Eliminating microleakage from the composite resin system

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Recent dental research has focused on making the physical properties of composite resins similar to those found in tooth structure. Variations still exist between composites and teeth, despite tremendous advances since the first generation of macro-filled composite resins. These variations can result in microleakage, which may cause the composite resin to fail.

Microleakage refers to very small or microscopic openings between the margins of the composite restoration and that tooth structure (Fig. 1 and 2). Microleakage, open margins, and poor margin adaptation can result in bacteria penetrating teeth and dentinal tubules, where they (and/or their toxins) can irritate the pulp and lead to pulpitis, secondary decay, and discoloration of tooth structure. Microleakage is considered the major cause of composite resin restoration failure. It is possible that eliminating the microleakage caused by variations in physical properties can decrease that rate of failure.

There are three differences between the physical properties of tooth and composite; all three can contribute to microleakage. Polymerization shrinkage is one of the major differences. During the polymerization of composite resins, the density of the composite resin mass changes, resulting in a volumetric shrinkage. As composite resins set, they shrink inward toward the center of the composite core and may pull away from tooth structure, generating an open margin or void.

The coefficient of thermal expansion for resin and tooth structure is another difference in their physical properties. Varying temperatures cause volumetric changes in the resin. The resin can undergo thermal expansion and contraction while inside a tooth; temperature changes in the mouth that result from food or drink also can change the resin's size. If the tooth cannot tolerate the change, an open margin or cusp fracture—both of which can lead to microleakage—may occur.

It should be noted that the modulus of elasticity is greater for enamel and dentin than it is for composite. The modulus of elasticity for enamel is 33.6 GPa, while the modulus for dentin is 11.7 GPa; several condensable composites demonstrate a modulus of elasticity of 10.5 GPa. A low modulus of elasticity may demonstrate weak bonds; these bonds can break when a material is placed under tension or compression. While enamel under compressive strength does not become deformed before fracture, composite's weak internal bonds produce a flexible material with elastic properties, allowing micromovement of the resin to occur under stress. Micromovement may cause bond failure, resulting in both microleakage and percolation of fluids around the restoration.

Condensable composites have a high viscosity, exhibit little wear, and can withstand occlusal forces, making them appropriate for posterior restorations. Condensable composites get their mechanical properties from the large percentage of filler material by weight. A study of five condensable composites revealed that filler material by weight comprised 66–86% of the material; this large percentage reduces the possibility of polymerization shrinkage by decreasing the amount of matrix, making a strong interproximal contact possible.

The viscosity of these materials makes it hard to place them accurately within a tooth preparation. Poor margin adaptation has caused these restorations to fail, resulting in the creation of restorative composites that are easier to place. Studies have found that microleakage is greatest at the margins of the proximal box in Class II restorations (Fig. 3), where it is difficult to confirm that a condensable composite has adapted to all line angles. Microleakage at the gingival
margin may result from a scarcity of enamel in this area as well as from weak dentin bonds.\textsuperscript{1,24-26}

\textbf{Material overview}

The desire to eliminate microleakage and its negative effects from composite has led to the creation of several other composite materials, including dentin bonding agents, resin sealants, flowable composite, and compomer. The images that accompany this article are extracted human molars, prepared using Class II preparations, restored with composite core material, etched with 37\% phosphoric acid, and bonded and filled with core material according to the manufacturer’s recommendations. The teeth were sectioned horizontally, 1.0 mm below the cementoenamel junction (CEJ), and vertically, along the buccal lingual surface of the long axis; at that point, the teeth were prepared for scanning electron microscope (SEM) viewing. The specimens were desiccated and coated with a 50 nm film of gold-palladium alloy by a vacuum coating unit. Specimens were examined at an accelerating voltage of 20 kV and 35x magnification.

