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EVALUATION OF MICROLEAKAGE IN CLASS V RESTORATIONS USING FOUR DIFFERENT COMPOSITE RESIN PLACEMENT TECHNIQUES: AN IN VITRO STUDY

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ABSTRACT

Class V restorations are common in restorative dentistry, frequently located at the cemento-enamel junction, where they face increased challenges such as wear, abrasion, and caries formation. Microleakage, the penetration of fluids and bacteria between the restoration and the tooth structure, is a major cause of failure in these restorations. Various methods have been proposed to minimize microleakage, with composite resins being widely used. This study evaluates four different composite resin placement techniques for their effectiveness in reducing microleakage in Class V restorations. Forty extracted human teeth were selected and randomly divided into four groups. Each group underwent restoration using one of the following techniques: horizontal incremental, U-shaped incremental, split incremental, and mat incremental. Microleakage was assessed using methylene blue dye after thermocycling and sectioning the teeth. A stereomicroscope was used to measure dye penetration along the restoration margin. The results revealed that the Mat incremental technique produced the least microleakage, with the majority of specimens exhibiting no dye penetration. The horizontal incremental technique showed the highest levels of microleakage, with many specimens showing dye penetration to two-thirds of the cavity depth. Statistical analysis indicated significant differences between the techniques ($p<0.05$). The Mat incremental technique is the most effective in minimizing microleakage in Class V composite restorations, followed by the split incremental technique. These findings suggest that these methods may offer greater long-term success and durability for composite restorations in clinical practice.

KEYWORDS: Microleakage, Composite resin, Class V restorations, Polymerization shrinkage, Incremental technique, Marginal adaptation, Dental restoration.

INTRODUCTION

The development of composite resins has transformed restorative dentistry by enabling adhesive bonding to tooth structure, allowing for more conservative cavity preparations than traditional amalgam restorations. This adhesive property reduces the need for extensive tooth reduction while ensuring a strong bond between the restoration and the tooth, making composite resins a preferred material for direct restorations.[1]

Class V restorations involve cavities in the gingival third of the facial, buccal, or lingual surfaces, typically occurring at the cemento-enamel junction (CEJ). These lesions result from caries, erosion, abrasion, or trauma and affect an area vulnerable to plaque accumulation and demineralization.[2] Restoring this zone presents challenges due to its proximity to the gingiva, making isolation difficult and increasing contamination risks, which can compromise the bond and lead to microleakage.

Microleakage—the infiltration of fluids, bacteria, or ions at the restoration interface—can cause secondary caries, sensitivity, and restoration failure. A key contributor to microleakage is polymerization shrinkage, where volumetric contraction during curing creates stresses that form gaps at the margins, allowing bacterial infiltration. This issue is particularly significant in Class V restorations due to the challenge of achieving an effective seal.[3]

To address microleakage, researchers have explored improved composite formulations, advanced curing techniques, and optimized placement methods.

1. **Composite Formulation Enhancements:** New resins with higher filler loading and optimized matrix components reduce polymerization shrinkage and stress at the tooth-restoration interface.[4]
2. **Advanced Curing Methods:** Optimized light-curing techniques, including variations in intensity and duration, enhance polymerization uniformity, reducing shrinkage stress and improving marginal adaptation.[5]
3. **Placement Techniques:** The method used to apply composites significantly impacts shrinkage and microleakage. Incremental layering techniques help control polymerization shrinkage, reducing stress and enhancing adaptation. Key techniques include.

- **Horizontal Incremental Technique:** Layers are placed horizontally and cured before applying the next.
- **U-Shaped Incremental Technique:** Composite follows the natural cavity contour for uniform distribution.
- **Split Incremental Technique:** A combination of horizontal and vertical layering for better stress control.
- **Mat Incremental Technique:** Thin, evenly spread layers minimize shrinkage and improve adaptation.[6]

Despite the theoretical benefits of incremental placement techniques, there remains a lack of consensus in the dental literature regarding their effectiveness in reducing microleakage in Class V restorations. By comparing the degree of microleakage associated with each placement technique, this study will provide valuable insights into the optimal method for reducing shrinkage stresses and improving the longevity of composite restorations in the clinical setting.[9]

