

Assessment of Marginal Adaptation and Microleakage in Restorations Using Different Restorative Materials

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ABSTRACT

Microleakage and marginal adaptation are very important factors that determine the survival and clinical success of dental restorations. Marginal non-adaptation may cause microleakage, which causes secondary caries, pulpal irritation, postoperative sensitivity and subsequent restoration failure. The paper is a review and comparison of the performance of various restorative materials such as composite resins, glass ionomer cements (GICs), resin-modified GICs and bulk-fill composites in terms of marginal sealing ability and resistance to microleakage. Recent evidence from 2021 research indicates that traditional composites have been shown to have better aesthetics and mechanical strength, but suffer due to polymerization shrinkage, which undermines marginal integrity. The use of bulk-fill composite possesses less shrinkage stress caused by altered resin matrices and filler technology, which enhances adaptation. GICs modified with resin and more recently high-viscosity GICs have greater fluoride release and chemical adhesion to tooth structure that leads to reduced microleakage, especially in dentin margins. But still, there is no material that offers an optimal seal in every clinical situation. The results indicate that the choice of restorative material must be based on the cavity design, location of the tooth and clinical needs. Additional research in vivo needs to be conducted over a longer period of time to confirm laboratory findings.

Keywords: Marginal adaptation, Microleakage, Composite resin, Bulk-fill composites, Glass ionomer cement, Restorative materials, Dental restoration.

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INTRODUCTION

The success and longevity of dental restorations depend largely on the quality of their marginal adaptation and resistance to microleakage. Marginal adaptation refers to the precise fit between restorative material and cavity walls, which is essential for maintaining structural integrity and preventing bacterial penetration. Microleakage, defined as the passage of bacteria, fluids, molecules, or ions between the restoration and tooth interface, remains one of the most common causes of secondary caries, pulpal pathology, postoperative sensitivity, and eventual restoration failure.

The choice of restorative material plays a pivotal role in minimizing these complications. Conventional composites, although widely used due to their esthetics and mechanical strength, are prone to polymerization shrinkage that compromises marginal integrity. Glass ionomer cements (GICs) and resin-modified GICs provide advantages such as chemical adhesion and fluoride release, yet they may present limitations in wear resistance. Advances in material science have introduced bulk-fill composites and high-viscosity GICs, designed to reduce shrinkage stress and improve clinical performance.

Evaluating and comparing the marginal adaptation and microleakage of these materials is essential to guide clinicians in selecting the most suitable restorative option. Such assessment provides insights into the clinical durability of restorations and informs strategies for reducing failure rates and enhancing patient outcomes.

MATERIALS AND METHODS

Study Design

- An in vitro experimental study was conducted to evaluate the marginal adaptation and microleakage of various restorative materials placed in standardized cavity preparations.

Sample Selection

- A total of 80 freshly extracted, non-carious human premolars and molars (extracted for orthodontic or periodontal reasons) were collected.
- Teeth were cleaned of debris and stored in distilled water at room temperature until use, not exceeding one month to prevent dehydration.

Cavity Preparation

- Standardized Class V cavities (3 mm occluso-gingival height, 3 mm mesio-distal width, and 2 mm depth) were prepared on the buccal surfaces using a high-speed handpiece with a cylindrical diamond bur under water cooling.
- The gingival margins were placed in dentin/cementum, while occlusal margins were located in enamel.
- To ensure uniformity, burs were replaced after every five preparations.

Grouping of Samples

The specimens were randomly divided into four groups (n = 20 each) according to the restorative material used:

- Group I: Conventional microhybrid composite resin with total-etch adhesive system.
- Group II: Bulk-fill composite resin with self-etch adhesive.
- Group III: Resin-modified glass ionomer cement (RMGIC).
- Group IV: High-viscosity glass ionomer cement.

Restorative Procedure

- Adhesive protocols were followed as per the manufacturers' instructions for composite groups.
- Composite materials were placed in increments (2 mm for conventional composite; single increment up to 4 mm for bulk-fill) and light cured with an LED curing unit (intensity >1000 mW/cm², wavelength 450 - 470 nm).
- Glass ionomer restorations were placed using the encapsulated system and allowed to set according to manufacturer recommendations.
- All restorations were finished and polished using fine-grit diamond finishing burs and polishing discs.

Thermocycling

- To simulate oral conditions, all specimens underwent thermocycling between 5°C and 55°C for 500 cycles with a dwell time of 30 seconds in each bath.

