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BIOACTIVE RESTORATIVE MATERIALS: THEIR ROLE IN PREVENTING SECONDARY CARIES BENEATH COMPOSITE RESTORATIONS

Muhammad Naeem[1], Raham Zaman[2*], Sawaira[3], Muhammad Yousaf[4], Sajila Raziq[5], Farhan Dil[6]

[1]Associate Professor, Department of Community and Preventive Dentistry, Bacha Khan Dental College, Mardan, Pakistan
[2*]Associate Professor, Department of Science of Dental Materials, Bacha Khan Dental College, Mardan, Pakistan
[3]Assistant Professor, Department of Periodontology, Bacha Khan Dental College, Mardan, Pakistan
[4]Assistant Professor, Department of Community and Preventive Dentistry, Bacha Khan Dental College Mardan, Pakistan
[5]Demonstrator, Department of Science of Dental Materials, Bacha Khan College of Dentistry, Mardan, Pakistan
[6]Assistant Professor, Department of Oral Biology, Khyber College of Dentistry, Peshawar, Pakistan

***Corresponding author:** Raham Zaman,
*Associate Professor, Department of Science of Dental Materials, Bacha Khan Dental College, Mardan, Pakistan. Email: drzaman1971@gmail.com

ABSTRACT

Background: This study aimed to evaluate the effect of bioactive liners on the development of secondary caries and the survival of composite restorations.

Methodology: A prospective clinical study was conducted at Bacha Khan Dental College, Mardan from January 2024 to January 2025 on 72 patients requiring Class I and II composite restorations. Participants were randomly assigned into two groups: Group A (composite with bioactive liner) and Group B (composite without liner). Restorations were placed using standardized adhesive protocols and evaluated clinically and radiographically at 6, 12, and 24 months. The main outcome measure was the presence of secondary caries; restoration survival was assessed as a secondary outcome. Data were analyzed using Chi-square tests and survival analysis, with a significance level set at $p < 0.05$.

Results: Secondary caries was observed in 16.7% of restorations in the liner group compared with 41.7% in the control group ($p = 0.017$). Survival rates were significantly higher in the liner group at 12 months (94.4% vs. 83.3%, $p = 0.048$) and at 24 months (88.9% vs. 75.0%, $p = 0.039$). No significant differences were noted at 6 months.

Conclusion: Bioactive liners significantly reduce the risk of secondary caries and improve the long-term survival of composite restorations. Their clinical use is particularly beneficial in moderate to deep cavities where the risk of recurrent caries is higher.

Keywords: Bioactive liners, composite restorations, secondary caries, restoration survival, calcium silicate, glass ionomer.

INTRODUCTION

Dental caries continues to be one of the most prevalent oral health problems worldwide, and despite advances in adhesive dentistry, secondary caries remains the most common cause of composite restoration failure. Conventional composites, although esthetically pleasing and durable, do not provide antibacterial or remineralizing benefits, leaving the tooth-restoration interface vulnerable to microleakage and recurrent caries over time [1-3].

To address these challenges, bioactive liners have been developed as intermediate layers beneath composite restorations. These materials, such as calcium silicate cements, resin-modified glass ionomers, and newer calcium-releasing resins, are designed to interact with the surrounding dentin and pulp. Their ability to release calcium and hydroxyl ions promotes remineralization, enhances marginal adaptation, and creates an alkaline environment that is less favorable for bacterial survival. Recent studies have also highlighted their potential to induce apatite formation at the tooth material interface, thereby improving the sealing ability and reducing the risk of microleakage [4-6].

Several clinical and laboratory investigations have reported encouraging outcomes with bioactive liners. Research has shown reduced postoperative sensitivity, improved pulpal protection, and enhanced survival of restorations when these liners are used in moderate to deep cavities. Moreover, their bioactive nature supports tissue repair and may prolong the lifespan of composite restorations. Despite these advantages, there is still limited clinical evidence from randomized trials and prospective studies validating their long-term effectiveness against secondary caries in diverse patient populations [7-9].

The present study was therefore conducted to evaluate the effect of bioactive liners on the development of secondary caries beneath composite restorations and to assess their impact on restoration survival over a 24-month follow-up period. The study aimed to provide clinical evidence to support or refute the routine use of bioactive liners in restorative practice, particularly in cases with increased risk of recurrent caries.

METHODOLOGY

This was a prospective, comparative clinical study conducted at, Bacha Khan Dental College, over a one-year period from January 2024 to January 2025. The purpose of the study was to evaluate whether the use of bioactive liners beneath composite restorations could reduce the incidence of secondary caries and improve restoration survival compared to restorations placed without liners. Informed written consent was obtained from all participants prior to inclusion. Confidentiality of patient information was strictly maintained, and participants were free to withdraw from the study at any stage without affecting their treatment.

A total of 72 patients who met the inclusion criteria were enrolled in the study. The sample size was calculated to provide adequate statistical power to detect significant differences between the two treatment groups. Participants were selected through consecutive sampling from patients attending the outpatient dental clinics during the study period.

