Microleakage of a Self-adhesive Composite of Class V Cavities: Effect of Surface Treatment and Thermocycling

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ABSTRACT

Aim: This study aimed to assess the microleakage of a self-adhesive composite compared to conventional composites in class V cavities.

Materials and methods: In this in vitro experimental study, standard class V cavities were prepared in the buccal surface of 204 extracted teeth and randomly divided into six groups for restoration with (A) Vertiseflow (Kerr) self-adhesive composite, (B) acid etching (Kerr) + Vertiseflow, (C) acid etching + Optibond FL (Kerr) + Vertiseflow, (D) Er,Cr:YSGG laser + Vertiseflow, (E) acid etching + Optibond FL + Premise Flowable (Kerr), and (F) acid etching + Optibond FL + Z250 (3M). The teeth in each group were then randomly divided into two subgroups of with and without thermocycling (10,000 cycles between 5°C and 55°C). The microleakage was then determined at the enamel and dentin margins under a stereomicroscope using the dye penetration method. Data were analyzed using the Kruskal–Wallis test (α = 0.05).

Results: No significant difference was noted in occlusal margin microleakage of no thermocycling groups, but acid etching + Vertiseflow showed the highest microleakage. At the gingival margin, the difference between acid etching + bonding agent + Z250 and laser + Vertiseflow was significant (p = 0.004). In thermocycling groups, the difference in the microleakage at the occlusal margin of Vertiseflow with that of acid etching + bonding agent + Premise (p = 0.002), acid etching + bonding agent + Vertiseflow (p = 0.009), and acid etching + bonding agent + Z250 (p = 0.037) groups was significant. The difference in the microleakage at the dentin margin was also significant among the groups (p < 0.05). The highest and the lowest microleakages were noted in laser + Vertiseflow and acid etching + bonding agent + Vertiseflow groups, respectively.

Conclusion: Surface preparation with etching and adhesive application results in lower microleakage in class V cavities. But laser irradiation and the use of self-adhesive composite increase the microleakage.

Clinical significance: It seems that self-adhesive composites cannot provide acceptable marginal integrity without any surface treatment.

Keywords: Composite dental resin, Dental leakage, Lasers, Self-adhesive composite.

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INTRODUCTION

Dental science deals with oral and dental conditions, their manifestations, and restoring the dental function and esthetics. The lost tooth structure is replaced with biocompatible restorative materials. Many advances have been made in the formulation of dental restorative materials over the years. Composite resins have been one of the great achievements of dental material science. Despite significant advances, composite resins still have clinical shortcomings due to their technical sensitivity. Failure of composite restorations may include the development of secondary caries, fracture of restoration, marginal microleakage, and inappropriate proximal contact. The microleakage is the main cause of tooth hypersensitivity and development of secondary caries under restorative materials. The microleakage may occur due to the presence of a gap between the tooth structure and restorative material, dentinal fluid, restorative material properties such as dissolution and coefficient of thermal expansion, polymerization shrinkage, cavity shape, and method of application of restorative material. The microleakage can cause pulp inflammation in vital teeth due to bacterial toxins. It also decreases the longevity of restoration due to bacterial colonization at the tooth–restoration gap or within the dentinal tubules.

Following the introduction of bonding agents, attempts were made to improve their properties to minimize microleakage, decrease their technical sensitivity, decrease their procedural steps, improve their adhesion, and simplify their application. However, the microleakage of adhesive dental restorations remains the main cause of their replacement.

Flowable composites used to be the first choice for restoration of class V cavities due to their optimal marginal adaptation and easy handling. Flowable composites have a lower viscosity than conventional composites due to having a lower filler content. Flowable composites often have higher polymerization shrinkage and lower modulus of elasticity than non-flowable composites.

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Composite shrinkage increases the microleakage at the tooth-restoration interface. Moreover, the technical sensitivity of adhesives compromises the success of the bonding process. Thus, self-adhering flowable composite seems to be an optimal choice for the use in the clinical setting.\textsuperscript{5,6}

Several generations of bonding agents have been introduced aiming to decrease the procedural steps and minimize the time spent for preparation of enamel and dentin surfaces in order to decrease the risk of contamination and subsequent failure of restorations (i.e., marginal discoloration, secondary caries, and debonding). Restorative materials with high bonding capacity and fewer clinical steps are more favorable for the restoration of class V cavities.\textsuperscript{3} For this purpose, self-etch composites (6th generation)\textsuperscript{6} and self-adhesive composites (7th generation)\textsuperscript{7} were introduced to the market.\textsuperscript{7} Besides, the quality of the adhesion of these composites to dental structures is not clear. Previous studies have used lasers to improve the quality of the adhesion.\textsuperscript{8,9}

Considering the high cost and time-consuming nature of clinical studies, artificial aging is performed to simulate the clinical setting. Thermocycling and water storage are the accepted methods for simulation of aging.\textsuperscript{10}

This study aimed to assess the microleakage of a self-adhesive composite compared to conventional composites in class V cavities.