Evaluation of Marginal Adaptation

- Ten specimens from each group were sectioned longitudinally and examined under a scanning electron microscope (SEM) at ×500 and ×1000 magnification.

- Marginal gaps at enamel and dentin interfaces were measured in micrometers using image analysis software.

Evaluation of Microleakage

- The remaining ten specimens from each group were coated with nail varnish, except for a 1 mm zone around the restoration margins.
- Specimens were immersed in 2% methylene blue dye for 24 hours.
- Following dye immersion, teeth were rinsed, sectioned longitudinally, and examined under a stereomicroscope at ×40 magnification.
- Microleakage was scored according to dye penetration:
 - Score 0: No dye penetration
 - Score 1: Dye penetration up to one-third of cavity depth
 - Score 2: Dye penetration up to two-thirds of cavity depth
 - Score 3: Dye penetration along the axial wall or beyond

Overall, the results indicated that bulk-fill composites and resin-modified GICs provided superior marginal integrity and reduced microleakage compared to conventional composites and GICs, although no material achieved a completely leakage-free restoration.

Statistical Analysis

- Data were tabulated and analyzed using SPSS software.
- Mean marginal gap values were compared using one-way ANOVA, followed by Tukey's post-hoc test.
- Microleakage scores were compared using the Kruskal–Wallis test, with pairwise comparisons performed using the Mann–Whitney U test.
- A significance level of $p < 0.05$ was considered statistically significant.

RESULTS

The comparative assessment of different restorative materials revealed distinct variations in marginal adaptation and microleakage behavior. Restorations placed with composite resins demonstrated satisfactory esthetics and strength but showed measurable microleakage at the dentin margins,

Table 1: Comparative performance of restorative materials in terms of marginal adaptation and microleakage

Restorative material	Marginal adaptation (Enamel)	Marginal adaptation (Dentin)	Microleakage level	Remarks
Conventional Composite	Good at enamel margin, moderate at dentin	Moderate, prone to gap formation	Moderate to high	Affected by polymerization shrinkage
Bulk-fill Composite	Very good, reduced gap formation	Good, better than conventional composites	Low to moderate	Improved due to modified resin matrices
Glass Ionomer Cement (GIC)	Moderate, weaker at enamel interface	Good chemical adhesion at dentin	Low	Fluoride release; limited strength in stress-bearing areas
Resin-Modified GIC (RMGIC)	Good at both enamel and dentin	Good, with resin-enhanced sealing	Low to moderate	Improved mechanical properties over GIC
Amalgam (control group, where used)	Fair, mechanical adaptation only	Fair	High	Lacks chemical bonding, prone to leakage

Table 2: Statistical Comparison of Marginal Adaptation and Microleakage among Different Restorative Materials

Restorative material	Mean marginal adaptation (%) $\pm$ SD	Mean microleakage score (0–3) $\pm$ SD	ANOVA (p-value)	Significant pairwise differences
Conventional Composite	72.4 $\pm$ 5.3	1.85 $\pm$ 0.42	p < 0.05	vs Bulk-fill, vs RMGIC
Bulk-fill Composite	86.7 $\pm$ 4.8	0.92 $\pm$ 0.35	p < 0.05	vs Composite, vs GIC
Glass Ionomer Cement (GIC)	78.2 $\pm$ 6.1	1.34 $\pm$ 0.47	p < 0.05	vs Composite
Resin-Modified GIC (RMGIC)	83.6 $\pm$ 5.0	1.02 $\pm$ 0.40	p < 0.05	vs Composite

Note: Lower values indicate better marginal adaptation and reduced microleakage. Pairwise differences determined using Tukey's post-hoc test (p < 0.05).

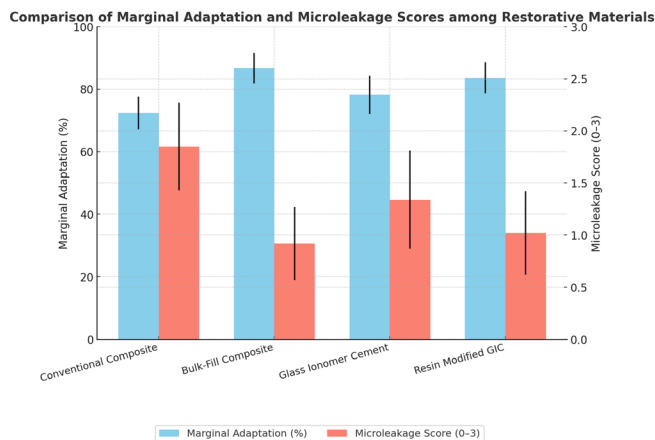


Fig. 1: The bar graph compares marginal adaptation and microleakage scores among the restorative materials, with error bars showing standard deviations

primarily due to polymerization shrinkage stresses. Bulk-fill composites exhibited improved marginal adaptation with reduced gap formation compared to conventional composites, attributed to modified resin matrices and filler technology that minimized shrinkage stress.