\textbf{Dentin bonding agents}

Dentin bonding agents have been shown to decrease microleakage while increasing bond strength. Yoshiyama et al found that sealing dentinal tubules completely renders the dentin insensitive and can eliminate postoperative sensitivity.\textsuperscript{27,28} Attaining a complete seal depends on sealing the restoration from the oral cavity as well; the restoration will fail if an open margin exists, regardless of how well the tubules are sealed.\textsuperscript{7}

Composite restorations depend on dentin bonding to composite via the dentin bonding agent. Dentin bonding agents are composite resins with very low viscosity and a minimal percentage of filler particles, capable of forming a hybrid layer between the resin and tooth structure. Dentin bonding agents should be nontoxic, provide adequate strength, resist wear and water absorption, and provide sufficient wetting capabilities and color stability.\textsuperscript{29}

\textbf{Resin sealants}

Resin sealants typically are used to prevent caries by covering the occlusal surfaces of primary and permanent teeth, although they also are effective at preventing pit and fissure decay.\textsuperscript{15,30} A 2000 study found that using a resin sealant at the CEJ significantly decreased microleakage in Class V composite restorations; the authors also found that Class V restorations with sealant added at the gingival margin displayed less microleakage than those without sealant.\textsuperscript{15}

\textbf{Flowable composites}

Flowable composites essentially are condensable composites with lower viscosity. They are dispensed from a syringe and can flow into a preparation, resulting in greater ease of placement and allowing the dentist to cover the entire preparation. This more accurate method of insertion reduces the possibility of voids at the interface. Flowable composites demonstrate a modulus of elasticity ranging from 1.0–5.0 GPa.\textsuperscript{7} The weak bonds give the material the ability to flex with tooth and resist fracture, making it possible to manipulate the material into all areas of cavity preparations. Flowable composites also include 30–50\% filler material, decreasing the amount of matrix material and reducing the amount of polymerization shrinkage that can occur.\textsuperscript{31,32}

Flowable composites are highly polishable due to the small particle size (microfilled), approximately 0.7 mm.\textsuperscript{15} A smoother tooth surface and cavosurface margin can improve the esthetics of the restoration and prevent the adherence of food and bacteria; by doing so, open margins, recurrent decay, and staining also can be prevented. Because flowable composites have lower tensile and compressive strengths than condensable composites, they are not indicated in areas of stress or wear. Resins generally have a lower hardness value than enamel, porcelain, or metal and are subject to wear from opposing dentition. Filler materials have been added to composites to reduce the amount of wear; these materials include barium silicate, quartz, trimethylol propane trimethacrylate, urethane dimethacrylate, and ytterbium fluoride.\textsuperscript{31,32} Increasing the amount of filler results in reduced particle size.\textsuperscript{31,32}

A toothbrush abrasion study performed by Bayne et al evaluated the wear resistance of flowable composite in relation to condensable composite.\textsuperscript{48} The study used soft bristle toothbrushes with toothpaste slurry and simulated normal brushing patterns for a 10-year period. The

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\textbf{Fig. 3.} A Class II restoration (the gingival proximal box is identified by the circle) and an enlargement of a proximal box 1.0 mm below the CEJ.
The study revealed no significant wear rate for toothbrush abrasion between the two types of composite (see Table 1). The researchers expected these results because the small particle size of flowable composites decreases the interparticle space, contributing to wear resistance. This small particle size also explains why flowable composite is indicated for Class V restorations.

Teeth wear in different ways and at different rates. A direct contact from a centric stop may cause teeth to wear faster than the contact-free wear resulting from a bolus of food. Numerous techniques are available for evaluating occlusal wear. The most precise method involves the use of a computer-driven digital laser that scans the stone cast and creates a three-dimensional image of the tooth surface. Another, more subjective approach is the human evaluator indirect cast comparison method (ICCM).

The Leinfelder method is the most common clinical method of ICCM, involving six calibrated clinical cast models that exhibit progressive wear in increments of 100 µm. Using the naked eye, the composite restorations are compared to the calibrated casts. The ICCM is more subjective because the human eye can differentiate up to only 100 µm while the digitizing laser can discriminate from 0–300 µm.

Using the Leinfelder method, Yu et al. performed a wear simulation involving 400,000 chewing cycles, comparing amalgam, condensable composite and flowable composite. Flowable composite indicated the highest wear, while amalgam showed the least (see Table 2).

