Original Article

# Microleakage of Class II Restoration Using Short Fiber-Reinforced Flowable Resin Composite with a Universal Adhesive

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## Abstract

With short-fiber reinforced resin composite (SFRC), improved mechanical strength and good workability could be achieved within a single material. However, there remains concerns related to microleakage, which could restrict the application of this material in certain clinical situations. Thus, the aim of the study is to investigate microleakage of class II cavities restored with SFRC compared to other resin composites, in a simulated aging environment using thermocycling. Class II cavities were prepared in 80 premolars at the cementoenamel junction. Each group, consisting of 10 specimens, was restored with different materials: bulk-fill flowable SFRC (EverX Flow), bulk-fill SFRC (EverX Posterior), flowable bulk-fill resin composite (Tetric N-flow), and conventional resin composite (Filtek Z350XT). The specimens were divided into two subgroups: one underwent thermocycling of 20,000 cycles, while the other did not. All specimens were subjected to the dye penetration test and then assessed for microleakage scores. In the non-thermocycling group, no significant differences in microleakage scores were observed. In the thermocycling group, EverX Posterior showed a significant difference in microleakage scores compared to Tetric N-flow ($p = 0.018$) and all other tested materials (all $p < 0.001$). However, there was no significant difference in microleakage scores between EverX Posterior and Filtek Z350XT ($p = 0.714$), or between Filtek Z350XT with Tetric N-flow ($p = 0.951$). In conclusion, when restored with a universal adhesive, bulk-fill flowable SFRC achieved the highest microleakage score compared to other tested resin composite after thermocycling. In addition, all materials showed a significantly higher microleakage score after thermocycling. The materials could be ranked in ascending order of susceptibility to microleakage after aging by bulk-fill SFRC, conventional resin composite, flowable bulk-fill resin composite, and bulk-fill flowable SFRC, respectively.

**Keyword:** Flowable Resin Composite, Microleakage, Short Fiber-reinforced Resin Composite, Thermocycling

**Received date:** Nov 13, 2023 **Revised date:** Feb 19, 2024 **Accepted date:** Apr 23, 2024

**Doi:** 10.14456/jdat.2024.15

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## Introduction

With the increasing demands of both esthetic and functional aspects of the dental restorative material, resin composite and adhesive technologies are rapidly evolving. The incorporation of fiber into resin composite material stems from industrial demands for high-strength material that could withstand stress in load-bearing areas. Consequently, short fiber-reinforced resin composite (SFRC) was introduced in 2013 as EverX Posterior (GC Corporation, Tokyo, Japan). Multiple studies reported that this material showed superior mechanical properties compared to conventional resin composite in many aspects.[1-4]

In recent years, further improvements have been made to improve the workability and handling properties of SFRC. In 2019, flowable SFRC (EverX flow; GC Corporation, Tokyo, Japan) has been introduced, combining the advantage of fiber reinforcement and good flowability in the same material, by changing the length and diameter of the fibers, the content percentage of fiber, particulate fillers, and the resin matrix. Moreover, flowable SFRC could also be placed in bulk up to 5.5 mm according to the manufacturer, reducing technical sensitivities and chair-time for restoration of extensive cavities.

However, it is known that one of the problems of flowable resin composite is the polymerization shrinkage due to high monomer content. Flowable SFRC is not an exception. An *in vitro* study found that, although flowable SFRC was superior to conventional bulk-fill resin composite in multiple aspects, such as flexural strength and fracture toughness, it exhibited more water sorption and polymerization shrinkage stress, which may lead to microleakage and post-operative sensitivity.[5] In addition, it was shown that polymerization shrinkage stress tremendously weakened the performance and longevity of the restorations.[6]

Even though there are numerous studies supporting SFRC superior properties, studies concerning flowable SFRC are still sparse. Criteria regarding selection and use of contemporary class of restorative material is always of benefit. Therefore, the objective of this study was to investigate the microleakage of class II cavities restored with SFRC compared to other resin composites, in a simulated aging environment using thermocycling.

## Materials and Methods

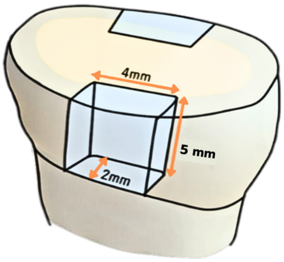

***Figure 1*** *Sample preparation and dimension of class II slot cavities*

### Sample Size Calculation

From the experimental design of this research; sample size calculation from G*Power 3.1.9.7, f-test, ANOVA: fixed effects, omnibus, one-way, with the level of significance ($\alpha$) as 0.05, the power of study (1-B) as 80%, number of groups as 8, effect size f as 0.51697347-9; total sample size calculated was 64, thus, the sample size per group was 8. To decrease the systematic error, the sample size was increased 20% of the calculated sample size, resulting in a total sample size of 80, which was 10 per group.

