RESEARCH PAPER

Evaluation of Marginal Integrity of Class V Bulk Composite Restorations: An In Vitro SEM Study

Samudhrasri S[1], Balaji Ganesh S[2*], S. Jayalakshmi[3], Thebez Veda Jeyaraj Thooyamani[4], Konmireddy Vaishnavi[5]

[1]Department of Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai, India. Email: 152001039.sdc@saveetha.com

[2*]Reader, White Lab - Materials Research Centre, Saveetha Dental College and Hospital, Saveetha Institute of Medical & Technical Sciences (SIMATS), Saveetha University, Chennai - 600077, Tamil Nadu, India. Email: balajiganeshs.sdc@saveetha.com (Corresponding Author)

[3]Professor, White Lab - Materials Research Centre, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai - 600077, Tamil Nadu, India. Email: jayalakshmisomasundaram@saveetha.com

[4]Biomedical Engineer, White Lab - Material Research Centre, Saveetha Dental College and Hospitals, Saveeth Institute of Medical and Technical Sciences (SIMATS)

[5]Tutor, White Lab - Material Research Centre, Department of Pedodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai - 600077, Tamil Nadu, India. Email: vaishnavik.sdc@saveetha.com

ABSTRACT

INTRODUCTION: One of the factors determining the long-term success of composite resin restorations is the presence or absence of gaps at the tooth–restoration interface. Gaps located at the interface will result in marginal leakage and may lead to pulpal sensitivity and caries. Secondary caries may occur whenever marginal leakage of a restoration allows the interface between the restoration and tooth to be invaded by bacteria.

MATERIALS AND METHODS: Class V cavities were prepared in teeth with the gingival margin on the dentin and the incisal margin on the enamel. The cavities were restored with microfilled composite resin using etch and rinse. After finishing and polishing the restorations, epoxy replicas were prepared. The marginal adaptation was analyzed using scanning electron microscopy (SEM, 500 × magnification). The higher gap width in each margin was recorded. After the first evaluation, the samples were submitted to thermal cycling and mechanical cycling (100,000 cycles of 50 kN and 2 Hz - T2). Replicas of samples were rebuilt after each cycling and analyzed under SEM.

RESULTS: The study shows that bulk-filled composite restorations have larger dentinal gaps without pH cycling (mean ≈ 129.12 µm). After pH cycling, the dentinal gap size significantly reduces (mean ≈ 73.03 µm). This indicates that pH cycling improves marginal adaptation, reducing gaps in composite restorations.

CONCLUSION: Based on the results of this in vitro study and within its limits it can be concluded that the tested high viscous bulk filled conventional composites showed good marginal integrity as a classical component after undergoing pH cycling.

Keywords: Composite, innovation, marginal integrity, restoration, sustainability, thermal cycling

How to cite this article: Samudhrasri S, Balaji Ganesh S, Jayalakshmi S, Thooyamani TVJ, Vaishnavi K. Evaluation of Marginal Integrity of Class V Bulk Composite Restorations: An In Vitro SEM Study. Int J Drug Deliv Technol. 2026;16(20s): 393-398. DOI: 10.25258/ijddt.16.20s.47

Source of support: Nil.

Conflict of interest: None

INTRODUCTION:

The primary goal of dental restoration work is to return the teeth's structure and function. In order to close the dentinal wound caused by caries, trauma, or cavity preparation, the dentist installs restorations. (1)Failure of restorations to create a tight seal causes microorganisms to colonize marginal holes, which in turn causes pulpal disease. Clinicians have come to the conclusion that every plaque retention site is a potential site for secondary caries based on their clinical experience and knowledge of the etiology of caries. Marginal integrity is crucial for preventing secondary caries and pulpal diseases.(2)

Modern restorative dentistry treatment incorporates adhesive bonding to tooth structure, which unquestionably enhances the biomechanical and aesthetic quality of restoration solutions. (3)Effective bonding to tooth structure would permanently seal dentinal tubules and restoration margins, preventing microleakage and its negative effects, including post-restoration hypersensitivity, marginal discoloration, recurrent caries, and detrimental effects on the pulp. Additionally, it would do away with the requirement for extension undercuts, protecting tooth structure(4).