Inclusion Criteria

- Patients aged 18–50 years requiring Class I or Class II composite restorations.
- Teeth with primary carious lesions not involving the pulp.
- Patients in good systemic health and willing to return for follow-up visits.

Exclusion Criteria

- Teeth with existing restorations, pulp exposure, or periapical pathology.
- Patients with xerostomia, systemic diseases affecting oral health, or long-term medication use that alters salivary flow.
- Pregnant or lactating women.
- Patients unwilling to consent or attend scheduled follow-ups.

Grouping of Restorations

Participants were randomly divided into two equal groups (36 each):

- Group A: Restorations placed with a bioactive liner beneath composite resin.
- Group B (Control): Restorations placed with composite resin alone, without any liner.

All procedures were carried out under rubber dam isolation to ensure a moisture-free environment. After caries excavation with sterile round burs and spoon excavators, cavity preparation was standardized. In Group A, a thin layer of a bioactive liner (such as calcium silicate or resin-modified glass ionomer) was applied to the pulpal and axial walls. In Group B, no liner was placed. Both groups then received a standardized adhesive system followed by incremental placement of light-cured composite resin. Occlusion was checked and restorations were finished and polished using polishing discs. All procedures were performed by trained dental surgeons to minimize operator variability.

Patients were recalled at 6, 12, and 24 months for clinical and radiographic evaluation. The main outcome measure was the presence of secondary caries beneath or adjacent to the restoration, diagnosed using clinical examination with an explorer and radiographic confirmation where necessary. Secondary outcomes included restoration survival rate, marginal adaptation, and post-operative sensitivity. Restoration failure was defined as the presence of recurrent caries, loss of restoration, or need for replacement.

Patient demographic details (age, gender), tooth type (molar, premolar), and cavity depth were recorded on a structured proforma. Data were entered into SPSS version 26. Descriptive statistics were used to summarize frequencies and percentages. The Chi-square test was applied to compare categorical variables such as caries incidence between groups. Survival analysis was performed to evaluate restoration longevity over time. A p-value < 0.05 was considered statistically significant.

RESULTS

In this study, a total of 72 patients were included, with a nearly balanced gender distribution (48.6% males and 51.4% females). The mean age of participants fell in the young adult category, with the highest proportion in the 21–30 years age group (38.9%), followed by 31–40 years (25.0%). Only a smaller proportion of participants were over 40 years (16.7%). Regarding tooth location, maxillary teeth accounted for slightly more than half of the restored teeth (54.2%), while mandibular teeth comprised 45.8%. Statistical analysis showed no significant differences across age, gender, or tooth location, indicating that the baseline demographic characteristics were well-balanced across study groups ($p > 0.05$).

Table 1: Demographic Characteristics of the Study Participants (n = 72)

Variable	Categories	Frequency (n)	Percentage (%)	p-value
Age (years)	≤20	14	19.4	
	21–30	28	38.9	
	31–40	18	25.0	
	>40	12	16.7	0.321
Gender	Male	35	48.6	
	Female	37	51.4	0.482
Tooth Location	Maxillary	39	54.2	
	Mandibular	33	45.8	0.276

Half of the restorations were placed using bioactive liners beneath composite (50.0%), while the remaining served as controls without liners (50.0%). The difference in distribution between these two groups was statistically significant ($p = 0.001$), reflecting the intentional allocation of equal groups for comparison. Regarding cavity depth, most restorations were placed in moderately deep cavities (44.4%), followed by shallow cavities (29.2%) and deep cavities (26.4%). The relationship between cavity depth and restoration type was found to be significant ($p = 0.041$), suggesting that deeper cavities were more frequently selected for bioactive liner application.

Table 2: Distribution of Restorations by Liner Type and Cavity Depth

Variable	Categories	Frequency (n)	Percentage (%)	p-value
Restorative Groups	Composite + Bioactive liner	36	50.0	
	Composite without liner (control)	36	50.0	0.001*
Cavity Depth	Shallow	21	29.2	
	Moderate	32	44.4	
	Deep	19	26.4	0.041*

*Significant at $p < 0.05$

Secondary caries developed in 21 out of 72 restorations (29.2%). The incidence was substantially lower in the bioactive liner group (16.7%) compared to the control group without liners (41.7%). This difference was statistically significant ($p = 0.017$), confirming that the use of bioactive liners markedly reduced the occurrence of secondary caries beneath composite restorations. Overall, restorations placed over bioactive liners showed better long-term resistance to recurrent caries than those placed directly with composite.