### Specimen Preparations

With the approval of the ethics committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022-048), eighty sound human maxillary premolars extracted with informed consent, for orthodontic reasons, were selected with similar occlusal table size (±1 mm) in both buccolingual and mesiodistal dimensions. All teeth were visualized under a microscope at 2x magnification to ensure that teeth with dental caries, fracture lines, or defects were excluded. Soft tissue remaining and dental calculus were cleaned with an ultrasonic scaler, and then stored in a 0.1 % thymol solution at room temperature. The root portion of the teeth were coated and sealed with molten sticky wax 3 mm from the apexes. Each tooth was assigned a single number from 1 to 80, and then randomly distributed into 8 groups (n=10 per group) using the Microsoft Excel randomized function. Occlusal table of each tooth was flattened using high-speed, super-coarse diamond burs (837H 060; Meisinger, Germany) with water irrigation. All teeth were measured that a 5 mm cavity depth could be prepared with gingival margin at CEJ, to ensure similar quality of dentin substrate among specimens.[10]

Standardized Class II slot on mesial and distal surfaces (OM and OD) was prepared by one operator, using high-speed, medium-grit diamond cylinder burs (837 025 Meisinger, Germany) with copious water irrigation. The bur was replaced after every five preparations.[11] The occlusal dimension of the cavity was in total of 4 mm in buccolingual dimension, with 2 mm gingival floor width and 5 mm axial height with the floor of the cavity at the CEJ level (Figure 1). All internal line angles were rounded using round-end cylinder burs (842 016 Meisinger, Germany. Additional measurements using a digital caliper were made to ensure standardization of all cavity preparations with the sensitivity of 0.1 mm.

### Restorative procedure

All prepared teeth were subjected to the same bonding procedures using a selective enamel etching protocol (Fig. 2). Enamel was etched with a 32 % phosphoric acid (Scotchbond Universal Etching Gel; 3M ESPE, USA) for 15 seconds, thoroughly rinsed with water for 15 seconds, and dried by a blotting technique with clean dental sponges to avoid over-drying of the dentin surface. Then, the universal adhesive resin (Scotchbond Universal; 3M ESPE, USA) was thoroughly applied in a single layer with a microbrush, gently rubbed for 20 seconds and dried with a gentle stream of air until the adhesive surface appeared immobile, followed by light curing for 10 seconds (1,200 mW/cm$^3$ by Bluephase N; Ivoclar Vivadent, Liechtenstein) as per the instructions of the manufacturer. The light curing unit was calibrated using a radiometer (Bluephase Meter II; Ivoclar Vivadent, Liechtenstein) after each day of use to standardize the light intensity. After the bonding procedure, a metal matrix band and a Tofflemire matrix retainer were used for cavity restoration.

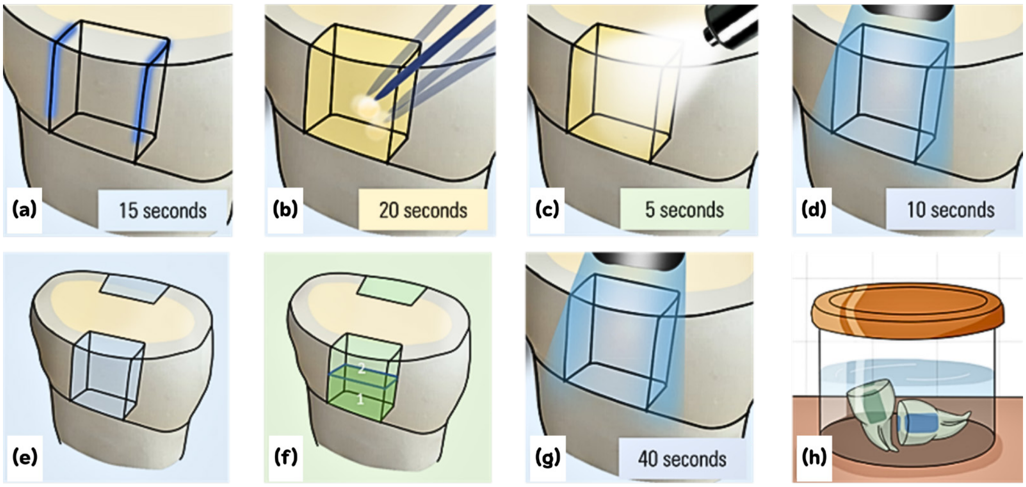

*Figure 2* *Restorative Procedures: (a) Selective etching for 15 seconds, rinsed with water and blot dried, (b) Applied the adhesive for 20 seconds and gently rubbed to the prepared tooth (c) Gently air dried to evaporate the solvent, (d) Light cured the adhesive layer for 10 seconds, (e) EXF group was restored as a bulk, (f) EXP, TNF, Z350 groups were restored using a horizontal increment technique, (g) Light cured from occlusal side for 40 seconds for every increment placed, and then from buccal and lingual sides after matrix removal, (h) Specimens stored in distilled water at room temperature for 24 hours*

For group 1, a SFRC bulk fill flowable resin composite (EverX flow; GC Corporation, Japan) was injected as a bulk for the entire cavity, starting from the deepest part of the proximal slot, and light-cured for 40 seconds from occlusal side. Then, the matrix was removed, and additional light curing was made from buccal and lingual sides of the tooth for 40 seconds each.

