Dental Research Journal

Original Article

Microleakage in fiber-reinforced versus conventional composite restorations

Nafiseh Zarenejad[1], Mohsen Ramazani[2], Negar Gholizadeh[1], Sara Yaghoubi[1], Mahmood Moosazadeh[3], Amirhossein Aliei[1], Narges Tavahodi[1]

[1]Department of Restorative Dentistry, Sari Dental School, Mazandaran University of Medical Sciences, [2]Department of Endodontics, Sari Dental School, Mazandaran University of Medical Sciences, [3]Gastrointestinal Cancer Research Center, Non-Communicable Diseases Institute, Mazandaran University of Medical Sciences, Sari, Iran

ABSTRACT

Background: Composite restorations are prone to hybrid structure degradation and microleakage over time, which causes destruction and discoloration of the restoration's margins, caries recurrence, postrestoration sensitivity, and pulp irritation. New fiber-reinforced restorations may reduce some of the disadvantages of conventional composite restorations. This study aimed to compare microleakage of fiber-reinforced and conventional composite restorations.

Materials and Methods: In this *in vitro* experimental study, 40 healthy extracted permanent premolars were included. The teeth were randomly divided into two groups: the first group consisted of teeth restored with fiber-reinforced composite and the second group consisted of teeth restored with conventional composite. In the teeth of both groups, two class II cavities were prepared, and then, according to the grouping, they were restored with composite or composite and fiber. Each cavity had a mesiodistal length of 2 mm, a buccopalatal width of 4 mm, and a depth of 5 mm, with proximal locations in the premolars. In the next step, the apex of all samples was sealed with adhesive wax, and the tooth surfaces were covered with two layers of nail polish and placed in 0.5% Fuchsin solution at room temperature for 24 h. Finally, the teeth were cut in half, and the extent of dye penetration was determined with a stereomicroscope equipped with a digital camera. The Mann–Whitney test was used to compare microleakage between groups. $P \leq 0.05$ was considered statistically significant.

Results: The median of microleakage score was 1 (interquartile range [IQR] = 2) in the intervention group and 2 (IQR = 1) in the control group. The difference between groups was statistically significant ($P = 0.012$).

Conclusion: This study revealed significantly lower microleakage with fiber-reinforced composite compared to conventional composite.

Key Words: Dental leakage, dental restoration, fiber-reinforced composite, microleakage

Received: 28-Jun-2025
Revised: 30-Sep-2025
Accepted: 19-Oct-2025
Published: 30-Dec-2025

Address for correspondence:
Dr. Mohsen Ramazani, School of Dentistry, Mazandaran University of Medical Sciences, Payambar Azam Academic Complex, 18 km of Khazarabad Road, Sari, Mazandaran, Iran.
E-mail: m.ramezani@mazums.ac.ir

INTRODUCTION

Restorative dentistry aims to remove carious tissue and bacteria, followed by the application of an appropriate restorative material to fill the cavity. This process helps restore the tooth's form and function.[1] The effectiveness of restorative materials in sealing cavity margins to prevent the ingress of

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480
DOI: 10.4103/drj.drj_337_25

How to cite this article: Zarenejad N, Ramazani M, Gholizadeh N, Yaghoubi S, Moosazadeh M, Aliei A, *et al*. Microleakage in fiber-reinforced versus conventional composite restorations. Dent Res J 2025;22:53.

salivary components is crucial. In fact, a critical characteristic of a restorative material is its ability to provide adequate, long-term sealing of the restorative margins.[2] However, all restorative materials permit a certain extent of fluid and micronutrient permeability. This phenomenon is referred to as leakage.[3]