### Table 1. The wear resistance of flowable composite compared to condensable composite.

<table>
<thead>
<tr>
<th>Material</th>
<th>Wear rate (in µm)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowable composite</td>
<td>21–28/10³</td>
<td>±17.0</td>
</tr>
<tr>
<td>Condensable composite</td>
<td>21–22/10³</td>
<td>±9.0</td>
</tr>
</tbody>
</table>

### Table 2. Wear rate of amalgam, condensable composite, and flowable composite following 400,000 chewing cycles.

<table>
<thead>
<tr>
<th>Material</th>
<th>Wear rate (in µm)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowable composite</td>
<td>17.2</td>
<td>±13.2</td>
</tr>
<tr>
<td>Condensable composite</td>
<td>7.4</td>
<td>±3.5</td>
</tr>
<tr>
<td>Amalgam</td>
<td>3.4</td>
<td>±1.5</td>
</tr>
</tbody>
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Compomers

Compomers are another class of composite resins for patients with a high caries rate and esthetic concerns. Compomers are composite resins combined with glass ionomer, developed to overcome poor margin adaptation and its negative effects. Glass ionomers are biologically compatible and capable of releasing fluoride and bonding to dentin and enamel; however, they are considered less esthetically pleasing than composite resin and are extremely technique-sensitive to moisture. For this reason, these materials have been used in conjunction. Compomers are more esthetic than glass ionomer alone; they also are relatively translucent and can assume the color of the surrounding tissues. However, the material must be in a dry environment until polymerization is complete.

**Discussion**

Dentists have modified their techniques to overcome the limitations of marginal adaptation for composite resins to tooth preparations. One modification involved using a less viscous flowable composite as a liner, placed beneath a condensable composite. Flowable composites shrink less during polymerization, reducing the chance of composite pulling away from the tooth, and are fluid enough to be dispensed from a syringe, giving the operator a greater chance to prevent voids at the interface. Flowable composites also reduce the likelihood of microleakage, open margins, and tooth fracture.

A second modification involves the incorporation of a bevel. Beveling enamel increases the surface area of the preparation for bonding while strengthening the margin adaptation of the composite resin material and reducing the chance of microleakage. Beveling the cavosurface margins also results in a more esthetic restoration, especially for a Class V restoration on an anterior tooth. Placing mechanical retention grooves in dentin also increases surface area for bonding. The greater bond strength may help to retain the restoration and prevent fracture or failure due to microleakage.

A microleakage study performed in 2000 demonstrated that flowable composite used in conjunction with a dentin bonding agent and condensable composite resulted in only 20% microleakage, compared to 67% microleakage when a dentin bonding agent was used alone. Another clinical study found that Class V restorations restored with flowable composite reduced sensitivity for all of the patients involved. It should be noted that postoperative sensitivity is possible.

The properties of the material differ from the properties of tooth structure; this difference leads to microleakage in composite resin restorations. Other factors that cause microleakage include but are not limited to improper moisture control, improper rubber dam placement, improper etching time, incomplete decay removal, collagen fiber desiccation, inadequate placement of material, inadequate photocuring, and poor margin adaptation. Placing a composite resin is a technique-sensitive procedure; postoperative sensitivity or recurrent decay can result if placement is not performed properly.

Current microleakage research demonstrates that the most successful method of composite restoration placement involves a combination of four products: acid etch is used to remove debris and open dentin tubules and dentin bonding agents flow into the tubules to create a seal that prevents bacterial invasion and postoperative sensitivity while providing an intermediate layer for composite adhesion. The flowable composite is placed as an intermediate so it can absorb stress and prevent the condensable composite from pulling away from the tooth structure; it is syringed into the preparation and adapted to the cavity wall. Finally, the condensable composite is placed.
Conclusion

Although recent advances have improved restorative materials, dentists will continue to modify their techniques until the ideal composite resin restorative material exists or the ideal combination of materials is determined. To limit the failure of composite resin restorations, microleakage must be eliminated. Patients should be granted the greatest chance of success with tooth-colored restorations.

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References


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