For groups 2, 3, and 4, the restorations were performed using a horizontal incremental technique consisting of 2 increments. For group 2, a SFRC bulk fill resin composite (EverX Posterior; GC Corporation, Japan) and group 3, a bulk fill flowable resin composite (Tetric N-Flow Bulk-Fill; Ivoclar Vivadent, Liechtenstein) was injected into the prepared cavities. For group 4, a conventional resin composite (Filtek Z350 XT; 3M ESPE, USA) was used as the control group. The cavities were restored using composite filling and packing instruments to ensure that the restorative material was properly placed and packed evenly. Then, light curing was performed in the same manner as group 1. All specimens were polished with a series of aluminum oxide discs and wheels (Sof-Lex discs and Sof-Lex wheels; 3M ESPE, USA). The materials used in this study and their composition are listed in Table 1.

The specimens were stored in distilled water at room temperature for at least 24 hours. The teeth in each group were then divided into 2 subgroups for testing: (a) without thermocycling, and (b) with thermocycling. The groups without thermocycling were subjected to microleakage test after 24-hour storage in distilled water. The other groups underwent thermocycling before being subjected to a microleakage test.

***Table 1*** *Composition of restorative materials according to manufactures' information*

| Test Materials (shade) | Composition | Manufacturer | Lot number |
|---|---|---|---|
| **EverX Flow; EXF (Translucent)** | ● Resin: Bis-MEPP, TEGDMA, UDMA<br>● Filler: Micrometer scale glass fiber filler (average length 140 µm, diameter 6 µm), barium glass<br>● Filler load: 70 wt%, 46 vol% | GC Corporation, Tokyo, Japan | 1911231 |
| **EverX Posterior; EXP (Translucent)** | ● Resin: bis-GMA, PMMA, TEGDMA<br>● Filler: Micrometer scale glass fiber filler (average length 800 µm, diameter 17 µm), barium glass<br>● Filler load: 74.2 wt%, 53.6 vol% | GC Corporation, Tokyo, Japan | 2112031 |
| **Tetric N-Flow Bulk-Fill; TNF (IVW)** | ● Resin: Bis-GMA, UDMA<br>● Filler: Barium glass fillers, YbF3, mixed oxides, silicon dioxide, copolymers<br>● Filler load: 68 wt%, 46.4 vol% | Ivoclar Vivadent, Schaan, Liechtenstein | Z03CBL |
| **Filtek Z350 XT; Z350 (A1)** | ● Resin: Bis-GMA, UDMA, TEGDMA and Bis-EMA<br>● Filler: ZrO2/SiO2 nanocluster, SiO2 nanofiller<br>● Filler load: 82 wt%, 60 vol% | 3M ESPE, St. Paul, Minnesota, USA | NF24321 |
| **Scotchbond Universal; SBU** | ● Etchant: 32% phosphoric acid (pH = 0.1)<br>● Adhesive: 2-HEMA, 10-MDP, dimethacrylate resins, Vitrebond copolymer, silane, filler, ethanol, water, initiators (pH = 2.7) | 3M ESPE, St. Paul, Minnesota, USA | 8563601 |

## Thermocycling Test

The designated specimens were subjected to thermocycling (Thermo Cycling Unit, KMITL, Thailand) in distilled water between 5°C and 55°C with a 30-second dwell time for 20,000 cycles. Subsequently, all specimens were observed under a stereomicroscope with a 5x magnification for signs of crack and fracture. The specimens would be rated as failure if debonding or fracture occurred, then excluded from the microleakage test.

**Microleakage test**

All designated untested specimens and all survived specimens from the thermocycling test were then subjected to a microleakage test. An adhesive tape, 5x10 mm in dimension, was used to cover the gingival margin of proximal surfaces on both the mesial and distal sides of the restoration. The rest of the surface was coated with 2 layers of nail varnish and left to dry for 24 hours. After the removal of adhesive tapes, the specimens were immersed in a 50 % silver nitrate solution at room temperature for 24 hours, followed by a photo-developing solution for 8 hours under fluorescent light in a dark container. The specimens were then removed from dye solution and gently rinsed under running water for 5 minutes without interfering with proximal parts.