Microleakage refers to the clinically imperceptible movement of fluids, microorganisms, ions, or molecules between the cavity wall and the restorative material. This signifies the introduction of a substance into a defect at the interface of the tooth margin and the restoration.[4] The occurrence and extent of microleakage depend on various factors, including the selection of dental restorative material, the condition of the tooth, the technique used in the restoration process, and the patient's oral hygiene practices.[5] Moreover, it is essential to acknowledge that several inherent properties of dental materials, including biocompatibility, strength, thermal compatibility, and chemical stability, can significantly impact the degree and severity of microleakage. Furthermore, microleakage serves as a pathway to secondary caries, potentially leading to unsuccessful endodontic treatments and increasing the tooth's susceptibility to brittleness. Therefore, microleakage is a significant concern in dental restorations, resulting in various clinical challenges.[6]

To date, no restorative material has been developed that is entirely adhesive to tooth structure, preventing microleakage. Adequate strength, shade-matching properties, and esthetics have led to the widespread use of resin composites. However, they exhibit susceptibility to microleakage. Polymerization shrinkage during curing can result in gaps at the restoration margins, thereby elevating the risk of microleakage.[3] Fiber-reinforced composite restorations appear to offer greater reliability as a restorative technique compared to conventional composite restoration.[7] Research indicates that the application of composite resin in conjunction with polyethylene fiber markedly decreases microleakage at the gingival margin in mesio-occluso-distal (MOD) restorations of class II cavities.[8-11]

The rationale for focusing on MOD class II restorations lies in their clinical challenge and prevalence. MOD class II cavities involve multiple surfaces, including the occlusal and two proximal walls, making them structurally complex and vulnerable to restoration failure due to high occlusal stresses and polymerization shrinkage forces. Studies emphasize that class II MOD restorations are among the most demanding for longevity because they compromise a significant amount of tooth structure, particularly the marginal ridges and proximal contacts, which are critical to tooth strength and function. Therefore, evaluating fiber-reinforced composites in this specific cavity type is advantageous to test reinforcement benefits under rigorous clinical conditions.[12]

Polyethylene fibers, specifically ultra-high molecular weight polyethylene fibers like Ribbond, play an important role in restorative dentistry as reinforcements in composite restorations.[13] These fibers significantly improve the mechanical properties of dental composites, including fracture resistance, flexural strength, and elastic modulus.[14] By embedding polyethylene fibers into composite resin matrices, stress is effectively absorbed and redistributed, which can reduce polymerization shrinkage stresses and limit crack propagation in restored teeth.[15] This reinforcement extends the durability and structural integrity of heavily restored or endodontically treated teeth, making them less likely to undergo catastrophic fractures.[16] Clinically, polyethylene fibers are used in various restorative applications such as periodontal splints, direct bridges, endodontic posts and cores, as well as orthodontic retainers. Their biomimetic properties help mimic natural dentin behavior by acting as stress-absorbing layers that internally splint the tooth in multiple directions.[13] While the incorporation of these fibers enhances fracture resistance and marginal adaptation, challenges such as adhesive failures and handling complexity exist, and their long-term superiority over conventional cusp coverage remains under investigation.[15]

This study aimed to address a gap in the current literature regarding the effectiveness of fiber-reinforced composites in reducing microleakage compared to conventional composites. While fiber-reinforced composites have been suggested to improve restoration longevity by reducing microleakage, previous studies have produced conflicting results, and few have performed direct comparisons under controlled laboratory conditions. Given that microleakage plays a critical role in the failure of composite restorations, this study seeks to provide clearer evidence on the potential advantages of fiber reinforcement in clinical dental applications, thus offering a more reliable solution to mitigate postrestoration complications, such as secondary caries and patient discomfort. The null hypothesis for this study is that there is no significant difference in microleakage between fiber-reinforced and conventional composite restorations.

MATERIALS AND METHODS

This *in vitro* experimental research was conducted at the Dental School of Mazandaran University of Medical Sciences, Sari, Iran, with the study protocol receiving approval from the university's ethics committee (ethics code: IR.MAZUMS.REC.1402.18070). Based on the results of the study by Hartanto *et al*.,[17] the sample size was calculated to ensure a confidence level of 95% and a statistical power of 95%. Using the below formula, it was determined that a total of 40 samples would be required for the study:

$$n=\frac{(Z_{1-\alpha/2}+Z_{1-\beta})^2\times(\sigma_1^2+\sigma_2^2)}{(\mu_1-\mu_2)^2}$$

The study included 40 maxillary permanent premolar teeth with the inclusion criteria of at least 2 mm of crown above the cementoenamel junction, intact crown without any dental caries, and healthy teeth having been extracted due to periodontal or orthodontic indications. The exclusion criteria included having a fracture, signs of dental caries, a history of previous restorations, and the presence of tooth wear.