Composite resins currently occupy an important position among restorative materials as they offer exemplary aesthetics and acceptable longevity. Much lower cost than comparable ceramic restorations for treating anterior and molar preparations when caries or missing tissue needs to be replaced. Additionally, when replacing decaying or missing tissues, composite restorations allow for little invasive or no preparation at all, which gives rise to a novel idea known as bio aesthetics. All composite resins shrink during polymerization, which causes adhesion and cohesion problems.For ensuring that resin composites have the right physical and biological qualities, adequate polymerization is thought to be a key element. However, one of the unavoidable drawbacks of subjecting visible light-activated resin composites to light polymerization is shrinkage stress(5). Failure associated with microleakage, postoperative discomfort, and other problems may result from stresses brought on by post-gel polymerization shrinkage that cause flaws in the link between the composite and the tooth.(6)

The existence or absence of gaps at the tooth-restoration interface is one of the factors affecting the long-term success of composite resin restorations. Gaps near the interface will cause marginal leakage and could cause caries and pulpal sensitivity. When a restoration's marginal leaks allow germs to enter the space between the restoration and tooth, secondary caries may develop. Secondary caries is a prominent factor in the replacement of amalgam and composite resin restorations in normal dentistry practice.

Research has improved the in vivo effectiveness and longevity of resin adhesive bonds to tooth structure in direct resin composite restorations, particularly at the cervical margins of class II cavities where the problem of microleakage becomes more severe(7). This is due to increased patient motivation toward an aesthetic, biocompatible, economical, and clinically durable restoration.Clinically effective and long-lasting bonding should be able to withstand stresses brought on by polymerization contraction as well as variations in the thermal expansion coefficient and elastic modulus between tooth structure and restorative materials. (8)They should also be able to endure a variety of oral environmental stressors, including bacterial biochemical activity, endogenous collagenolysis, hydrolytic degradation, functional loading, heat cycling, and pH changes.

Aim: To evaluate the marginal integrity and sealing ability of Class V bulk composite restorations and to assess the influence of polymerization shrinkage–induced stresses on marginal gap formation and microleakage.

MATERIALS AND METHODS:

2.1**Teeth selection**:Freshly extracted maxillary premolars were selected for this study from the Oral Surgery department. All the teeth were examined microscopically under stereomicroscope (20× magnification) to rule out the presence of external defects. Soft tissue remnants were removed using a hand scaler, then teeth were disinfected with hydrogen peroxide solution, and subsequently kept for 24 hours at 37°C distilled water in an incubator.

2.2**Cavity preparation**:On the buccal surfaces of each tooth, standardized rectangular class V conventional cavities with 90 degrees cavosurface angles were prepared using carbide burs No. 245 with a high speed handpiece. The depth of the cavity was checked using a periodontal probe.

2.3**Restorative procedure and study groups**:The selected teeth were assigned randomly into two main groups.Group one was restored with composite restorations .

2.4 **pH cycling**:Samples were subjected to Ph cycling according to featherstone pH cycling regimen(1986).It is recommended 16 hours of remin and 6 hours of demin with 2 hours of handling period.

DEMINERALISING SOLUTION	
Calcium	2.0 mmol/L
phosphate	2.0 mmol/L
Acetic acid	75.0 mmol/L

REMINERALISING SOLUTION	
calcium	1.5 mmol/L
phosphate	0.9 mmol/L
KCL	130.0 mmol/L
Sodium cacodylate	20.0 mmol/L

2.5 **Sectioning**:Samples are mounted in acrylic resin blocks and sectioned in buccolingual plane through the center of the restoration using Isomet 1000 precision saw and the marginal adaptation is evaluated by Scanning Electron Microscopy.

2.6**Marginal Adaptation Evaluation by Scanning Electron Microscope**: The specimens of each group were dehydrated, mounted on aluminum stubs, and then platinum sputter coated and visualized under Scanning Electron Microscopy at 500 x Magnification.

RESULT:

Figure :1

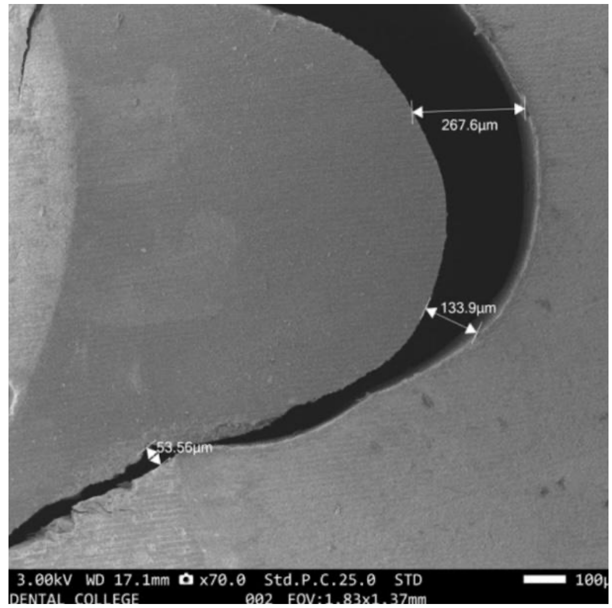

Figure 1 : The SEM micrograph shows a pronounced marginal gap at the tooth–restoration interface.Measured gap widths range approximately from 53.56 µm to 267.6 µm, indicating significant interfacial separation suggesting polymerization shrinkage stress induced debonding.

Figure:2

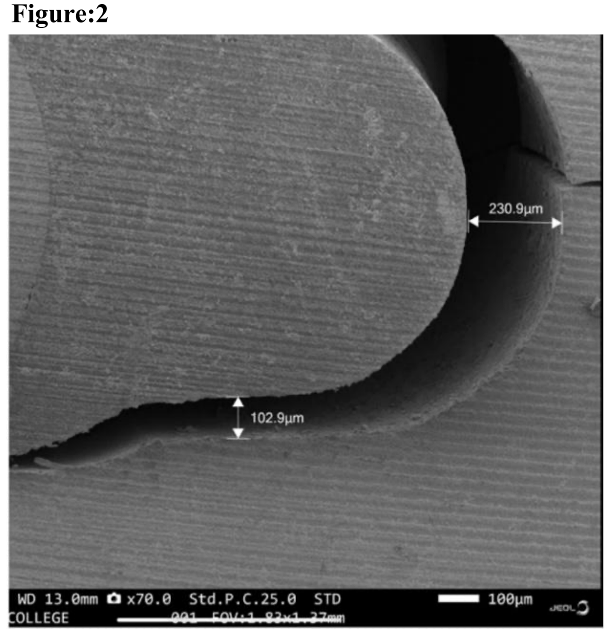

Figure 2: The SEM micrograph reveals marginal discontinuity however, the gap dimensions are comparatively smaller.Measured gap widths range from approximately 102.9 µm to 230.9 µm.This suggests

partial resistance to thermo-mechanical stresses, though marginal integrity is not completely preserved.

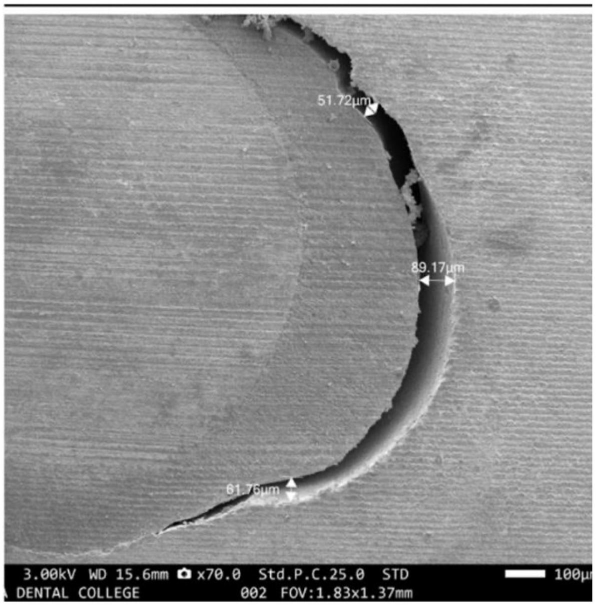

Figure:3

Figure 3: The micrograph demonstrates a reduced marginal gap along the cervical interface.The recorded gap widths range approximately from 68.72 µm to 78.82 µm.the magnitude of the gap is comparatively smaller, suggesting moderate marginal adaptation.