**Evaluation of microleakage score**

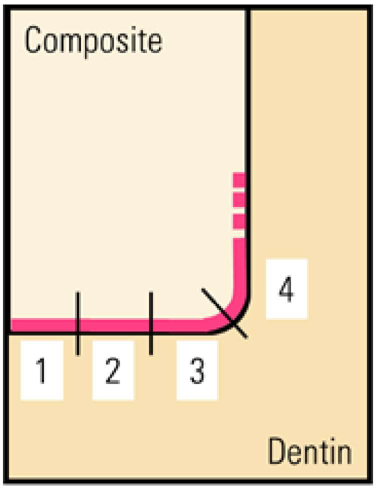

***Figure 3*** *Schematic representation of scoring scale. Pink line indicated the degree of dye penetration at the gingival margin and axial wall. Score 0; no dye penetration. Score 1; dye penetration up to one-third of the gingival wall. Score 2; dye penetration up to two-third of the gingival wall. Score 3; dye penetration up to full length of the gingival wall. Score 4; dye penetration up to the whole length of the gingival wall and along the axial wall*

The specimens were cut through a bucco-lingual plane. Then, each separated part was sectioned mesiodistally in a vertical plane using a low-speed diamond saw (ISOMET 1000, Buehler, Binghamton, NY, USA) with constant water cooling. With 2 cuts, a total of 4 proximal reading surfaces from both mesial and distal sides were obtained. The sections were evaluated for the degree of dye penetration under a stereomicroscope (SZ 61, Olympus, Japan) at a 40x magnification, based on degree of dye penetration at gingival margin and axial wall (Fig. 3).[12]

## Statistics

All statistical analyses were performed using an IBM SPSS Statistics version 26.0 (SPSS, Chicago, IL, USA). The level of significance of 0.05 was used for all analyses. For the analysis of microleakage scores, Kruskal-Wallis with Dunn post-hoc tests were used to compare between studied material groups. The Mann-Whitney U-test was used to compare the effect of thermocycling between study groups.

## Results

The frequency distribution and percentages of microleakage scores for each material in non-thermocycling and thermocycling groups are presented in Table 2. Kruskal-Wallis test revealed no statistically significant difference in microleakage scores among 4 materials in the non-thermocycling groups ($p$ = 0.151). In contrast, a statistically significant difference was observed among the materials in the thermocycling groups ($p < 0.001$), in which pairwise comparison showed that there was a statistically significant difference in the microleakage score between EXP and TNF ($p$ = 0.018), and EXF with all other tested materials (all $p < 0.001$). However, there was no statistically significant difference in the microleakage score between EverX Posterior with Z350 ($p$ = 0.714), and Z350 with TNF ($p$ = 0.951).

*Table 2* *Frequency distribution of microleakage score (percentages) in non-thermocycling group and thermocycling group for all tested materials*

| Material | Test | Microleakage score (% within group) | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | |
| **Z350** | NT | 0 | 33 (82.5%) | 6 (15%) | 1 (2.5%) | 0 | 40 |
| | T | 0 | 19 (47.5%) | 14 (35%) | 6 (15%) | 1 (2.5%) | 40 |
| **TNF** | NT | 0 | 34 (85%) | 6 (15%) | 0 | 0 | 40 |
| | T | 0 | 15 (37.5%) | 11 (27.5%) | 9 (22.5%) | 5 (12.5%) | 40 |
| **EXP** | NT | 0 | 39 (97.5%) | 1 (2.5%) | 0 | 0 | 40 |
| | T | 0 | 29 (72.5%) | 7 (17.5%) | 3 (7.5%) | 1 (2.5%) | 40 |
| **EXF** | NT | 0 | 36 (90%) | 4 (10%) | 0 | 0 | 40 |
| | T | 0 | 0 | 8(20%) | 10(25%) | 22(55%) | 40 |

In addition, the Mann-Whitney U test found that the microleakage scores of the thermocycling groups were higher than the non-thermocycling groups with a statistically significant difference. In the non-thermocycling group, there was no statistically significant difference in the microleakage score for each material ($p = 0.154$), with the median microleakage score of one across all groups. In contrast to the thermocycling group, EXP exhibited the lowest median microleakage score of 1, followed by Z350 and TNF which exhibited a median microleakage score of 2. EXF exhibited the highest median microleakage score of 4, as shown in table 3.

*Table 3* *Median value and interquartile range (IQR) of microleakage score for each material in both groups*

| Material | Median (IQR) | | *P*-value |
|---|---|---|---|
| | NT | T | |
| Z350 | 1.00 (0)$^{a}$ | 2.00 (1)$^{AB}$ | 0.001 |
| TNF | 1.00 (0)$^{a}$ | 2.00 (2)$^{B}$ | <0.001 |
| EXP | 1.00 (0)$^{a}$ | 1.00 (1)$^{A}$ | 0.002 |
| EXF | 1.00 (0)$^{a}$ | 4.00 (1)$^{C}$ | <0.001 |
| *P*-value | 0.154 | <0.001 | |

*Different superscript letters indicated a statistically significant different at a 0.05 level of significance (P ≤ 0.05)*

## Discussion

The results from the study indicated that class II slot cavities restored with short fiber-reinforced flowable resin composite showed a significantly higher microleakage score than other tested materials in the thermocycling group. In addition, class II slot cavities that underwent thermocycling showed a significantly higher microleakage score than the non-thermocycling group, regardless of materials tested.