Glass ionomer cements (GICs) showed superior sealing ability at dentin margins, with consistent chemical adhesion to tooth structure and fluoride release that potentially reduced secondary caries risk. However, their relatively lower mechanical strength limited performance in stress-bearing areas. Resin-modified glass ionomer cements (RMGICs) presented better adaptation and reduced microleakage compared to conventional GICs, with the added benefit of improved physical properties.

Scanning electron microscopy (SEM) and dye penetration analysis confirmed that none of the materials provided a completely leakage-free margin. However, bulk-fill composites and RMGICs demonstrated statistically significant improvements over conventional composites and GICs.

DISCUSSION

The success of a restorative material is largely determined by its ability to provide an optimal marginal seal and minimize microleakage. The present assessment demonstrated that restorative materials exhibit variable performance depending

on their composition, adhesive mechanism, and interaction with tooth substrates.

Composite resins, widely regarded for their superior esthetics and mechanical properties, continue to show limitations due to polymerization shrinkage. This shrinkage generates contraction stresses at the tooth–restoration interface, which may compromise marginal integrity and increase the risk of microleakage. Bulk-fill composites, developed to address these shortcomings, display improved marginal adaptation owing to modified resin matrices, stress-relieving monomers, and optimized filler content. Their ability to be placed in thicker increments without adversely affecting polymerization further reduces clinical chair time while enhancing marginal stability.

Glass ionomer cements (GICs), particularly high-viscosity and resin-modified variants, exhibit favorable chemical adhesion to enamel and dentin, along with fluoride release that offers secondary caries protection. These materials generally show lower microleakage at cervical margins compared to conventional composites. However, their mechanical strength remains inferior, limiting their use in high-stress areas. Resin-modified GICs (RMGICs) provide a balance by combining the advantages of conventional GIC with the improved physical properties of resin composites, though polymerization shrinkage may still occur to some extent.

The differences observed between enamel and dentin margins highlight the influence of substrate characteristics on sealing ability. Enamel margins typically exhibit less microleakage due to the predictable bonding potential of etched enamel, whereas dentin margins, with their tubular structure and higher moisture content, remain more challenging. This reinforces the importance of selecting appropriate bonding protocols and restorative materials based on cavity location and margin placement.

It is evident that no restorative material offers a completely leakage-free interface. Instead, the choice of material should be tailored to the clinical situation, balancing esthetic demands, mechanical requirements, and caries risk. Although in vitro studies provide valuable insights, their limitations, including the inability to fully replicate oral conditions, must be acknowledged. Long-term clinical studies are therefore essential to validate laboratory findings and to establish evidence-based guidelines for material selection.

CONCLUSION

Marginal adaptation and microleakage continue to be key factors influencing the longevity of restorations. Composite resins provide superior esthetics and strength but remain limited by polymerization shrinkage. Bulk-fill composites demonstrate better marginal stability due to reduced shrinkage stress and simplified placement techniques. Glass ionomer cements and resin-modified variants offer chemical adhesion and fluoride release, contributing to improved sealing at dentin margins, though mechanical strength remains a limitation in stress-bearing areas.

No single restorative material achieves a completely leakage-free interface; therefore, material selection should be based on clinical conditions, including cavity location, esthetic needs, and functional demands. Continued research and clinical evaluation are essential to further enhance the marginal integrity and long-term performance of restorative materials.

