ORIGINAL ARTICLE

Analysis of Microleakage in Different Composite Resin Systems

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ABSTRACT

Background

"Microleakage is a critical factor in the long-term success of dental restorations, particularly in composite resin systems. It can lead to postoperative sensitivity, secondary caries, and eventual failure of the restoration. Different composite resin systems may exhibit varying degrees of microleakage due to differences in their composition, polymerization techniques, and adhesive systems. The purpose of this study is to analyze the microleakage in different composite resin systems.

Materials and Methods

In this in-vitro study, 60 extracted human molars were prepared with standardized Class V cavities. The teeth were randomly divided into three groups (n=20) based on the composite resin system used: Group A (nanohybrid composite), Group B (microhybrid composite), and Group C (bulk-fill composite). A standardized bonding procedure was followed for all samples. After placement of the restorations, the samples were thermocycled for 500 cycles between 5°C and 55°C. The teeth were then immersed in a 2% methylene blue dye solution for 24 hours to assess microleakage. Following dye penetration, the teeth were sectioned and examined under a stereomicroscope for dye penetration at both the occlusal and gingival margins. Microleakage scores were recorded using a 0-3 scale, with 0 indicating no leakage and 3 indicating maximum leakage.

Results

The results showed significant differences in microleakage between the composite resin systems. Group A (nanohybrid composite) showed the least microleakage, with an average score of 0.75 ± 0.5, while Group B (microhybrid composite) exhibited moderate microleakage, with an average score of 1.25 ± 0.6. Group C (bulk-fill composite) demonstrated the highest microleakage, with an average score of 2.0 ± 0.8. Statistical analysis using ANOVA revealed a significant difference between the groups ($p < 0.05$), with Group A performing better in terms of microleakage resistance.

Conclusion

The study concludes that nanohybrid composite resin exhibits superior performance in preventing microleakage compared to microhybrid and bulk-fill composite systems. This may be attributed to the smaller particle size and better polymerization properties of the nanohybrid composite. Clinicians should consider these differences when selecting materials for restorative procedures to minimize the risk of microleakage and enhance the longevity of restorations".

Keywords

Microleakage, Composite resin, Nanohybrid composite, Microhybrid composite, Bulk-fill composite, Dental restoration, Dye penetration test

INTRODUCTION

A cavity's wall and the restorative material might be said to be microleaky if germs, fluids, molecules, or ions are able to pass through. This phenomenon can compromise the longevity of dental restorations by causing postoperative sensitivity, secondary caries, and pulpal irritation (1). The prevention of microleakage is a critical factor in determining the success of restorative materials used in dental practice.

The cosmetic attractiveness of composite resins has led to their widespread adoption as a restorative dental material, ease of manipulation, and adhesive properties (2). However, different types of composite resins, such as nanohybrid, microhybrid, and bulk-fill systems, demonstrate varying performance in terms of microleakage resistance. The formulation of the resin, including filler particle size, polymerization shrinkage, and the bonding system, can significantly influence the extent of microleakage in dental restorations (3,4).

Nanohybrid composites, which contain smaller filler particles, have been introduced to improve physical and mechanical properties, potentially reducing polymerization shrinkage and enhancing marginal adaptation (5). On the other hand, microhybrid composites, characterized by larger filler particles, are believed to provide good handling properties but may exhibit higher microleakage due to greater polymerization shrinkage (6). Bulk-fill composites are designed for faster, more efficient placement, but their ability to reduce microleakage has been debated (7).

This study aims to evaluate and compare the microleakage in nanohybrid, microhybrid,

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and bulk-fill composite resin systems. By identifying differences in microleakage performance, the study seeks to provide insights into the appropriate selection of composite resin systems for clinical applications.

MATERIALS AND METHODS STUDY DESIGN

The purpose of this in-vitro investigation was to examine and contrast three distinct composite resin systems with respect to microleakage: hybrids, both nano and micro, and composites with bulk fill. Sixty healthy human molars were chosen for extraction and kept in a 0.5% chloramine T solution until needed. Each tooth type's composite resin repair was utilised to randomly assign 20 teeth to one of three groups.

Cavity Preparation

On the buccal side of every tooth, we made a standardised Class V cavity. In terms of measurement, the cavities were 3 mm tall, 4 mm wide, and 2 mm deep. One person used a high- speed handpiece with a #330 carbide bur irrigated heavily with water to prepare each cavity. The bur was changed after each five preparations to ensure consistency in the process.

Grouping and Materials

The teeth were randomly divided into three groups:

- **Group A**: "Nanohybrid composite resin (Filtek Z350 XT, 3M ESPE, USA)
- **Group B**: Microhybrid composite resin (Filtek Z250, 3M ESPE, USA)
- **Group C**: Bulk-fill composite resin (Filtek Bulk Fill, 3M ESPE, USA)"

Bonding Procedure

Participants in each group used Adper Single Bond 2, a total-etch adhesive system made by 3M ESPE in the USA, according to the instructions provided by the manufacturer. "After 15% phosphoric acid gel was etched for 15 seconds, the cavities were washed with water and let to air dry. Two thin coatings of the bonding agent were applied, then the mixture was light-cured for 20 seconds under an LED curing lamp with an intensity of 1200 mW/cm²".

Composite Placement

Group A (Nanohybrid Composite): Two horizontal increments were used to apply the nanohybrid composite resin. The curing process took 20 seconds for every 2 mm increase.

- **Group B (Microhybrid Composite)**: Consistent with Group A, the microhybrid composite was applied in two horizontal layers and allowed to cure for 20 seconds in each layer.
- **Group C (Bulk-fill Composite)**: Following the manufacturer's instructions, the bulk-fill composite was applied in a single step and allowed to cure for 40 seconds.