**Materials and Methods**

This study was performed on 204 (The sample size calculation with chi-squared test analysis at a power of 99%, $\alpha = 0.05$, $\beta = 0.2$, and df = 11 indicated that there should be 17 specimens per group.) sound human premolars with no caries, cracks, fracture or restoration, extracted within 5 months prior to the onset of study as part of orthodontic treatment or due to periodontal disease or the need for a complete denture (ethical approval code: IR.TUMS.VCR.1395.240). The teeth were cleaned, and debris, calculus, and tissue remnants were removed using a scaler. The teeth were cleaned using pumice paste, and they were then immersed in chloramine T solution at 4°C for 7 days for disinfection. They were then stored in distilled water at room temperature (25°C) until the experiment. The teeth were randomly divided into six groups and each group was divided into two subgroups of 17 ($n = 17$).

A total of 204 modified class V cavities were created on the buccal surfaces of the teeth such that their occlusal margin was in the enamel and their gingival margin was in dentin. The teeth were then sectioned perpendicular to their longitudinal axis using a high-speed diamond fissure bur under water irrigation.

Group I: class V cavities were restored with Vertiseflow (Kerr, Italy) without acid etching or application of bonding agent. After cavity preparation, it was dried for 5 seconds using air spray. Composite resin was then applied as a thin layer with less than 0.5 mm thickness on all cavity walls within 15–20 seconds and was then cured for 20 seconds using a LED light curing unit. The remaining cavity space was filled by incremental application of the same composite with less than 2 mm thickness.

Group II: the cavities were first etched with 37.5% phosphoric acid for 15 seconds. They were then rinsed with water spray for 15 seconds and blotted dry. Optibond FL (Kerr) was then applied on the cavity walls. For this purpose, first the primer was applied on all cavity surfaces by a microbrush within 15 seconds and air-dried for 5 seconds using air spray. Adhesive was then applied by a microbrush within 15 seconds, dried with air spray for 3 seconds, and cured for 2 seconds. The cavities were then restored using Vertiseflow composite according to the manufacturer’s instructions.

Group III: the cavities were first etched with 37.5% phosphoric acid for 15 seconds. They were then rinsed with water spray for 15 seconds and blotted dry. Vertiseflow composite was then applied according to the manufacturer’s instructions.

Group IV: the cavities were irradiated with Er,Cr:YSGG laser (Waterlase, Biolase, Technology, San Clemente, CA, USA) with 100 mJ energy, 15 Hz frequency, and 1.5 W power for 15 seconds. The distance from the laser tip (MZ6, 6 mm tip) to the surface of samples was 1 mm (Fig. 1). Laser irradiation was performed accompanied by water spray. The cavities were then restored using Vertiseflow composite according to the manufacturer’s instructions.

Group V: the cavities in this group were etched with 37.5% phosphoric acid and restored using Optibond FL (Kerr) bonding agent and Vertiseflow composite resin.

Group VI: the cavities in this group were etched with 37.5% phosphoric acid and restored using Optibond FL (Kerr) bonding agent and Filtek Z250 (3M ESPE, USA) composite resin.

After restoration of teeth, they were polished using flexible aluminum oxide discs (SofLex; 3M ESPE). Each group was then divided into two subgroups and half of the samples in each group were subjected to 10,000 thermal cycles between 5°C and 55°C with a dwell time of 15 seconds for aging.

The samples were then completely dried and the apices of teeth and their occlusal grooves were sealed with sticky wax. All dental surfaces except for 1 mm around the restoration margin were sealed with two layers of nail varnish (Fig. 2).

The 12 subgroups were then separately immersed in 2% fuschine (Microscopy Certistain, Germany) and incubated at 37°C for 24 hours. The teeth were then rinsed with water to remove excess fuchsin from the tooth surface and mounted in transparent polyester acrylic resin in molds and sectioned (Fig. 3).

