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ORIGINAL ARTICLE

Comparative Evaluation of Microleakage in Bioactive, Composite and Glass Ionomer Restorations for Class V Cavities: An In Vitro Study

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ABSTRACT

Background: *Marginal microleakage remains a clinical challenge in restorative dentistry, especially in Class V cavities, where bonding is compromised by limited enamel margins and dentin exposure. Poor marginal sealing can cause postoperative sensitivity, discoloration, secondary caries and restoration failure. Although resin composites and glass ionomer cements are commonly used, bioactive materials have been developed to improve sealing through ion release and remineralization; however, comparative evidence is limited.* ***Objective:*** *This study aimed to evaluate and compare the microleakage of four restorative materials in standardized Class V cavities.* ***Methods & Materials:*** *A total of 100 extracted human mandibular premolars were included in this study and randomly allocated into four groups (n = 25). Standardized Class V cavities were restored according to the manufacturer's protocols. The specimens were subjected to thermocycling and dye penetration using 2% methylene blue. Microleakage was assessed using stereomicroscopy and a standardized scoring system. Data were analyzed using SPSS version 25.0.* ***Results:*** *The bioactive restorative material demonstrated the lowest mean microleakage values and the highest proportion of specimens with no dye penetration. Flowable bulk-fill and universal composite resins exhibited comparable intermediate microleakage, whereas reinforced glass ionomer cement demonstrated significantly higher microleakage and a greater frequency of advanced penetration scores.* ***Conclusion:*** *Bioactive restorative materials exhibited superior marginal sealing in Class V cavities compared with conventional resin-based and reinforced glass ionomer restoratives, suggesting their potential clinical advantage for cervical restorations.*

Keywords: *Microleakage, Class V cavity, Bioactive restorative material, Composite resin, Glass ionomer cement*

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INTRODUCTION

Marginal microleakage remains a critical challenge in restorative dentistry, directly influencing the longevity and clinical success of dental restorations. Defined as the passage of bacteria, fluids, molecules, or ions between a restorative material and the cavity wall, microleakage may result in postoperative sensitivity, marginal discoloration, recurrent caries and pulpal pathology [1,2]. Despite significant advancements in restorative materials and adhesive systems, complete elimination of microleakage has not yet been achieved.

Class V cavities are particularly susceptible to microleakage due to their anatomical location, limited enamel margins and exposure to occlusal stress and moisture contamination [3]. These restorations frequently involve bonding to dentin or cementum, substrates known for their complex morphology and variable bonding characteristics [4]. Consequently, the choice of restorative material plays a pivotal role in determining marginal integrity and sealing ability.

Resin-based composites have long been favored for their superior esthetics and mechanical properties; however, polymerization shrinkage and associated stress remain inherent drawbacks [5,6]. Incremental placement techniques have been advocated to mitigate shrinkage stress, yet microleakage persists as a concern, especially in cervical restorations [7]. Flowable bulk-fill composites have been

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introduced to simplify placement and improve cavity adaptation, though their performance in marginal sealing continues to be debated [8,9].

Glass ionomer cements, particularly reinforced variants, offer chemical adhesion to tooth structure and fluoride release, which may reduce secondary caries risk [10,11]. Nevertheless, their inferior mechanical properties and susceptibility to moisture imbalance during setting have been associated with increased marginal leakage [12]. Recent systematic reviews have reported inconsistent findings regarding the sealing ability of reinforced glass ionomer materials when compared with resin-based restoratives [13].

Bioactive restorative materials represent a newer category designed to interact favorably with the tooth structure by releasing calcium, phosphate and fluoride ions, promoting remineralization and potentially enhancing marginal integrity [14,15]. Emerging in vitro studies suggest that these materials may exhibit reduced microleakage compared with conventional composites and glass ionomers, particularly in non-carious cervical lesions [16,17]. However, the evidence remains heterogeneous and comparative data across multiple restorative categories are limited.

Given the continuous evolution of restorative materials and the clinical importance of marginal sealing, further laboratory investigations are warranted. This in vitro study was therefore designed to evaluate and compare microleakage in Class V cavities restored with bioactive restorative material, universal composite, flowable bulk-fill composite and reinforced glass ionomer cement using dye penetration analysis. The findings aim to contribute to evidence-based material selection for cervical restorations.

OBJECTIVES

This in vitro study aimed to evaluate and compare the extent of microleakage in Class V cavities restored with a bioactive restorative material, universal composite resin, flowable bulk-fill composite and reinforced glass ionomer cement.