Microleakage was defined as an invasion of bacteria and fluids between the cavity walls and restorative material, which many researchers indicated as the primary cause of recurrent caries, tooth hypersensitivity, and pulpal inflammation.[12,13] Microleakage occurred from the micrometer gap at the margin of the cavity, resulting from several factors including properties of restorative material, filling techniques, bonding procedures, cavity configuration and its substrate.[14] In addition, different CTE between the resin composite material and the dental structure would generate stresses at the bonding interface, potentially leading to degradation and failure.[14] This phenomenon was simulated by thermocycling in our study. However, it is important to consider the multifactorial nature of microleakage, which resulted from the previously mentioned factors.

Despite efforts to control the dental substrate through inclusion and exclusion criteria, and bonding procedures through a streamlined restorative process using a universal bonding agent and a single operator, these factors could still potentially influence the microleakage score. Therefore, the microleakage score of this study could not be entirely attributed to the performance of the tested restorative material, but rather to the overall tooth-restoration complex.

From the results, all materials showed a significantly higher microleakage score after the aging process compared to non-aging, regardless of the material tested. Thermocycling test was regarded as the most frequently used method to simulate thermal changes and hydrolytic activities in the intraoral environment, which tested bond durability of the tooth-restoration.[15] Thermocycling procedures in various studies were different in aspect of temperature, number of cycles, and dwell time, rendering it challenging to compare results from different studies.[15] In regard to the numbers of cycle, long-term function could not be simulated if the number of cycles was too low.[15-17] It was estimated by Gale *et al.* that 10,000 cycles represented 1 year of service.[16] In the present study, 20,000 cycles was used to represent 2 years of function, and to ensure that the number of cycles was sufficient to accelerate aging process of the tested restorative materials. Thus, the increased microleakage score after aging could be the result of repeated stress and degradation from accelerated aging by thermocycling, leading to more tooth-and-restoration degradation compared to the non-thermocycling group.

From this study, the lowest microleakage score from both groups was achieved by EverX Posterior, which was the representative of the short fiber-reinforced resin composite (SFRC). SFRC had been extensively studied for its superior mechanical properties, which include a higher fracture resistance,[1] fatigue limits[2] and flexural strength.[18] From a previous study by Tsujimoto *et al.,* EverX Posterior exhibited the lowest volumetric shrinkage compared to other bulk fill resin composites.[4] In addition, Patel *et al.* concluded that SFRC obtained the lowest microleakage score with good homogeneity of the restoration compared to bulk fill and conventional resin composite when subjected to artificial aging by thermocycling, which was in concordance with this study.[9]

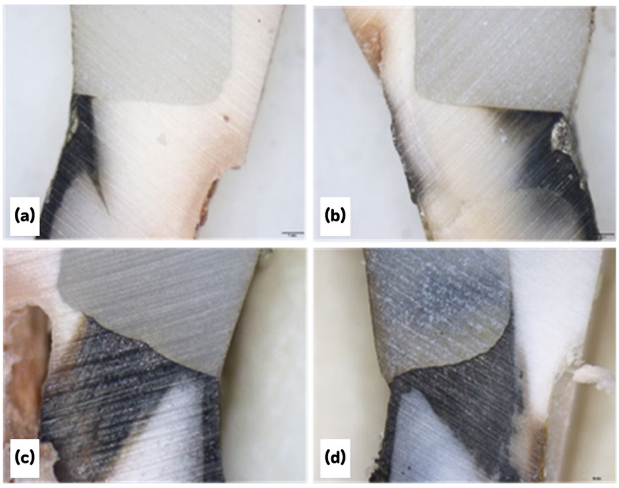

***Figure 4*** *Stereo micrographs of the specimens, represented microleakage score 1 (a), 2 (b), 3 (c) and 4 (d)*

The superior performance of SFRC was speculated to be the result of the incorporation of randomly oriented millimeter-scale E-glass fibers into the material. With its randomized orientation, the resin matrix could not shrink along the length of the fibers. Thus, its initial dimension could be mostly maintained,[3] which decreased overall volumetric contraction of the composite.[19] Furthermore, the inclusion of short-fiber could increase resistance to microcracking of the restoration, reducing polymerization shrinkage stress leading to a lower microleakage score.[19] However, from this present study, its flowable counterparts (EverX Flow) performed differently from EverX Posterior and other tested materials in terms of a microleakage score. Although EverX Flow exhibited comparable microleakage to other tested materials without thermocycling, it exhibited the highest microleakage with a statistically significant difference after undergoing thermocycling.