After the samples were collected, debridement was carried out on the teeth using water pressure. The samples were disinfected by immersion in a chloramine-T 0.5% solution for 1 week. Subsequently, the teeth were cleaned with pumice powder and a rubber cap before being stored in isotonic saline. The samples were then randomly divided into two groups: the first group of teeth was restored using fiber-reinforced resin composite (intervention). In contrast, the second group received restoration with a conventional composite (control).

Both groups had teeth with one class II cavity. Each cavity was prepared to have a mesiodistal length of 2 mm, a buccopalatal width of 4 mm, and a depth of 5 mm. Calipers were used to measure the mesiodistal length and buccopalatal width, while the depth was assessed with a probe. The preparation was performed using parallel diamond burs (ISO 806 314 107 524 012, Mani, Japan), employing underwater cooling to maintain optimal temperature control. Clearfil SE Bond (Kuraray Noritake Dental Inc., Tokyo, Japan) was utilized for tooth restoration. Initially, the primer was applied to the dentin for 20 s. Following this, the surface was dried for 10 s using an air blower. In the next step, the bonding layer was applied for an additional 10 s and then dried once more. Finally, the bonding was cured for 20 s using a Valo light cure (UltraDent, USA). The light-curing tip was placed 2–3 mm from the restoration surface and directed perpendicularly to the area to be cured. Curing was performed in a continuous motion to ensure uniform light exposure. The light-curing unit (Valo, UltraDent, USA) was set at an output intensity of 1,200 mW/cm² in high-intensity mode. This intensity and mode were used for all curing procedures in this study.

In the first group, the cutting surfaces of the teeth were coated with flowable composite (Estelite Flow Quick, Tokuyama Dental Corp., Tokyo, Japan). The polyethylene fiber (Ribbond Inc., Seattle, WA, USA) was first cut to the appropriate length (4 mm) with a 0.3 mm thickness, and then, it was carefully impregnated with resin for approximately 2 min. Subsequently, it was positioned on top of the composite. This fiber was placed horizontally and extended 2 mm beyond the polished palatal surface and 2 mm above it, maintaining a distance of 1 mm from the occlusal edge.

Following this preparation, the teeth in both groups were restored using Filtek™ Z250 composite (3M ESPE, St. Paul, MN, USA), which was applied in layers of 1–2 mm thickness. Each layer was cured for 20 s. All restorations were performed by a single operator, an experienced clinician, to minimize operator variability and ensure consistency across the procedures. Once the restoration was completed, the teeth were polished with an extra-fine bur. The teeth were stored at room temperature for 24 h before being immersed in a 0.5% Fuchsin solution (Merck, Darmstadt, Germany, Cat. No. 569-61-9). In addition, following the teeth restoration, the samples were subjected to 500 thermal cycles, alternating between 5°C and 55°C, with each cycle lasting 20 s. This procedure utilized a custom-made thermocycler (manufactured by Vafaei Factory and Lunapark Co., Tehran, Iran).

In the following step, the apex of each tooth sample was sealed with adhesive wax. The surfaces of the teeth were then coated with two layers of nail polish before being immersed in a 0.5% Fuchsin solution (Merck, Darmstadt, Germany, Cat. No. 569-61-9) at room temperature for 24 h. The nail polish was applied at least 1 mm away from the margin of the restoration to avoid interference with the dye penetration test. After rinsing with water, the teeth were longitudinally sectioned in the middle using a Struers Accutom-10 tooth cutter (Struers, Darmstadt, Germany) operating at 100 rpm.