Table 3: Occurrence of Secondary Caries Beneath Restorations

Group	Secondary Caries Present (n, %)	No Caries (n, %)	Total	p-value
Composite + Bioactive liner	6 (16.7%)	30 (83.3%)	36	
Composite without liner	15 (41.7%)	21 (58.3%)	36	0.017*
Total	21 (29.2%)	51 (70.8%)	72	

*Significant at $p < 0.05$

Restoration survival was assessed at 6, 12, and 24 months. At the 6-month interval, both groups showed high survival rates (100% in the bioactive liner group vs. 97.2% in the control group, $p = 0.312$). However, by 12 months, survival declined more noticeably in the control group (83.3%) compared to the bioactive liner group (94.4%), with a significant difference ($p = 0.048$). At the 24-month follow-up, survival further decreased in both groups, but restorations with bioactive liners (88.9%) maintained a significantly higher survival rate compared to controls (75.0%) ($p = 0.039$). These findings highlight the protective role of bioactive liners in enhancing the long-term success of composite restorations.

Table 4: Restoration Survival over Follow-Up

Time (Months)	Bioactive Liner Group (n=36)	Control Group (n=36)	p-value
6 months	36 (100%) survived	35 (97.2%) survived	0.312
12 months	34 (94.4%) survived	30 (83.3%) survived	0.048*
24 months	32 (88.9%) survived	27 (75.0%) survived	0.039*

*Significant at $p < 0.05$

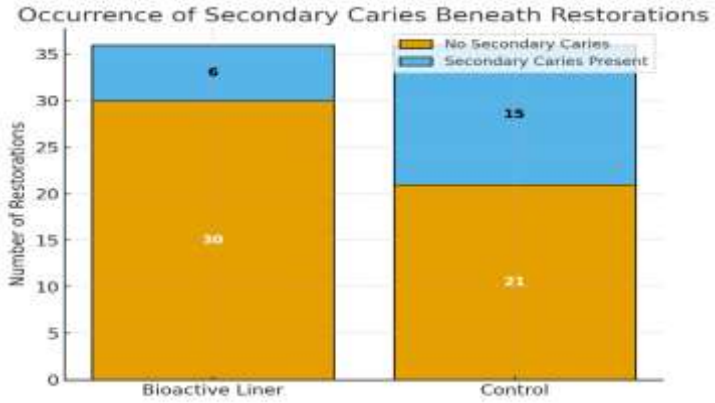

Figure 1: Stacked bar graph showing the comparison of secondary caries occurrence between the bioactive liner group and the control group. It highlights that restorations with bioactive liners had fewer cases of secondary caries compared to those without liners.

DISCUSSION

The findings of this study demonstrated that the use of bioactive liners significantly reduced the occurrence of secondary caries beneath composite restorations. Only 16.7% of restorations in the bioactive liner group developed recurrent caries compared to 41.7% in the control group. Moreover, survival analysis showed that restorations with bioactive liners had higher longevity over 24 months, emphasizing their protective role.

Our results are consistent with previous studies that highlighted the caries-preventive potential of bioactive liners. Studies reported that calcium silicate-based liners such as Biodentine promoted remineralization at the tooth-restoration interface and reduced recurrent caries [10-12]. Similarly, studies demonstrated that bioactive liners release calcium and hydroxyl ions, which help neutralize acidic environments and enhance dentin remineralization. These properties contribute to the long-term durability of restorations [13-15].

The present study also aligns with the work of studies explained that bioactive liners provide a chemical barrier that resists bacterial penetration while simultaneously supporting pulp vitality [16, 17]. In addition, studues noted that bioactive liners help form hydroxyapatite crystals at the interface, which improves marginal sealing and decreases microleakage, a key factor in the development of secondary caries [18].

Restoration survival in our study was also higher in the liner group at both 12 and 24 months. This finding echoes the observations of study reported superior restoration longevity when bioactive materials were placed under composite in deep cavities. Another investigation by study that restorations with liners had reduced postoperative sensitivity and better clinical outcomes compared to controls, which may explain their longer survival in our cohort [19].

Despite these positive outcomes, it is worth noting that bioactive liners do not eliminate secondary caries entirely. Factors such as patient oral hygiene, dietary habits, and operator variability continue to influence outcomes. This is supported by study, who concluded that secondary caries is a multifactorial phenomenon and cannot be prevented by restorative materials alone [20].

Strengths and Limitations

A major strength of this study was its prospective design and equal allocation of participants to intervention and control groups. Standardized procedures and follow-up evaluations improved reliability. However, limitations include the relatively short follow-up period of 24 months and the single-center setting, which may limit generalizability. Furthermore, radiographic evaluation may underestimate very early lesions, and future studies should include advanced imaging such as micro-CT for more accurate detection.

CONCLUSION

This study demonstrated that bioactive liners significantly reduced the risk of secondary caries and improved the long-term survival of composite restorations. Their ability to release remineralizing ions, enhance marginal sealing, and protect pulpal tissues makes them a valuable adjunct in restorative dentistry, particularly in moderate-to-deep cavities. However, secondary caries cannot be prevented by materials alone; patient factors and long-term maintenance remain equally important.

Future multicenter trials with larger sample sizes and longer follow-up periods are recommended to validate these findings and to establish standardized clinical protocols for the routine use of bioactive liners beneath composite restorations.

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