andrade MR, Borges A, Bresciani E, Caneppele T. Clinical evaluation of noncarious cervical lesions of different extensions restored with bulk-fill or conventional resin composite: preliminary results of a randomized clinical trial. Oper Dent. 2020;45(1):E11-20.

15. Sekundo C, Fazeli S, Felten A, Schoilew K, Wolff D, Frese C. A randomized clinical split-mouth trial of a bulk-fill and a nanohybrid composite restorative in class II cavities: three-year results. Dent Mater. 2022;38(5):759-68.

16. Yazici AR, Antonson SA, Kutuk ZB, Ergin E. Thirty-six-month clinical comparison of bulk fill and nanofill composite restorations. Oper Dent. 2017;42(5):478-85.

17. Yazici AR, Kutuk ZB, Ergin E, Karahan S, Antonson SA.

Six-year clinical evaluation of bulk-fill and nanofill resin composite restorations. Clin Oral Investig. 2022; 26(1): 417-26.

18. Canali GD, Ignácio SA, Rached RN, Souza EM. One-year clinical evaluation of bulk-fill flowable vs. regular nanofilled composite in non-carious cervical lesions. Clin Oral Investig. 2019;23(2):889-97.

19. Nayyer M, Zahid S, Hassan SH, Mian SA, Mehmood S, Khan HA, et al. Comparative abrasive wear resistance and surface analysis of dental resin-based materials. Eur J Dent. 2018;12(1):57-66.

20. Azam MT, Khan AS, Muzzafar D, Faryal R, Siddiqi SA, Ahmad R, et al. Structural, surface, in vitro bacterial adhesion and biofilm formation analysis of three dental restorative composites. Materials. 2015;8(6):3221-37.

21. Goda B, Hamdi K, Eltoukhy RI, Ali AI, Mahmoud SH. Clinical performance of different bulk-fill composite resin systems in class II cavities: a 2-year randomized clinical trial. J Esthet Restor Dent. 2024;36(8):1122-37.

22. Leinonen KM, Leinonen J, Bolstad NL, Tanner T, Al-Haroni M, Johnsen JK. Procedure time and filling quality for bulk-fill base and conventional incremental composite techniques: a randomised controlled in vitro trial. J Dent. 2023;138:104725.

23. Schliebe LRSO, Braga SSL, da Silva Pereira RA, Bicalho AA, Verissimo C, Novais VR, et al. The new generation of conventional and bulk-fill composites do not reduce the shrinkage stress in endodontically-treated molars. Am J Dent. 2016;29(6):333-8.

24. Ferracane JL. Placing dental composites—a stressful experience. Oper Dent. 2008;33(3):247-57.

25. Ferracane JL, Hilton TJ. Polymerization stress–is it clinically meaningful? Dent Mater. 2016;32(1):1-10.

26. Zorzin J, Maier E, Harre S, Fey T, Belli R, Lohbauer U, et al. Bulk-fill resin composites: polymerization properties and extended light curing. Dent Mater. 2015;31(3):293-301.

27. Balkaya H, Arslan S, Pala K. A randomized, prospective clinical study evaluating effectiveness of a bulk-fill composite resin, a conventional composite resin and a reinforced glass ionomer in Class II cavities: one-year results. J Appl Oral Sci. 2019;27:e20180678.

28. Barceleiro MO, Tardem C, Albuquerque EG, Lopes LS, Marins SS, Poubel LA, et al. Can composite packaging and selective enamel etching affect the clinical behavior of bulk-fill composite resin in posterior restorations? 24-month results of a randomized clinical trial. J Appl Oral Sci. 2023;31:e20220323.

29. Heck K, Manhart J, Hickel R, Diegritz C. Clinical evaluation of the bulk fill composite QuiXfil in molar class I and II cavities: 10-year results of a RCT. Dent Mater. 2018;34(6):e138-47.

30. Colak H, Tokay U, Uzgur R, Hamidi MM, Ercan E. A prospective, randomized, double-blind clinical trial of one nano-hybrid and one high-viscosity bulk-fill composite restorative systems in class II cavities: 12 months results. Niger J Clin Pract. 2017;20(7):822-31.

31. Twigg J, Vaid N, Chavda A, Seymour D, Hyde TP, Nixon PJ. A randomised controlled trial of postoperative sensitivity after class II restoration with bulk-fill vs conventional composites. Eur J Prosthodont Restor Dent. 2024;32(2):234-42.

32. Hoffmann L, Neuerer C, Heck K, Kunzelmann KH. Bulk-fill composites compared to a nanohybrid composite in class-II cavities: a two-year follow-up study. J Adhes Dent. 2021;23(5):389-96.

33. Tardem C, Albuquerque EG, Lopes LS, Marins SS, Calazans FS, Poubel LA, et al. Clinical time and postoperative sensitivity after use of bulk-fill (syringe and capsule) vs. incremental filling composites: a randomized clinical trial. Braz Oral Res. 2019;33:e089.