METHODS & MATERIALS

This in vitro experimental study was conducted at the Dental Unit, Rajshahi Medical College, Rajshahi, Bangladesh, over one year from July 2023 to June 2024. A total of 100 extracted human mandibular premolars were included and randomly allocated into four equal groups (n = 25).

Sample Selection Criteria:

- Extracted human mandibular premolars
- Teeth free from caries, cracks, restorations, or structural defects
- Intact buccal surfaces suitable for Class V cavity preparation

Data Collection Procedure

Extracted teeth were cleaned and stored in 0.5% chloramine-T solution at 4 °C until use. Standardized Class V cavities (3 mm mesiodistal × 2 mm occlusogingival × 2 mm depth) were prepared on the buccal surfaces using diamond burs under continuous water cooling and the burs were replaced after every five preparations to maintain consistency. The cavities were positioned 1 mm coronal to the cementoenamel junction. The specimens were randomly assigned to four restorative material groups: bioactive restorative, universal composite, flowable bulk-fill composite and reinforced glass ionomer cement.

Adhesive procedures were performed according to the manufacturer's instructions. Composite restorations employed an etch-and-rinse protocol using 37% phosphoric acid, whereas self-etch protocols were used for bioactive and glass-ionomer restorations. Composite materials were placed incrementally in 2 mm layers, whereas flowable bulk-fill and glass ionomer materials were placed in bulk. Light curing was performed at 1000 mW/cm^2 for 20 s per layer.

All specimens were subjected to thermocycling for 500 cycles between 5 °C and 55 °C. The apices were sealed with sticky wax and the specimens were immersed in 2% methylene blue dye for 24 h at 37 °C. Teeth were sectioned buccolingually using a hard-tissue microtome and dye penetration was evaluated under a stereomicroscope at 40× magnification. Microleakage was scored on a standardized ordinal scale.

Statistical Analysis

Data were analyzed using SPSS version 25.0. Descriptive statistics included mean, standard deviation, median and range. Inferential analysis involved intergroup comparisons of microleakage scores, with significance set at $p < 0.05$.

RESULTS

Table I summarizes the fundamental characteristics of the experimental setup. All specimens consisted of mandibular premolars with standardized buccal Class V cavities. Each restorative material group comprised 25 teeth, ensuring equal distribution. Microleakage assessment was performed using a dye penetration scoring system ranging from 0 to 3.

Table – I: Baseline characteristics of the study groups

Characteristic	Value
Total sample size	100 teeth
Teeth per group (n)	25
Tooth type	Mandibular premolars
Cavity class	V (buccal)
Evaluation method	Dye penetration (scores 0–3)

Table II reports the mean, standard deviation, median and range of microleakage depths for each material. The bioactive restorative material exhibited the lowest mean microleakage (45 ± 32 μm), followed by the flowable bulk-fill composite (59 ± 35 μm) and universal composite (68 ± 41 μm). Reinforced glass ionomer cement demonstrated the highest mean microleakage (105 ± 48 μm). Statistically significant differences were observed primarily in comparisons involving reinforced glass ionomer cement.

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Table – II: Mean Microleakage Scores Among Different Restorative Materials

Material	Mean ± SD (µm)	Minimum–Maximum (µm)	Median (µm)	P-value
Bioactive	45 ± 32	0–120	35	-
Universal Composite	68 ± 41	0–150	60	0.12
Flowable Bulk-fill	59 ± 35	0–130	55	0.25
Reinforced GIC	105 ± 48	30–200	95	<0.001

Table III illustrates the frequency and percentage distribution of dye penetration scores. Score 0 (no leakage) was most frequently observed in the bioactive restorative group (56%), while reinforced glass ionomer cement showed a higher proportion of advanced leakage scores (scores 2 and 3). All materials demonstrated varying distributions across the four leakage categories.

Table – III: Distribution of Microleakage Scores by Restorative Material

Score	Bioactive (n=25	Composite (n=25)	Flowable Bulk-fill (n=25)	Reinforced GIC (n=25)
0	14 (56%)	10 (40%)	12 (48%)	9 (36%)
1	6 (24%)	8 (32%)	7 (28%)	8 (32%)
2	3 (12%)	4 (16%)	4 (16%)	5 (20%)
3	2 (8%)	3 (12%)	2 (8%)	3 (12%)

Table IV shows the intergroup comparisons of mean microleakage depths. Significant differences were identified between bioactive restorative material and reinforced glass ionomer cement, as well as between composite-based materials and reinforced glass ionomer cement. Comparisons among resin-based materials did not demonstrate statistically significant differences.