SFRC flowable bulk-fill resin composite, represented by EverX Flow, had been developed to ease the complexity of the restorative process, while maintaining improved mechanical properties from glass-fibers.[3] However, some differences between SFRC bulk-fill and its flowable version could be noted. For instance, the average diameter and length of glass fiber were 17 μm and 800 μm in SFRC, while the average diameter and length of glass fibers were 6 μm and 140 μm in SFRC flowable respectively. It is generally known that critical fiber length, aspect ratio, fiber orientation and amount of fiber loading could influence the mechanical properties of SFRC.[2] Critical length is the minimal length of fiber that can effectively reinforce the polymer matrix by transferring stress to the fiber, which could be as much as 50 times the diameter of the fiber.[20] However, the diameter of EverX Flow was 6 μm, therefore, the critical fiber length should be approximately 300 μm. In addition, the aspect ratio, which is the ratio of fiber length to diameter, affects tensile strength, flexural modulus and reinforcing efficacy of SFRC.[21] For optimal stress transfer, the aspect ratio should be in the range of 30-94.[21] From the calculations, EverX Posterior would have an aspect ratio of 47 when determined from its fiber average length. Meanwhile, EverX Flow would have an aspect ratio of 23.3, which is less than the recommended aspect ratio for optimal stress transfer.[21] This could compromise shrinkage stress alleviation of the EverX Flow. Thus, for these reasons, EverX Posterior and EverX Flow might perform differently in terms of polymerization shrinkage and microleakage score as observed in this study.

Another difference between EverX Posterior and EverX Flow was the number of particulate fillers and fiber content. Generally, flowable materials required lower filler loading by volume to adjust the viscosity of the material, thus making them flow properly.[22] EverX Posterior had a total inorganic and filler content of 76 wt%/57 vol%, meanwhile EverX Flow had a total inorganic and filler content of 70 wt%/46 vol%. A higher amount of resin matrix could lead to higher polymerization contraction, which may compromise adhesion between bonding material, restoration, and cavity walls.[23] Lower filler loading of EverX Flow, compared to EverX Posterior, might contribute to a more polymerization contraction, leading to a higher microleakage score as seen in this study. Unlike EverX Posterior, there are no other studies comparing the microleakage score of EverX Flow to other materials. However, there are some studies observing various different parameters between EverX Posterior and EverX Flow. For instances, a study by Lassila *et al.* revealed that EverX Flow exhibited higher shrinkage stress value compared to EverX Posterior.[5] Also, Magne *et al.* stated that EverX Flow had more shrinkage-induced cuspal deformation despite more favorable failure modes.[24] Nevertheless, further investigation and more clinical trials should be done before confirming its performance.Otherwise, it seems reasonable to use other resin composite materials as an outer layer to protect EverX Flow from an intraoral environment, as seen in the recommendation of the manufacturer.

Universal adhesives have gained popularity in dentistry due to their simplified procedure which reduced technical sensitivity and application time. Nevertheless, adhesion to dentin remained a challenge.[25] In this present study, Scotchbond Universal adhesive was used. With a pH of 2.7, it is considered to be a mild acidic adhesive, which can be used in both total-etch and self-etch modes. Due to its less acidic composition, adhesion to enamel might be compromised when used in self-etch mode.[26] In this study, selective etching technique was performed, meaning the etchant was applied exclusively to enamel on the proximal cavosurface of the prepared cavity, excluding dentin on the internal cavity walls. Although many studies concluded that a mild self-etch adhesive was currently recommended for dentin adhesion,[27] the content of acidic monomers could affect bond stability over time.[25,28] A previous study by Perdigaõ *et al.* found a deterioration of marginal adaptation from baseline to 18-months using Scotchbond Universal in self-etch mode compared to total-etch mode, with no difference in the clinical retention rate.[29] Also, a 5-year clinical evaluation from Matos *et al.* discovered that the clinical performance of the universal adhesive in total-etch mode was superior to self-etch mode, and selective etching was recommended.[30] From this present study, the dentin surface of the specimens were not treated with phosphoric etchant. Thus, the bonding interface between the universal adhesive and dentin could deteriorate, potentially leading to an increased microleakage score from all materials after the aging process. However, it is important to note that the most favorable etching mode remained a highly controversial topic, and diverse results have been reported in various studies.[25,28,30]

Apart from the materials, restorative techniques may have some degree of effect on the microleakage score in this present study. The manufacturer of EverX flow claimed that it could be filled as a single bulk of 5.5 mm, thus all samples in this material group were filled as a bulk for the entire cavity, contrary to other material groups which were filled incrementally because of their lesser depth of cure. Currently, there was no study comparing the effects of different filling techniques using SFRC bulk-fill materials. Nevertheless, several studies had examined different parameters associated with both the bulk-fill technique and incremental techniques using other bulk-fill resin composites. From a study by Mulder *et al.,* evaluating the shrinkage of bulk-fill flowable composites, restored with bulk-fill and incremental technique compared to conventional resin composite using electronic mercury dilatometer, reported that even though all tested bulk-fill flowable resin composites can be filled up to 4 mm as recommended by the manufacturer, their volumetric shrinkage was higher than that of a conventional resin composite restored incrementally in 2 mm layers, including the bulk-fill resin composites when restored incrementally in 2 mm layers themselves. Therefore, the standard increment technique was still advisable even when using bulk-fill materials.[31] On the other hand, a study by Han *et al.* demonstrated no difference in the microtensile bond strength for class II cavities restored with bulk-fill resin composites using different filling techniques.[32] Additionally, a systematic review and meta-analysis by Kunz *et al.* showed similar clinical performance in class II restorations in posterior teeth for both incremental and bulk-fill techniques.[33] It is important to note that, due to variations in materials, specimens, and methodologies used, the comparison of these results should be done with caution.