![Fig. 1: Water laser](image-url)
The sections were then evaluated under a stereomicroscope (SMZ 800, Nikon, Tokyo, Japan) at ×40 magnification, and enamel and dentin restoration margins were evaluated blindly by one observer. The measurements for the occlusal and gingival marginal leakage proportion and penetration ability of the dye were reassessed after 2 weeks by the same examiner in order to determine the intra-examiner reliability. One-tenth (10%) of the sample sizes were randomly selected for this purpose. A paired *t* test was used to evaluate the differences between the actual measurement and the repeated measurement. There were no significant differences in both the occlusal and gingival marginal leakage proportion and penetration ability of the dye scores when the measurements were repeated (*p* < 0.05).

The microleakage score was determined based on the dye penetration depth at the occlusal and gingival margins according to ISO/TS, 11405: 20031 as follows and Figure 4:

| Score | Dye penetration depth indicative of the microleakage |
|-------|-----------------------------------------------------|
| 0     | No dye penetration                                   |
| 1     | Dye penetration to half the depth of gingival floor  |
| 2     | Dye penetration exceeding half the depth of gingival floor but not reaching the axial wall |
| 3     | Dye penetration to the axial wall but not involving the wall |
| 4     | Dye penetration involving the axial wall            |

The microleakage scores were analyzed using IBM SPSS Statistics version 25.0 statistical package (SPSS, Chicago, IL, USA). The Kruskal–Wallis nonparametric test was used at 0.05 level of significance to compare the microleakage scores of study groups.

**Results**

The results showed that the effect of restoration margin (occlusal/gingival) and thermocycling on the microleakage of different groups was statistically significant (Figs 5 and 6).
No Thermocycling Group

No significant difference was noted among the groups in terms of microleakage at the enamel (occlusal) margin ($p = 0.058$). The highest and the lowest microleakage were noted in acid etching + Vertiseflow and acid etching + bonding agent + Z250 groups, respectively (Table 1).

Thermocycling Group

A significant difference was noted among the groups in terms of microleakage at the dentin (gingival) margin. Pairwise comparisons revealed a significant difference only between laser + Vertiseflow and acid etching + bonding agent + Vertiseflow ($p = 0.004$). The highest microleakage was noted in laser + Vertiseflow, and the lowest microleakage was recorded in acid etching + bonding agent + Z250 group (Table 2).

Table 1: Microleakage at the occlusal margin of no thermocycling groups

| No thermocycling groups                  | 0   | 1   | 2   | 3   | 4   |
|-----------------------------------------|-----|-----|-----|-----|-----|
| Vertiseflow                             | 14  (82.4%) | 3  (17.6%) | 0.0% | 0.0% |     |
| Acid etching + Vertiseflow              | 11  (64.7%) | 5  (29.4%) | 0.0% | 1  (5.9%) |     |
| Acid etching + bonding agent + Vertiseflow | 14  (82.4%) | 2  (11.8%) | 1  (5.9%) | 0.0% |     |
| Laser + Vertiseflow                     | 12  (70.6%) | 2  (11.8%) | 1  (5.9%) | 2  (11.8%) |     |
| Acid etching + bonding agent + Premise  | 16  (94.1%) | 1  (5.9%) | 0.0% | 0.0% |     |
| Acid etching + bonding agent + Z250     | 100.0% | 0.0% | 0.0% | 0.0% |     |

Table 2: Microleakage at the gingival margin of no thermocycling groups

| No thermocycling groups                  | 0   | 1   | 2   | 3   | 4   |
|-----------------------------------------|-----|-----|-----|-----|-----|
| Vertiseflow                             | 7   (41.2%) | 6  (36.3%) | 2  (11.8%) | 2  (11.8%) |     |
| Acid etching + Vertiseflow              | 7   (41.2%) | 8  (47.1%) | 2  (11.8%) | 0  (0.0%) |     |
| Acid etching + bonding agent + Vertiseflow | 7   (41.2%) | 8  (47.1%) | 2  (11.8%) | 0  (0.0%) |     |
| Laser + Vertiseflow                     | 5   (29.4%) | 1  (5.9%) | 7  (41.2%) | 4  (23.5%) |     |
| Acid etching + bonding agent + Premise  | 10  (58.8%) | 4  (23.5%) | 1  (5.9%) | 2  (11.8%) |     |
| Acid etching + bonding agent + Z250     | 13  (76.5%) | 3  (17.6%) | 1  (5.9%) | 0  (0.0%) |     |