A stereomicroscope equipped with a digital camera (Moticam 2500, Motic, Hong Kong) was utilized to evaluate the degree of color penetration in the samples. The software associated with the digital camera is (Spanish) Motic Images Plus 2.0 ML. To compare different groups, the samples were examined under the stereomicroscope at a magnification of 32× using a millimeter scale to assess the level of microleakage. Teeth were randomly assigned to the intervention and control groups and coded to prevent any bias during the evaluation. The microleakage evaluation was conducted by a blinded examiner, who was unaware of the group assignments. The intensity of color penetration was analyzed based on a scale of 0–3, defined as follows:[18]

0 = No color penetration.
1 = Color penetration of less than half the depth of the cavity.
2 = Color penetration of more than half the depth of the cavity but not reaching the axial wall.
3 = Color penetration up to the axial wall or extending beyond it.

Data analysis

Data analysis was conducted using SPSS software (version 26.0, Armonk, NY: IBM Corp., USA). Median and interquartile range (IQR) were used to describe microleakage in both groups. The Mann–Whitney test was used to compare microleakage between groups. $P \leq 0.05$ was considered statistically significant.

RESULTS

The median of microleakage score was 1 (IQR = 2) in the intervention group and 2 (IQR = 1) in the control group. Microleakage score was significantly lower in the fiber-reinforced composite group compared to the conventional composite group ($P = 0.012$) [Table 1].

Table 1: Comparison of microleakage score between the intervention and control groups

Variables	Mean (SD)	Median (IQR)	Maximum	Minimum	*P**
Intervention (*n*=20)	1.35 (1.34)	1 (2)	2	0	0.012
Control (*n*=20)	2.25 (1.16)	2 (1)	3	0	

*Analyzed by the Mann–Whitney test. SD: Standard deviation; IQR: Interquartile range

DISCUSSION

The results of the current study showed that microleakage was significantly higher with conventional composite restorations compared to fiber-reinforced composite restorations. According to the study by Azimi *et al*., microleakage poses a risk to the bond between the tooth and the restorative material, which can lead to various complications, including postrestorative sensitivity, pulpitis, secondary caries, and ultimately, failure of the restoration.[19] It has been demonstrated that conventional composites often fail to adhere well to dentin, resulting in gaps that can lead to microleakage.[20,21] This aligns with our results, which indicated that the control group exhibited significantly higher levels of microleakage.

Recent studies show that advancements in adhesive technology have improved the performance of conventional composites. For instance, Kaur *et al*. reported that modern bonding agents can significantly reduce microleakage in conventional composite restorations.[22] However, inconsistencies persist among different studies. The incorporation of fibers into the resin matrix can reinforce the composites and may help to minimize microleakage. The findings of the current study support this conclusion.

Furthermore, consistent with our results, a study by Sfeikos *et al*. investigated the effects of using fiber on marginal microleakage in class I restorations, and the results revealed that these dental materials significantly reduce microleakage.[20] Furthermore, research conducted by Ozel and Soyman showed that incorporating polyethylene fibers into composite restorations can decrease the overall resin matrix required, thereby further reducing microleakage.[23]

The method by which fiber-reinforced composites reduce microleakage involves several factors. One proposed mechanism is the enhancement of the bonding ability between the fiber-reinforced composites and the tooth structure. The presence of fibers can increase the surface area available for bonding agents, leading to a stronger binding interface.[24] Furthermore, fiber enhances the strength of the restorative material, significantly lowering the risk of gaps developing between the restorative material and the tooth structure. This effectively prevents the infiltration of oral fluids, bacteria, and other microorganisms at the interface between the tooth and the restorative material.[25]

A significant factor in minimizing microleakage is the viscoelastic properties of fiber-reinforced composites. Recent studies have shown that composite reinforcements utilizing fiber exhibit enhanced stress absorption compared to conventional composites. This improvement may reduce the effects of thermal and mechanical stresses on the surface of dental restoration interfaces, making it particularly advantageous for preventing microleakage over time.[26,27]