It should be acknowledged that this study had certain limitations. The current experimental design utilized only four restorative materials from each category and only one universal adhesive system. Consequently, the findings of this study may not be inferred to other product and adhesive systems. To address this limitation, a future experimental design should include a wider range of products from different brands, such as other adhesive systems, bulk fill resin composite, and flowable resin composite products. Ultimately, randomized controlled trials may be the most essential source of information to help clinicians make decisions regarding material and technique choices in different clinical situations.

## Conclusion

Within the limitations of the present study, it can be concluded that short fiber-reinforced bulk-fill flowable resin composites achieved the highest microleakage score compared to other tested resin composite, with a universal adhesive after the aging process by thermocycling. In addition, all materials showed a significantly higher microleakage score after the aging process. The materials could be ranked in ascending order of susceptibility to microleakage after aging by short fiber-reinforced bulk-fill resin composites, conventional resin composite, flowable bulk-fill resin composite, and short fiber-reinforced bulk-fill flowable resin composites, respectively.

### Clinical Implications

The recently developed short fiber-reinforced bulk-fill flowable resin composite aimed to simplify the restorative process while maintaining the improved mechanical properties of glass fibers. However, because of its susceptibility to microleakage, it may not be advisable to use this material alone as a definitive restoration.

### Conflict of Interest

The authors declare that they have no conflict of interest.

## Acknowledgement

The authors would like to express our gratitude for the assistance provided at CU Dental Innovation Centre, Faculty of Dentistry, Chulalongkorn University. Furthermore, the authors would like to offer our heartfelt appreciation to Assist. Prof. Dr. Soranun Chantarangsu for her valuable guidance on statistical analyses.

## References

1. Bijelic-Donova J, Garoushi S, Vallittu PK, Lassila LVJ. Mechanical Properties, Fracture Resistance, and Fatigue Limits of short Fiber Reinforced Dental Composite Resin. ***J Prosthet Dent*** 2016;115(1):95-102.

2. Bijelic-Donova J, Garoushi S, Lassila LVJ, Keulemans F, Vallittu PK. Mechanical and Structural Characterization of Discontinuous Fiber-Reinforced Dental Resin Composite. ***J Dent*** 2016;52:70-8.

3. Garoushi S, Säilynoja E, Vallittu PK, Lassila L. Physical Properties and Depth of Cure of a New Short Fiber Reinforced Composite. ***Dent Mater*** 2013;29(8):835-41.

4. Tsujimoto A, Barkmeier WW, Takamizawa T, Latta MA, Miyazaki M. Mechanical Properties, Volumetric Shrinkage and Depth of Cure of Short Fiber-Reinforced Resin Composite. ***Dent Mater*** 2016;35(3):418-24.

5. Lassila L, Keulemans F, Vallittu PK, Garoushi S. Characterization of Restorative Short-Fiber Reinforced Dental Composites. ***Dent Mater*** 2020;39(6):992-9.

6. Sakaguchi R, Wiltbank B, Murchison C. Cure Induced Stresses and Damage in Particulate Reinforced Polymer Matrix Composites: A Review of the Scientific Literature. ***Dent Mater*** 2005;21(1):43-6.

7. Cohen J. Statistical Power Analysis for the Behavioral Sciences, Rev. Ed. 2nd ed. Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc; 1988. Chapter 10, The Effect Size Index: f2; p. 473-4.

8. G*Power: Users Guide-Analysis by Design [Internet]. Heinrich-Heine-Universitat. 2010 [cited 05 May 2021]. Available from: https://www.psychologie.hhu.de/fileadmin/redaktion/Fakultaeten/Mathematisch-Naturwissenschaftliche_Fakultaet/Psychologie/AAP/gpower/GPowerManual.pdf.

9. Patel P, Shah M, Agrawal N, Desai P, Tailor K, Patel K. Comparative Evaluation of Microleakage of Class Ii Cavities Restored with Different Bulk Fill Composite Restorative Systems: An *in Vitro* Study. ***J Res Adv Dent*** 2016;5(2):52-62.

10. Arambawatta K, Peiris R, Nanayakkara D. Morphology of the Cemento-Enamel Junction in Premolar Teeth. ***J Oral Sci*** 2009;51(4):623-7.

11. Emir F, Ayyildiz S, Sahin C. What Is the Changing Frequency of Diamond Burs? ***J Adv Prosthodont*** 2018;10(2):93-100.