Table 3: Microleakage at the occlusal margin of thermocycling groups

| Thermocycling groups                  | 0   | 1   | 2   | 3   |
|---------------------------------------|-----|-----|-----|-----|
| Vertiseflow                           | 8   (47.1%) | 7  (41.2%) | 2  (11.8%) |     |
| Acid etching + Vertiseflow            | 14  (82.4%) | 3  (17.6%) | 0.0% |     |
| Acid etching + bonding agent + Vertiseflow | 16  (94.1%) | 1  (5.9%) | 0.0% |     |
| Laser + Vertiseflow                   | 11  (64.7%) | 5  (29.4%) | 5.9% |     |
| Acid etching + bonding agent + Premise | 100.0% | 0.0% | 0.0% | 0.0% |
| Acid etching + bonding agent + Z250   | 15  (82.2%) | 2  (11.8%) | 0.0% | 0.0% |

Fig. 6: Microleakage count in occlusal margins
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**Table 4: Microleakage at the gingival margin of thermocycling groups**

| Thermocycling groups | 0   | 1   | 2   | 3   | 4   |
|----------------------|-----|-----|-----|-----|-----|
| Vertiseflow          | 2 (11.8%) | 12 (70.6%) | 2 (11.8%) | 1 (5.9%) |
| Acid etching + Vertiseflow | 3 (29.4%) | 10 (58.8%) | 1 (5.9%) | 1 (5.9%) | 0.0% |
| Acid etching + Vertiseflow | 12 (70.6%) | 3 (29.4%) | 0.0% | 0.0% | 0.0% |
| Laser + Vertiseflow  | 0.0% | 4 (23.5%) | 7 (41.2%) | 6 (35.3%) | 0.0% |
| Acid etching + bonding agent + Vertiseflow | 7 (47.1%) | 3 (17.6%) | 2 (11.8%) | 6 (23.5%) | 0.0% |
| Acid etching + bonding agent + Premise | 7 (41.2%) | 6 (35.3%) | 5.9% | 2 (11.8%) | 5.9% |

**DISCUSSION**

The microleakage of composite restorations is a major concern for dentists. It is the main cause of the failure of the composite restorations due to their polymerization shrinkage and coefficient of thermal expansion.\(^{12-14}\) The microleakage at the restoration margin can result in tooth hypersensitivity, marginal discoloration, secondary caries, and pulp irritation.\(^3\) The type of restorative material and its method of application are among the important factors affecting the microleakage.\(^{15,16}\) This study aimed to assess the effect of cavity surface treatment on the microleakage of a self-adhesive composite in class V cavities.

Class V cavities were evaluated in this study because they are easy to restore and do not require macromechanical undercuts during the cavity preparation. Thus, the sealing ability of the composite resins can be assessed only based on their bonding potential.\(^{14}\) On the contrary, both enamel and dentin margins can be evaluated in this type of cavity. Restoration of such cervical lesions is challenging since part of their margin is in the enamel and part of it is in dentin or cementum.\(^{17,18}\)

Simplifying the application of restorative dental materials is favorable to save time and decrease procedural errors. Recently, flowable self-adhesive composites were introduced to the market that bond to tooth structure without requiring an adhesive system because of their acidic monomer. In the current study, Vertiseflow, which is the first product of this group of composites released into the market, was compared with conventional and flowable composites. Vertiseflow has a glycerophosphate–dimethacrylate adhesive monomer that serves as a coupling agent. This acidic phosphate group etches the tooth structure and chemically bonds to calcium ions.\(^{19}\) The current results showed that no thermocycling groups were not significantly different in terms of microleakage at the enamel margin. But, among the thermocycling groups, the microleakage at the enamel margin was significantly higher in acid etching + bonding agent + Premise \((p = 0.002)\), acid etching + bonding agent + Vertiseflow \((p = 0.009)\), and acid etching + bonding agent + Z250 \((p = 0.037)\) groups compared to Vertiseflow group. This finding indicates that enamel surface treatment with acid etching and bonding agent application decreases the microleakage and provides a better occlusal seal. Such a difference in the microleakage between self-adhesive composite and enamel surface treatment by acid etching and bonding agent application can be due to incomplete elimination of smear layer, inadequate micromechanical retention between the restoration and tooth structure due to low etching capacity of self-adhesive flowable composites and low flowability of self-adhesive flowable composites compared to bonding agents. The separate etching step with phosphoric acid in etch and rinse systems efficiently eliminates the smear layer and results in the formation of irregular microretentive grooves on the enamel surface that increase the enamel surface energy.\(^{13}\)

Celik et al. found no significant difference in enamel margin microleakage of Vertiseflow and Fusio Liquid Dentin self-adhesive composites after thermocycling, but these composites had higher microleakage than the etch and bond flowable composite used as control. Surface treatment by acid etching significantly decreased the microleakage of Fusio Liquid Dentin and Vertiseflow compared to Vertiseflow self-adhesive composite.\(^{13}\) In line with our findings, Asefzadeh et al.\(^4\) and Sadeghi et al.\(^{12}\) also showed that the application of bonding agent prior to the use of Wetbond self-adhesive composite in class V cavities decreased enamel margin microleakage.