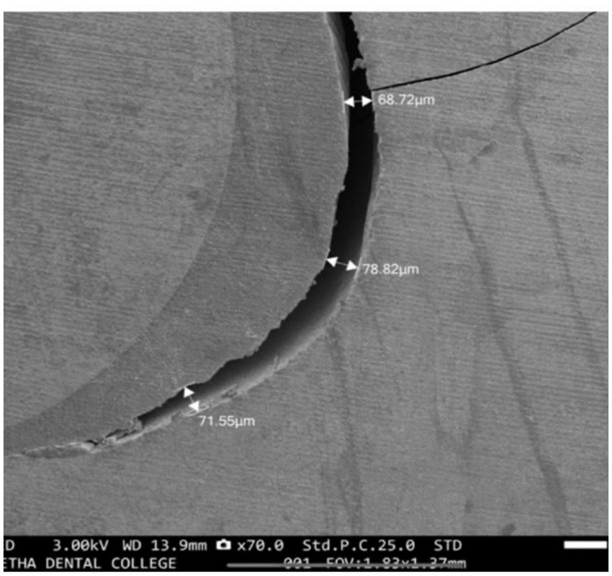

Figure :4

Figure 4 : The SEM image reveals marginal discontinuity with gap widths ranging from approximately 51.72 µm to 89.17 µm.The interfacial gap appears irregular, with localized areas of greater separation.

Photomicrography showing the presence of a gap in the dentinal margin of a restoration performed with Composite and the reduction of gap after Ph cycling.

The results signified that the gap in the composite restorations reduced after being subjected to Ph cycling .

Control sample when not subjected to ph cycling:

	Location of margin	**Gap in dentinal margin**	**Mean value**
Bulk filled composite	dentin	230.9um 102.9um 53.56um	129.12um

Test sample when subjected to ph cycling:

	Location of margin	**Gap in dentinal margin**	**Mean value**
Bulk filled composite	dentin	68.72um 78.82um 71.55um	73.03um

- In the control sample (no pH cycling), bulk-filled composite restorations show larger gaps at the dentinal margin (values: 230.9, 102.9, 53.56 µm; mean ≈ 129.12 µm), indicating poorer marginal adaptation.
- In the test sample (after pH cycling), the gap values are much lower (68.72, 78.82, 71.55 µm; mean ≈ 73.03 µm), showing a clear reduction in marginal discrepancy.
- This suggests that pH cycling (simulating oral conditions) promotes changes like hygroscopic expansion or remineralization, thereby improving the seal and reducing microgaps in composite restorations.

DISCUSSION:

Polymerization shrinkage is an inherent characteristic of resin-based composites and represents one of the primary causes of marginal deterioration. During polymerization, volumetric contraction generates internal stresses that are transmitted to the tooth–restoration interface(9). If these stresses are not adequately compensated by the adhesive bond, marginal defects may occur. Over time, hygroscopic expansion resulting from water sorption may partially compensate for polymerization shrinkage; however, this expansion may also influence marginal integrity. Therefore, evaluating the influence of marginal expansion on the integrity of bonded and unbonded Class V composite restorations, particularly when cervical margins are positioned below the CEJ, is of significant clinical relevance.

For composite resin restorations to last longer, adequate marginal sealing is crucial. Class V cavities were chosen for this investigation because restorative techniques continue to have difficulty with them(10). As a result, class V cavities are used in the majority of clinical investigations assessing an adhesive system's performance. The composite resin's ability to flow during polymerization shrinkage is impaired by these cavities' C-factor, which raises tension at the bonding interface.Stresses placed on composite restorations may prevent the bonding from forming and cause gaps to appear. Therefore, a good bond between an adhesive and the oral tissue helps to prevent marginal microleakage.(11)

The present study intended to clarify the influence of marginal expansion upon marginal integrity and time of appearance of marginal expansion observed at the tooth-restoration interface bonded and unbonded Class v composite restorations with their cervical margin below the CEJ(12). The preservation of tight and leakproof tooth restoration margins is a key concern for a clinically effective and long-lasting resin composite restoration(13). Although testing restorations in vitro is a crucial screening step, it does not negate the obvious need of looking at the clinical efficacy of restorations. Different levels of clinical significance are shown by lab tests(14). The simulation of oral environmental parameters, including temperature changes, masticatory forces, pH fluctuations, and others, is necessary for a marginal sealing test that is more clinically relevant.

The advantages and disadvantages of various in vitro marginal sealing tests have been discussed particularly with regard to their applicability in predicting the clinical performance of restoration margins. Dye penetration testing is not clinically relevant and cannot be compared across studies. The replica SEM method, in contrast, is a tried-and-true process that enables both qualitative and quantitative evaluation of margin examination.(15)

A core issue for a clinically effective and durable resin composite restoration is to maintain tight and leakproof tooth restoration margins. Although in vitro testing of restorations is an important screening, it does not rule out the clear significance of analyzing the clinical effectiveness of restorations.A number of studies have listed the pros and cons of different in vitro marginal sealing tests, especially toward the validity in predicting the clinical performance of restorations margins.