12. Arora R, Kapur R, Sibal N, Juneja S. Evaluation of Microleakage in Class Ii Cavities Using Packable Composite Restorations with and without Use of Liners. ***Int J Clin Pediatr Dent*** 2012;5(3):178-84.

13. AlHabdan A. Review of Microleakage Evaluation Tools. ***J Int Oral Health*** 2017;9(4):141-5.

14. Mariani A, Sutrisno G, Usman M. Marginal Microleakage of Composite Resin Restorations with Surface Sealant and Bonding Agent Application after Finishing and Polishing. ***JPCS*** 2018;1073(4):042005.

15. Amaral FLB, Colucci V, Palma-Dibb RG, Corona SAM. Assessment of *in Vitro* Methods Used to Promote Adhesive Interface Degradation: A Critical Review. ***J Esthet Restor Dent*** 2007;19(6):340-53.

16. Gale MS, Darvell BW. Thermal Cycling Procedures for Laboratory Testing of Dental Restorations. ***J Dent*** 1999;27(2):89-99.

17. Miyazaki M, Sato M, Onose H, Moore BK. Influence of Thermal Cycling on Dentin Bond Strength of Two-Step Bonding Systems. ***American J Dent*** 1998;11(3):118-22.

18. Shouha P, Swain M, Ellakwa A. The Effect of Fiber Aspect Ratio and Volume Loading on the Flexural Properties of Flowable Dental Composite. ***Dent Mater*** 2014;30(11):1234-44.

19. 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(3):298-305.

20. Lassila L, Säilynoja E, Prinssi R, Vallittu P, Garoushi S. Characterization of a New Fiber-Reinforced Flowable Composite. ***Odontology*** 2019; 107(3):342-52.

21. Vallittu PK. High-Aspect Ratio Fillers: Fiber-Reinforced Composites and Their Anisotropic Properties. ***Dent Mater*** 2015;31(1):1-7.

22. Baroudi K, Rodrigues JC. Flowable Resin Composites: A Systematic Review and Clinical Considerations. ***J Clin Diagn Res*** 2015;9(6):Ze18-24.

23. Braga RR, Ballester RY, Ferracane JL. Factors Involved in the Development of Polymerization Shrinkage Stress in Resin-Composites: A Systematic Review. ***Dent Mater*** 2005;21(10):962-70.

24. Magne P, Carvalho MA, Milani T. Shrinkage-Induced Cuspal Deformation and Strength of Three Different Short Fiber-Reinforced Composite Resins. ***J Esthet Restor Dent*** 2023;35(1):56-63.

25. Cardoso GC, Nakanishi L, Isolan CP, Jardim PDS, Moraes RR. Bond Stability of Universal Adhesives Applied to Dentin Using Etch-and-Rinse or Self-Etch Strategies. ***Braz Dent J*** 2019;30(5):467-75.

26. de Goes MF, Shinohara MS, Freitas MS. Performance of a New One-Step Multi-Mode Adhesive on Etched Vs Non-Etched Enamel on Bond Strength and Interfacial Morphology. ***J Adhes Dent*** 2014;16(3):243-50.

27. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt KL. State of the Art of Self-Etch Adhesives. ***Dent Mater*** 2011;27(1):17-28.

28. Stape THS, Wik P, Mutluay MM, Al-Ani AAS, Tezvergil-Mutluay A. Selective Dentin Etching: A Potential Method to Improve Bonding Effectiveness of Universal Adhesives. ***J Mech Behav Biomed Mater*** 2018;86:14-22.

29. Perdigão J, Kose C, Mena-Serrano AP, De Paula EA, Tay LY, Reis A, *et al.* A New Universal Simplified Adhesive: 18-Month Clinical Evaluation. ***Oper Dent*** 2014;39(2):113-27.

30. de Paris Matos T, Perdigão J, de Paula E, Coppla F, Hass V, Scheffer RF, *et al.* Five-Year Clinical Evaluation of a Universal Adhesive: A Randomized Double-Blind Trial. ***Dent Mater*** 2020;36(11):1474-85.

31. Mulder R, Grobler SR, Osman YI. Volumetric Change of Flowable Composite Resins Due to Polymerization as Measured with an Electronic Mercury Dilatometer. ***Oral Biology and Dentistry*** 2013;1(1)1-5.

32. Han SH, Park SH. Incremental and Bulk-Fill Techniques with Bulk-Fill Resin Composite in Different Cavity Configurations. ***Oper Dent*** 2018;43(6):631-41.

33. Kunz PVM, Wambier LM, Kaizer MDR, Correr GM, Reis A, Gonzaga CC. Is the Clinical Performance of Composite Resin Restorations in Posterior Teeth Similar If Restored with Incremental or Bulk-Filling Techniques? A Systematic Review and Meta-Analysis. ***Clin Oral Investig*** 2022;26(3):2281-97.