In no thermocycling groups in our study, the microleakage at the dentin margins of Vertiseflow \((p = 0.01)\), laser + Vertiseflow \((p = 0.03)\), acid etching + bonding agent + Premise \((p = 0.007)\), and acid etching + bonding agent + Z250 \((p = 0.01)\) was significantly higher than the enamel margin microleakage. The mechanism of bonding in the dentin margins is not as simple as that in the enamel margins because dentin is a complex substrate for bonding due to its hydrophilic nature and lower mineral content compared to enamel.\(^{19}\)

The possible causes of the microleakage at the dentin margins of restorations include the shape of cavity (C factor), orientation of dentinal tubules towards the cervical wall (cementoenamel junction), organic content beneath the dentin layer and movement of dentinal fluid in dentinal tubules, partial modification or elimination of smear layer by acidic primers (self-etch system) for complete demineralization and formation of hybrid layer, unstable infiltration of primer into demineralized collagen fibrils, level of hydration of underlying dentin layers, incomplete solvent vaporation from the dentin surface prior to adhesion of adhesive monomers, incompatibility of bonding agent and composite resin, the composition of acid (pH, osmolarity, thickening agent), polymerization shrinkage, physical properties of restorative material (filler content, volumetric expansion, and modulus of elasticity), inadequate marginal adaptation of restorative material, incomplete polymerization of photo-initiator, instrumentation, and the effects of finishing and polishing.\(^{20}\)

In the present study, the highest microleakage at the dentin margin of no thermocycling groups was noted in laser + Vertiseflow group, and the microleakage of this group was significantly higher than that of acid etching + bonding agent + Z250 group \((p = 0.004)\). In the thermocycling groups, the microleakage at the dentin margins of laser + Vertiseflow group was significantly higher than that in acid etching + Vertiseflow \((p = 0.01)\), acid etching + bonding agent + Vertiseflow \((p < 0.001)\) and acid etching + bonding agent + Z250 \((p = 0.01)\) groups. At the dentin margins, the lowest microleakage was noted in acid etching + bonding agent +
Vertiseflow group; these results indicate that the surface treatment with laser increases the dentin margin microleakage.

Laser has been recommended for tooth surface etching as an alternative to acid etching. However, studies are ongoing on the efficacy of this technique. Some researchers have confirmed the efficacy of laser for dentin surface etching and preparation while some others have denied it. Some authors believe that the morphological changes caused by Er,Cr:YSGG laser negatively affect the function of adhesive and the bonding process. 21

De Munck et al. 22 through scanning electron microscopic observations reported that the bond strength of surfaces irradiated with Er:YAG laser was lower than that of surfaces prepared with silicon carbide abrasive papers or diamond bur; the reason was explained to be the loss of fibrillar collagen in the underlying dentin layers that would eliminate the gaps between fibrils and prevent hybridization. 25 In line with our study, Celik et al. 13 showed that in thermocycling group, laser etching + Vertiseflow significantly increased the microleakage of the dentin margin compared to the application of Vertiseflow alone and Vertiseflow after etching. 10 Synarelis et al. 23 reported that conventional surface treatment by high-speed diamond bur significantly decreased the microleakage at the enamel margins compared to surface preparation by Er,Cr:YSGG laser.

In contrast to the current study, Tuna et al. 24 reported that surface treatment with Er:YAG laser had no significant effect on microleakage following the use of flowable and Vertiseflow composites; although the microleakage was slightly higher in the laser group. In the current study, laser was used for surface etching.

In general, no thermocycling groups in our study had less microleakage than the thermocycling groups at the enamel and dentin margins. The thermocycling process can increase debonding at the resin–enamel interface due to thermal stresses and water sorption. Self-adhesive composites include functional acidic monomers that significantly increase the hydrophilic nature of the resin. This results in water sorption and plasticity over time and increases the risk of debonding of fillers and destruction of matrix-filler bonds due to water sorption by the hydrophilic resin. 5

**CONCLUSION**

The current results revealed that surface preparation of class V cavities by acid etching and bonding agent application results in better marginal and occlusal seal and lower microleakage. However, surface treatment with laser and the use of self-adhesive composite increase the microleakage.

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