CONCLUSION:

Based on the results of this in vitro investigation and within the inherent limitations of laboratory-based studies, it can be concluded that the tested high-viscosity bulk-fill conventional composite demonstrated satisfactory marginal integrity when used as a restorative material in Class V cavities.Despite exposure to thermo-mechanical cycling designed to simulate intraoral conditions, the material maintained relatively stable adaptation at the tooth–restoration interface. Although measurable marginal gaps were observed, their magnitude remained within a moderate range, indicating that the composite was able to withstand polymerization shrinkage stresses and functional loading to a considerable extent.However, it must be emphasized that complete marginal sealing was not achieved in all specimens. Therefore, while the tested high-viscosity bulk-fill composite appears to provide acceptable marginal adaptation under simulated conditions, long-term clinical studies are required to validate its performance and durability in the oral environment.

REFERENCES:

1. Heintze SD. Systematic reviews: I. The correlation between laboratory tests on marginal quality and bond strength. II. The correlation between marginal quality and clinical outcome. J Adhes Dent. 2007;9 Suppl 1:77–106.
2. Nicholson J, Czarnecka B. Materials for the Direct Restoration of Teeth. Woodhead Publishing; 2016. 242 p.
3. Nakabayashi N, Pashley DH. Hybridization of Dental Hard Tissues. Quintessence Publishing (IL); 1998. 129 p.
4. Salem MN, Hassanein OE, ElKassas DW, Shaalan OO. 12-months Clinical Evaluation of Fiber

Reinforced Bulk Fill Resin Composite versus Incremental Packing of Nanohybrid Resin Composite in Restoration of Deep Proximal Lesions of Permanent Molars: A Randomized Controlled Trial. Acta Stomatol Croat. 2022 Sep;56(3):267–80.

5. Haak R, Schäfer P, Hanßen B, Ziebolz D, Park KJ, Häfer M, et al. OCT Evaluation of Marginal and Internal Interface Integrity of Class V Composite Restorations after 36 to 48 Months. J Adhes Dent. 2022 Apr 13;24(1):165–74.

6. Bud M, Zlăvog M, Jitaru Ş, Korkut B, Spataru S, Delean A. The outcome of direct composite restorations using the dental operating microscope. Med Pharm Rep. 2021 Oct;94(4):477–82.

7. McGrath CE, Bonsor SJ. Survival of direct resin composite onlays and indirect tooth-coloured adhesive onlays in posterior teeth: a systematic review. Br Dent J [Internet]. 2022 Jun 20; Available from: http://dx.doi.org/10.1038/s41415-022-4395-3

8. Heyder M, Sigusch B, Hoder-Przyrembel C, Schuetze J, Kranz S, Reise M. Clinical effects of laser-based cavity preparation on class V resin-composite fillings. PLoS One. 2022 Jun 23;17(6):e0270312.

9. Machine learning prediction of marginal gingival adaptation of direct composite veneering with or without mock-up in Upper anterior [Internet]. [cited 2026 Mar 31]. Available from: https://doi.org/10.1109/ICBSII65145.2025.11014011

10. Association of age with class VI composite restoration [Internet]. [cited 2026 Mar 31]. Available from: https://doi.org/10.6026/973206300161094

11. Heboyan A, Vardanyan A, Karobari MI, Marya A, Avagyan T, Tebyaniyan H, et al. Dental Luting Cements: An Updated Comprehensive Review. Molecules [Internet]. 2023 Feb 8;28(4). Available from: http://dx.doi.org/10.3390/molecules28041619

12. Sheefaa MI, Balaji GS, Jayalakshmi S. Comparative evaluation of color stability of bulk fill and flowable composite restorative materials after immersion in different Indian spices - An in vitro study. CDF. 2025 Feb 3;54(3):1300–5.

13. Azeem RA, Sureshbabu NM. Clinical performance of direct versus indirect composite restorations in posterior teeth: A systematic review. J Conserv Dent. 2018 Jan-Feb;21(1):2–9.

14. Lynch CD. Successful Posterior Composites. Quintessence Publishing Company Limited; 2019. 148 p.

15. Vaghela LL, Patel MC, Bhatt RK, Patel CN, Joshi KR. Clinical Performance and Parental Satisfaction with Composite Strip Crown and Prefabricated Zirconia Crown for Primary Anterior Teeth: A Randomized Clinical Trial. J Contemp Dent Pract. 2021 Dec 1;22(12):1462–70.