Thermocycling

After the repairs were finished, the specimens were kept in distilled water at 37°C for one day. After that, the teeth went through 500 cycles of heating and cooling, with each cycle allowing for a 30-second dwell time, to mimic the circumstances seen in the mouth.

Microleakage Evaluation

The teeth were subjected to a 24-hour immersion in a 2% methylene blue dye solution after thermocycling in order to evaluate microleakage. After soaking the teeth in dye, they were cleaned well and their roots were extracted using a diamond disc. Under water cooling, a low-speed diamond saw was used to segment the crowns buccolingually, across the centre of the repair.

Each specimen was examined under a stereomicroscope set at 40x magnification to ascertain the extent to which the dye permeated the gingival and occlusal margins. In order to measure microleakage, the following parameters were employed:

- "**Score 0**: No dye penetration.
- **Score 1**: Dye penetration extending less than one-third of the cavity wall.
- **Score 2**: Dye penetration extending up to two-thirds of the cavity wall.
- **Score 3**: Dye penetration extending beyond two-thirds of the cavity wall, including the pulp".

Statistical Analysis

After keeping track of each group's microleakage scores, we used one-way ANOVA to find any statistically significant differences. To find The results showed significant differences in the microleakage values between the different composite resin systems. Group A (nanohybrid Statistically significant differences across the categories, a post hoc Tukey test was used. We considered $p < 0.05$ to be statistically significant.

RESULTS

The microleakage scores of the three groups (nanohybrid composite, microhybrid composite, Dye penetration at the gingival and occlusal borders was used to assess the materials (bulk-fill composite and occlusal). Table 1 displays the average and standard deviation of the microleakage scores for each category.

Microleakage Scores

Table 1: Mean Microleakage Scores at the Occlusal and Gingival Margins

Group	Mean Occlusal Microleakage (± SD)	Mean Gingival Microleakage (± SD)
Nanohybrid Composite (Group A)	0.70 ± 0.48	1.00 ± 0.54
Microhybrid Composite (Group B)	1.25 ± 0.60	1.50 ± 0.64
Bulk-fill Composite (Group C)	1.75 ± 0.72	2.25 ± 0.80

composite) exhibited the lowest mean microleakage values at both the occlusal and gingival margins, with an average occlusal microleakage score of 0.70 ± 0.48 and gingival microleakage score of 1.00 ± 0.54.

Group B (microhybrid composite) demonstrated higher microleakage compared to Group A, with an average occlusal microleakage score of 1.25 ± 0.60 and gingival microleakage score of 1.50 ± 0.64.

Group C (bulk-fill composite) exhibited the highest levels of microleakage, with a mean occlusal microleakage score of 1.75 ± 0.72 and gingival microleakage score of 2.25 ± 0.80.

Microleakage ratings at the occlusal and gingival borders were found to be significantly different across the groups, according to one-way ANOVA ($p < 0.05$). Group A (nanohybrid composite) had considerably decreased microleakage compared to Group B (microhybrid composite) and Group C (bulk-fill composite) at both edges, As per the results of post-hoc Tukey testing ($p < 0.05$). With a p-value of less than 0.05, Group C showed much more microleakage than Groups A and B.

DISCUSSION

The results of this study demonstrate significant differences in microleakage among nanohybrid, microhybrid, and bulk-fill composite resin systems, with the nanohybrid composite exhibiting the least microleakage. These findings are consistent with previous studies that have highlighted the superior marginal integrity and reduced polymerization shrinkage of nanohybrid composites (1,2).

Nanohybrid composites contain smaller filler particles, which enhance their mechanical properties and improve the marginal adaptation by reducing polymerization shrinkage stresses (3). This reduction in shrinkage is a likely explanation for the lower microleakage values observed in Group A. The superior marginal sealing provided by nanohybrid composites has been previously supported by studies that have demonstrated their ability to prevent dye penetration better than other composite systems (4,5).

In contrast, microhybrid composites (Group B) exhibited higher microleakage values in this study. Microhybrid composites, which contain larger filler particles, tend to have higher polymerization shrinkage and may be more prone to gaps at the margins of the restoration (6). These findings align with other research that reports moderate microleakage for microhybrid composites compared to newer, more refined systems such as nanohybrid composites (7).

The bulk-fill composite (Group C) exhibited the highest levels of microleakage, particularly at the gingival margins. This result is concerning, as

bulk-fill composites are commonly used to reduce the time required for composite placement by allowing for larger increments of material to be cured at once. However, their capacity to maintain marginal integrity has been questioned in several studies, with similar observations of increased microleakage in restorations with bulk-fill materials (8,9). One possible reason for the increased microleakage in bulk-fill composites could be their rapid polymerization, which may cause more significant shrinkage stresses at the cavity walls, leading to gap formation (10).

Another key observation in this study is that gingival margins exhibited higher microleakage compared to occlusal margins across all groups. This may be due to the difference in bonding effectiveness between enamel and dentin. Enamel, with its higher mineral content, forms a stronger bond with adhesive systems, whereas dentin, which is more organic and hydrated, provides a weaker bond, making it more susceptible to microleakage, especially at the gingival margins (11). This has been supported by several studies that report higher microleakage at the gingival margins of restorations, particularly when located in dentin or cementum (12).

The clinical implications of these findings suggest that nanohybrid composites may be the material of choice when minimizing microleakage is a priority, particularly in high-risk areas such as the gingival margins. However, despite the improvements in composite resin technology, no material completely eliminates microleakage, underscoring the importance of careful clinical technique and adequate bonding procedures (13).

CONCLUSION

Future research should focus on investigating newer adhesive systems and polymerization techniques that could further reduce microleakage in bulk-fill composites. Additionally, To validate the results of in-vitro investigations and evaluate the materials' therapeutic efficacy over time, long- term in-vivo trials are required.

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