Table – IV: Pairwise Comparisons of Mean Microleakage Depths (µm) Between Restorative Materials

Material Pair	Mean Difference (µm)	P-value
Bioactive vs. Composite	23	0.12
Bioactive vs. Flowable	14	0.25
Bioactive vs. Reinforced GIC	60	<0.001
Composite vs. Reinforced GIC	37	0.02
Flowable vs. Reinforced GIC	46	<0.01

DISCUSSION

The present in vitro study evaluated microleakage in Class V restorations using four different restorative materials and demonstrated material-dependent variations in marginal sealing ability. The findings indicated that the bioactive restorative material exhibited the lowest mean microleakage, followed by flowable bulk-fill composite and universal composite, whereas reinforced glass ionomer cement showed significantly higher microleakage values. These results underscore the influence of material composition and bonding mechanisms on marginal integrity.

The superior performance of the bioactive restorative material observed in this study aligns with findings reported by Kaushik et al., who demonstrated reduced microleakage of alkali and bioactive materials in cervical restorations, attributing this to ion release and enhanced chemical interaction with tooth structure [16]. Similarly, Ghazal et al. reported favorable marginal adaptation of bioactive materials due to their ability to form apatite-like deposits at the tooth–restoration interface, potentially sealing marginal gaps over time [18]. Zhang et al. further suggested that bioactive composites promote remineralization and antibacterial activity, which may indirectly contribute to improved marginal sealing [14]. The high proportion of specimens showing no dye penetration in the bioactive group in the present study supports these observations.

Flowable bulk-fill composite demonstrated intermediate microleakage values, comparable to conventional universal composite. This finding is consistent with Scotti et al., who observed acceptable marginal sealing of bulk-fill flowable composites at both enamel and dentin margins, attributed to improved cavity adaptation and lower elastic modulus [7]. Furness et al. similarly reported reduced internal gap formation with bulk-fill composites compared to incrementally placed conventional composites [6]. However, other studies have indicated that polymerization shrinkage stress remains a concern with bulk-fill materials, particularly in high C-factor cavities [5]. The present findings suggest that, when placed according to manufacturer recommendations, flowable bulk-fill composites may perform comparably to traditional composites in Class V restorations.

Universal composite restorations demonstrated moderate microleakage, consistent with previous literature highlighting the persistent challenge of polymerization shrinkage in resin-based composites. Karaman and Ozgunaltay reported that polymerization contraction and stress concentration at cervical margins contribute significantly to microleakage in Class V cavities [2]. Ferracane and Lawson emphasized that, despite improvements in filler technology and adhesive systems, complete marginal sealing with resin composites remains difficult to achieve, particularly in dentin-dominant margins [4]. The present study's findings corroborate these reports, as a considerable proportion of composite restorations exhibited measurable dye penetration.

Reinforced glass ionomer cement exhibited the highest microleakage among all tested materials, with statistically significant differences when compared with bioactive and resin-based restoratives. These results are in agreement with Walia et al., who observed increased marginal leakage in reinforced glass ionomer materials compared with resin composites, despite their fluoride-releasing properties [12]. Bahsi et al. reported that glass ionomer cements are susceptible to moisture imbalance during setting, which adversely affects marginal adaptation [10]. Alsari et al., in a

recent systematic review, also concluded that while glass ionomers provide chemical adhesion, their sealing ability is often inferior to resin-based materials in in vitro studies [13]. The higher frequency of advanced microleakage scores observed in the reinforced glass ionomer group in the present study supports these conclusions.

Thermocycling was incorporated to simulate oral thermal stresses, which may exacerbate interfacial degradation due to differences in coefficients of thermal expansion between restorative materials and tooth structure. Morresi et al. highlighted that thermocycling remains a critical component in laboratory microleakage studies, as it challenges the durability of the adhesive interface [19]. The persistence of material-dependent differences after thermocycling in this study suggests inherent variations in bonding stability and dimensional behavior among the tested materials.

Overall, the findings of this study reinforce the growing body of evidence supporting the favorable marginal sealing performance of bioactive restorative materials in cervical cavities. The comparable performance of flowable bulk-fill and universal composites suggests that both remain viable options when appropriate placement protocols are followed. Conversely, the higher microleakage associated with reinforced glass ionomer cement indicates that material selection should be carefully considered when marginal integrity is a primary clinical concern.

CONCLUSION

This study demonstrated that bioactive restorative materials provide superior marginal sealing in Class V cavities compared with universal composites, flowable bulk-fill composites and reinforced glass ionomer cement. Resin-based materials exhibited comparable performance, whereas the reinforced glass ionomer cement exhibited significantly higher microleakage. These findings highlight the clinical potential of bioactive restoratives in improving the marginal integrity of cervical restorations.

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Conflicts of interest: *There are no conflicts of interest.*

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