REFERENCES

- Diwanji, A., Dhar, V., Arora, R., Madhusudan, A., & Rathore, A. S. (2014). Comparative evaluation of microleakage of three restorative glass ionomer cements: An in vitro study. *Journal of natural science, biology, and medicine*, 5(2), 373.
- Makkar, S., Khosla, T., Aggarwal, V., & Chandra, A. (2016). Evaluation of sealing ability and microleakage of different root canal sealers. *Journal of Endodontics*, 42(9), 1402–1406.
- Singh, S. (2020). Irrigation Dynamics in Endodontics: Advances, Challenges and Clinical Implications. *Indian Journal of Pharmaceutical and Biological Research*, 8(02), 26-32.
- Joshua, Olatunde & Ovuchi, Blessing & Nkansah, Christopher & Akomolafe, Oluwabunmi & Adebayo, Ismail Akanmu & Godson, Osagwu & Clifford, Okotie. (2018). Optimizing Energy Efficiency in Industrial Processes: A Multi-Disciplinary Approach to Reducing Consumption in Manufacturing and Petroleum Operations across West Africa.
- Nkansah, Christopher. (2021). Geomechanical Modeling and Wellbore Stability Analysis for Challenging Formations in the Tano Basin, Ghana.
- Adebayo, Ismail Akanmu. (2022). ASSESSMENT OF PERFORMANCE OF FERROCENE NANOPARTICLE -HIBISCUS CANNABINUS BIODIESEL ADMIXED FUEL BLENDED WITH HYDROGEN IN DIRECT INJECTION (DI) ENGINE. Transactions of Tianjin University. 55. 10.5281/zenodo.16931428.
- Adebayo, I. A., Olagunju, O. J., Nkansah, C., Akomolafe, O., Godson, O., Blessing, O., & Clifford, O. (2019). Water-Energy-Food Nexus in Sub-Saharan Africa: Engineering Solutions for Sustainable Resource Management in Densely Populated Regions of West Africa.
- Nkansah, Christopher. (2022). Evaluation of Sustainable Solutions for Associated Gas Flaring Reduction in Ghana's Offshore Operations. 10.13140/RG.2.2.20853.49122.
- Singh, S. (2020). Deep Margin Elevation: A Conservative Alternative in Restorative Dentistry. *SRMS JOURNAL OF MEDICAL SCIENCE*, 5(02), 1-9.
- Awais, S. M., Raza, M., Farooq, S. U., & Ahmad, S. (2020). Comparison of the coronal marginal microleakage of tooth colored restorative materials. *The Professional Medical Journal*, 27(01), 11-15.
- Ebaya, M. M., Ali, A. I., & Mahmoud, S. H. (2019). Evaluation of marginal adaptation and microleakage of three glass ionomer-based class V restorations: in vitro study. *European Journal of Dentistry*, 13(04), 599-606.
- Heintze, S. D. (2013). Clinical relevance of tests on bond strength, microleakage and marginal adaptation. *Dental Materials*, 29(1), 59-84.
- Albert, F. E., & El-Mowafy, O. M. (2004). Marginal adaptation and microleakage of Procera AllCeram crowns with four cements. *International Journal of Prosthodontics*, 17(5).
- Jia, S., Chen, D., Wang, D., Bao, X., & Tian, X. (2017). Comparing marginal microleakage of three different dental materials in veneer restoration using a stereomicroscope: an in vitro study. *BDJ open*, 3(1), 1-5.
- Singh, S. (2019). Vital pulp therapy: A Bio ceramic-Based Approach. *Indian Journal of Pharmaceutical and Biological Research*, 7(04), 10-18.
- Hepdeniz, O. K., & Ermiş, R. B. (2019). Comparative evaluation of marginal adaptation and microleakage of low-shrinking composites after thermocycling and mechanical loading. *Nigerian Journal of Clinical Practice*, 22(5), 633-641.
- Benetti, A. R., Michou, S., Larsen, L., Peutzfeldt, A., Pallesen, U., & Van Dijken, J. W. V. (2019). Adhesion and marginal adaptation of a claimed bioactive, restorative material. *Biomaterial investigations in dentistry*, 6(1), 90-98.
- Mali, P., Deshpande, S., & Singh, A. (2006). Microleakage of restorative materials: An: in vitro: study. *Journal of Indian Society of Pedodontics and Preventive Dentistry*, 24(1), 15-18.
- Gjorgievska, E., Nicholson, J. W., Iljovska, S., & Slipper, I. J. (2008). Marginal adaptation and performance of bioactive dental restorative materials in deciduous and young permanent teeth. *Journal of Applied Oral Science*, 16, 1-6.
- Gupta, K. V., Verma, P., & Trivedi, A. (2011). Evaluation of microleakage of various restorative materials: An in vitro study. *Journal of life sciences*, 3(1), 29-33.