Contrary to our findings, a study by Sharafeddin *et al*. revealed that the incorporation of polyethylene fiber did not significantly impact the level of microleakage in class II composite resin restorations.[18] This discrepancy in findings may be attributed to several specific methodological differences, including the type of composite resin used (e.g. silorane-based versus methacrylate-based composites), differences in fiber placement techniques (e.g. orientation and impregnation procedures), variations in curing protocols (such as light intensity or curing time), and differences in sample preparation and storage conditions (e.g. the use of thermal cycling or aging techniques). In addition, the age of the samples and the follow-up period may also have influenced the results, as longer follow-up periods allow more time for degradation and potential microleakage development.

While fibers possess numerous advantages, they also exhibit certain disadvantages. These include a low tensile modulus, inadequate fatigue resistance, high density, and a notable sensitivity to attrition. Although using fiber-reinforced resin composites may reduce microleakage, they could be more expensive than conventional composites.[28] Thus, a balanced approach that considers both clinical effectiveness and economic factors is essential.

CONCLUSION

This research reveals significant differences in microleakage rates between conventional composites and fiber-reinforced composites. The results suggest that fiber reinforcement in composites may effectively reduce microleakage and prolong the longevity of restorations. Current studies support these findings; however, additional research is needed to deepen our understanding of the underlying mechanisms and to enhance the clinical application of these materials.

Acknowledgments

We express our sincere gratitude to the investigators, coordinators, participants, and laboratory personnel at the Department of Restorative Dentistry, Mazandaran University of Medical Sciences, Sari, Iran.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Shih WY. Microleakage in different primary tooth restorations. J Chin Med Assoc 2016;79:228-34.
2. Panchbhai A. Nanocomposites: Past, present, and future of dentistry. In: Applications of Nanocomposite Materials in Dentistry. Woodhead Publishing: Elsevier; 2019. p. 181-90. (https://www.sciencedirect.com/science/article/pii/B9780128137420000110).
3. Rathi SD, Nikhade P, Chandak M, Motwani N, Rathi C, Chandak M. Microleakage in composite resin restoration-a review article. J Evol Med Dent Sci 2020;9:1006-11.
4. Fabianelli A, Pollington S, Davidson CL, Cagidiaco MC, Goracci C. The relevance of microleakage studies. Int Dent SA 2007;9:64-74.
5. Muliyar S, Shameem KA, Thankachan RP, Francis PG, Jayapalan CS, Hafiz KA. Microleakage in endodontics. J Int Oral Health 2014;6:99-104.
6. Aljehani W, Almakinah A, Alshahri A, Albluwy O, Alamray S, Alaiyed A, *et al*. Microleakage among different dental restorative materials: causes, detection, and impact on marginal integrity. J Healthc Sci 2023;3:489-97.
7. Özüdoğru S, Tosun G. Evaluation of microleakage and fatigue behaviour of several fiber application techniques in composite restorations. Ann Dent Spec 2022;10:60-6.
8. Belli S, Orucoglu H, Yildirim C, Eskitascioglu G. The effect of fiber placement or flowable resin lining on microleakage in Class II adhesive restorations. J Adhes Dent 2007;9:175-81.
9. Sharafeddin F, Darvishi F, Malekzadeh P. The Effect of incorporation of polyethylene and glass fiber on the microleakage of silorane-based and methacrylate-based composites in class II restorations: An *in vitro* study. J Dent Biomater 2015;2:39-46.
10. El-Mowafy O, El-Badrawy W, Eltanty A, Abbasi K, Habib N. Gingival microleakage of Class II resin composite restorations with fiber inserts. Oper Dent 2007;32:298-305.
11. Sharma V, Kumar S, Nishad SG, Tomer A, Sharma M. SEM evaluation of the effect of fiber placement or flowable resin lining on microleakage in Class II adhesive restorations: An: *In vitro*: Study. J interdiscip Dent 2011;1:22-7.
12. Mohamed MH, Abouauf EA, Mosallam RS. Clinical performance of class II MOD fiber reinforced resin composite restorations:

An 18-month randomized controlled clinical trial. BMC Oral Health 2025;25:159.
13. Ferrando Cascales Á, Andreu Murillo A, Ferrando Cascales R, Agustín-Panadero R, Sauro S, Carreras-Presas CM, *et al*. Revolutionizing restorative dentistry: The role of polyethylene fiber in biomimetic dentin reinforcement-insights from *in vitro* research. J Funct Biomater 2025;16:38.
14. Belli S, Eskitascioglu G. Biomechanical properties and clinical use of a polyethylene fibre post-core material. Int Dent S Afr 2006;8:20-6.
15. Aggarwal V, Singla M, Miglani S, Sharma V, Kohli S. Effect of polyethylene fiber reinforcement on marginal adaptation of composite resin in Class II preparations. Gen Dent 2018;66:e6-10.
16. Metwaly AA, Elzoghby AF, Abd ElAziz RH. Clinical performance of polyethylenefiber reinforced resin composite restorations in endodontically treated teeth: (a randomized controlled clinical trial). BMC Oral Health 2024;24:1285.
17. Hartanto C, Farahanny W, Dennis D. Comparative evaluation of short fiber-reinforced composite resin thickness on fracture resistance of class II composite restoration: An *in vitro* study. J Contemp Dent Pract 2020;21:1201-4.
18. Sharafeddin F, Yousefi H, Modiri SH, Tondari A, Safaee Jahromi S. Microleakage of posterior composite restorations with fiber inserts using two adhesives after Ging. J Dent (Shiraz) 2013;14:90-5.
19. Azimi N, Mohammadi N, Parsaie Z, Fereidouni K. Microleakage and marginal integrity of surface-coated and laser-pretreated class V composite restorations in primary teeth. J Lasers Med Sci 2023;14:e11.
20. Sfeikos T, Dionysopoulos D, Kouros P, Naka O, Tolidis K. Effect of a fiber-reinforcing technique for direct composite restorations of structurally compromised teeth on marginal microleakage. J Esthet Restor Dent 2022;34:650-60.
21. Haralur SB, Al Ghaseb GA, Alqahtani NA, Alqahtani B. Comparison of microleakage between different restorative materials to restore marginal gap at crown margin. PeerJ 2021;9:e10823.
22. Kaur J, Kapoor D, Garg D, Sunil MK, Sawhney A, Malaviya N, *et al*. Evaluation of microleakage of dental composites using bonding agents with different placement techniques: An *invitro* study. J Clin Diagn Res 2015;9:C61-4.
23. Ozel E, Soyman M. Effect of fiber nets, application techniques and flowable composites on microleakage and the effect of fiber nets on polymerization shrinkage in class II MOD cavities. Oper Dent 2009;34:174-80.
24. Alla RK, Sanka GS, Saridena DS, Av R, Makv R, Mantena SR. Fiber-reinforced composites in dentistry: Enhancing structural integrity and aesthetic appeal. Int J Dent Mater 2023;5:78-85.
25. Hua Y, Ding B, Jiang S, Li H, Gu X, Zhang S. Surface modification of glass fibers for flame retardant and reinforced polyamide 6 composites. Compos Commun 2022;35:101308.
26. Garoushi S, Gargoum A, Vallittu PK, Lassila L. Short fiber-reinforced composite restorations: A review of the current literature. J Investig Clin Dent 2018;9:e12330.
27. Bijelic-Donova J, Keulemans F, Vallittu PK, Lassila LV. Direct bilayered biomimetic composite restoration: The effect of a cusp-supporting short fiber-reinforced base design on the chewing fracture resistance and failure mode of molars with or without endodontic treatment. J Mech Behav Biomed Mater 2020;103:103554.
28. Ratner BD, Hoffman AS, Schoen FJ, Lemons JE. Biomaterials Science. An Introduction to Materials in Medicine; San Diego, California. 2004;5:162-4.