34. Cieplik F, Hiller KA, Buchalla W, Federlin M, Scholz KJ. Randomized clinical split-mouth study on a novel self-adhesive bulk-fill restorative vs. a conventional bulk-fill composite for restoration of class II cavities–results after three years. J Dent. 2022;125:104275.

35. Moda MD, Briso AF, Hoshino I, Frascino S, Santos PH, Gonçalves DM, et al. Three-year randomized prospective clinical trial of class II restorations using flowable bulk-fill resin composites. Oper Dent. 2021;46(5):516-28.

36. Schoilew K, Fazeli S, Felten A, Sekundo C, Wolff D, Frese C. Clinical evaluation of bulk-fill and universal nanocomposites in class II cavities: five-year results of a randomized clinical split-mouth trial. J Dent. 2023; 128: 104362.

37. Strazzi-Sahyon HB, Passos Rocha E, Gonçalves Assunção W, Henrique dos Santos P. Influence of light-curing intensity on color stability and microhardness of composite resins. Int J Periodontics Restorative Dent. 2020;40(1):129-34.

38. Khalaj K, Soudi A, Tayefi-Nasrabadi M, Keshvad M. The evaluation of surface sealants' effect on the color stability of nano-hybrid composite after polishing with one-step system (in-vitro). J Clin Exp Dent. 2018;10(9):e927-33.

39. Venz S, Dickens B. NIR-spectroscopic investigation of water sorption characteristics of dental resins and

composites. J Biomed Mater Res. 1991;25(10):1231-48.
40. Gajewski VE, Pfeifer CS, Fróes-Salgado NR, Boaro LC, Braga RR. Monomers used in resin composites: degree of conversion, mechanical properties and water sorption/solubility. Braz Dent J. 2012;23(5):508-14.
41. Morsy KES, Salama MM, Genaid TM. Clinical evaluation of thermo-viscous and sonic fill-activated bulk fill composite restorations. Am J Dent. 2023;36(2):81-5.
42. Imazato S, Tarumi H, Kato S, Ebi N, Ehara A, Ebisu S. Water sorption, degree of conversion, and hydrophobicity of resins containing Bis-GMA and TEGDMA. Dent Mater J. 1999;18(1):124-32.
43. Bilgili Can D, Özarslan M. Evaluation of color stability and microhardness of contemporary bulk-fill composite resins with different polymerization properties. J Esthet Restor Dent. 2022;34(6):924-32.
44. Sjögren P, Halling A. Survival time of Class II molar restorations in relation to patient and dental health insurance costs for treatment. Swed Dent J. 2002;26(2):59-66.
45. Sadowsky SJ. An overview of treatment considerations for esthetic restorations: a review of the literature. J Prosthet Dent. 2006;96(6):433-42.
46. Schwendicke F, Göstemeyer G, Stolpe M, Krois J. Amalgam alternatives: cost-effectiveness and value of information analysis. J Dent Res. 2018;97(12):1317-23.
47. Tuncdemir MT, Yeşilyurt NG, Arıkan M. Comparison of the stress distribution in class I and class II amalgam and bulk-fill composite restorations using CAD-FEM modeling. Int J Periodontics Restorative Dent. 2021;41(1):e1-9.
48. Agarwal A, Verma P, Yadav R, Bharti R, Bains R, Kumar M, et al. Evaluation of pulpal response at varying remaining dentin thickness in teeth restored with resin bulk fill composite, conventional glass ionomer cement and silver amalgam: histomorphometric analysis. J Oral Biol Craniofac Res. 2025;15(2):347-54.
49. Al-Asmar AA, Ha Sabrah A, Abd-Raheam IM, Ismail NH, Oweis YG. Clinical evaluation of reasons for replacement of amalgam vs composite posterior restorations. Saudi Dent J. 2023;35(3):275-81.
50. Al-Qudah A, Jawad DA, Jaradat M. Periapical status of non-root-filled teeth with amalgam, composite, or crown restorations: a cross-sectional study. Int Dent J. 2023; 73 (5):645-50.
51. Al Ghadban A, Al Shaarani F. Antibacterial properties of amalgam and composite resin materials used as cores under crowns. Eur J Prosthodont Restor Dent. 2012; 20 (2):71-6.
52. Gallusi G, Libonati A, Piro M, Di Taranto V, Montemurro E, Campanella V. Is dental amalgam a higher risk factor rather than resin-based restorations for systemic conditions? A systematic review. Materials (Basel). 2021;14(8):1980.
53. World Alliance for Mercury-Free Dentistry. Toward mercury-free dentistry [Internet]. 2016 [cited 2025 Jan 15]. Available from: https://mercuryfreedentistry.net/2016/02/12/toward-mercury-free-dentistry/.
54. Lohbauer U. Dental glass ionomer cements as permanent filling materials?—Properties, limitations and future trends. Materials. 2009;3(1):76-96.
55. Hoshika S, De Munck J, Sano H, Sidhu SK, Van Meerbeek B. Effect of conditioning and aging on the bond strength and interfacial morphology of glass-ionomer cement bonded to dentin. J Adhes Dent. 2015;17(2):141-6.
56. Nantanee R, Santiwong B, Trairatvorakul C, Hamba H, Tagami J. Silver diamine fluoride and glass ionomer differentially remineralize early caries lesions, in situ. Clin Oral Investig. 2016;20(6):1151-7.
57. Joshi G, Heiss M. Glass-hybrid technology for long-term restorations. Compend Contin Educ Dent. 2021;42(Suppl 1):2-5.
58. Uyumaz F, Abaklı İnci M, Özer H. Could bulk fill glass hybrid restorative materials replace composite resins in treating permanent teeth? A randomized controlled clinical trial. J Esthet Restor Dent. 2024;36(5):702-9.
59. Atmaca Y, Karadas M. Clinical comparison of high-viscosity glass-hybrid systems with a sculptable bulk-fill composite resin in different cavity types. J Esthet Restor Dent. 2024;36(8):1138-52.
60. Akman H, Tosun G. Clinical evaluation of bulk-fill resins and glass ionomer restorative materials: a 1-year follow-up randomized clinical trial in children. Niger J Clin Pract. 2020;23(4):489-97.
61. Bayazıt E, Başeren M, Meral E. Clinical comparison of different glass ionomer-based restoratives and a bulk-fill resin composite in Class I cavities: a 48-month randomized split-mouth controlled trial. J Dent. 2023;131:104473.
62. Olegário IC, Hesse D, Bönecker M, Imparato JC, Braga MM, Mendes FM, et al. Effectiveness of conventional treatment using bulk-fill composite resin versus atraumatic restorative treatments in primary and permanent dentition: a pragmatic randomized clinical trial. BMC Oral Health. 2016;17(1):34.
63. Kaisarly D, ElGezawi M, Haridy R, Elembaby A, Aldegheishem A, Alsheikh R, et al. Reliability of class II bulk-fill composite restorations with and without

veneering: a two-year randomized clinical control study. Oper Dent. 2021;46(5):491-504.
64. Schenke IM, Pfister JL, Hiller KA, Buchalla W, Cieplik F, Ettenberger S, et al. Randomized clinical split-mouth study on a self-adhesive vs. a conventional bulk-fill composite in class II cavities: results after five years. J Dent. 2025; 156: 105663.
65. Ellithy MS, Abdelrahman MH, Afifi RR. Comparative clinical evaluation between self-adhesive and conventional bulk-fill composites in class II cavities: a 1-year randomized controlled clinical study. J Esthet Restor Dent. 2024;36(9):1311-25.
66. El-Shazly RK, El-Zayat IMA, Mohsen MMA, Labib MEM. Clinical evaluation of self-adhesive bulk-fill composite versus conventional nano-hybrid composite in cervical cavities: a randomized controlled clinical trial. J Esthet Restor Dent. 2025;37(7):1907-19.
67. Maghaireh GA, Albashaireh ZS, Allouz HA. Postoperative sensitivity in posterior restorations restored with self-adhesive and conventional bulk-fill resin composites: a randomized clinical split-mouth trial. J Dent. 2023;137:104655.
68. Favoreto MW, de Souza Carneiro T, Wendlinger M, Naupari-Villasante R, de Matos TP, Kunz PM, et al. Various ways of pre-heating a bulk-fill thermoviscous composite in restoration in non-carious cervical lesions: 12-month randomized clinical trial. Clin Oral Investig. 2023; 27(8): 4345-59.
69. Favoreto MW, Condolo L, de Souza Carneiro T, Wendlinger M, Ñaupari-Villasante R, de Matos TP, et al. Evaluation of preheating methods for bulk-fill thermoviscous composite in non-carious cervical lesions: a 24-month randomized controlled trial. J Dent. 2024; 151: 105409.
70. Ibrahim I, Helal H, Ibrahim SH, Riad M. 24 months clinical prospective of proximal restorations with repeated preheating bulk fill composite up to ten cycles: randomized controlled trial. Sci Rep. 2024;14(1):23966.
71. Elkady M, Abdelhakim SH, Riad M. Impact of repeated preheating of bulk-fill resin composite on postoperative hypersensitivity; a randomized controlled clinical trial. BMC Oral Health. 2024;24(1):453.
72. Loguercio AD, Carpio-Salvatierra B, Ñaupari-Villasante R, Wendlinger M, Armas-Vega A, Cavagnaro S, et al. Clinical evaluation of a new chemically-cured bulk-fill composite in posterior restorations: 6-month multicenter double-blind randomized clinical trial. J Dent. 2024;149:105246.
73. Elawsya ME, Montaser MA, El-Wassefy NA, Zaghloul NM. Two-year clinical performance of dual- and light-cure bulk-fill resin composites in Class II restorations: a randomized clinical trial. Clin Oral Investig. 2024; 28(2): 138.