MATERIALS

- High-Speed Handpiece
- Low-Speed Handpiece
- Burs -Round, pear-shaped, finishing burs and polishing points
- Etchant
- Bonding Agent
- Microbrushes
- Composite Resin- TETRIC N-CERAM(Ivoclar)
- Composite Placement Instruments.
- LED curing light for polymerizing the composite
- Thermocycling Machine
- 2% methylene blue
- Diamond disc with straight handpiece
- Stereomicroscope

METHODOLOGY

Study Design

This in vitro study was conducted to assess the microleakage of composite restorations in Class V cavities prepared in human teeth. Forty extracted human mandibular incisors were selected, cleaned, and stored in 0.5% chloramine-T solution to prevent bacterial contamination. The teeth were then randomly divided into four groups, with each group receiving a different composite resin placement technique.

Cavity Preparation

Class V cavities (5 mm wide, 3 mm high, and 2 mm deep) were prepared on the buccal surfaces of the teeth using a high-speed handpiece and a No. 245 bur. The cavities were then etched with 37% phosphoric acid for 15 seconds, rinsed thoroughly, and gently air-dried. A bonding agent was applied according to the manufacturer's instructions and light-cured for 20 seconds.

Restoration Techniques

A composite resin material (Tetric N-Ceram, Ivoclar Vivadent) was used for all restorations. The placement techniques were as follows.

1. **Group 1: Horizontal Incremental Technique (FIGURE - 2)**

The composite resin was placed incrementally, with each layer filling half of the cavity's depth. Each increment was light-cured for 40 seconds, and the next layer was placed on top of the previous one. This process continued until the cavity was completely filled.

2. **Group 2: U-shaped Incremental Technique (FIGURE - 3)**

In this technique, the composite resin was first placed as a U-shaped layer within the cavity. The material was condensed along the edges and light-cured for 40 seconds. The remaining increments were placed inside the U-shaped configuration and light-cured after each layer.

3. **Group 3: Split Incremental Technique (FIGURE - 4)**

The first increment of composite was placed and condensed to fill the cavity. The material was then split into four smaller triangular sections using a dental probe, followed by light-curing each section for 40 seconds. The remaining layers were placed incrementally and light-cured.

4. **Group 4: Mat Incremental Technique(FIGURE - 5)**

In this technique, the composite resin was placed into the cavity in a continuous mat-like layer. Three cuts were made through the composite to create square-shaped portions, which were individually light-cured for 40 seconds. Each layer was carefully applied to minimize voids and gaps.

Thermocycling and Dye Penetration: After the restoration process, the specimens were subjected to thermocycling (1000 cycles at temperatures of 5°C and 55°C, with a 30-second dwell time) to simulate oral temperature fluctuations. Subsequently, the teeth were immersed in a 1% methylene blue dye solution for 24 hours at room temperature to allow dye penetration at the interface.

Microleakage Evaluation: (FIGURE - 6)

After dye immersion, the teeth were rinsed thoroughly and sectioned longitudinally in the buccolingual direction. Microleakage was then assessed under a stereomicroscope at ×40 magnification. The level of dye penetration was scored according to the following system.

- **Score 0:** No dye penetration
- **Score 1:** Dye penetration up to one-third of the cavity depth
- **Score 2:** Dye penetration up to two-thirds of the cavity depth
- **Score 3:** Dye penetration to the full cavity depth
- **Score 4:** Dye penetration onto the axial wall

Statistical Analysis: Descriptive statistics were used to summarize the microleakage scores. The Kruskal-Wallis test with Monte Carlo exact tests was used to compare the microleakage between the four groups. A p-value of <0.05 was considered statistically significant.

RESULTS

The results of this study revealed significant differences in the degree of microleakage among the four placement techniques. The **Mat incremental technique** consistently produced the least microleakage, with 60% of specimens showing no dye penetration (score 0). Additionally, 40% of specimens using this technique exhibited only slight dye penetration (score 1), suggesting good sealing of the restoration.

On the other hand, the **Horizontal incremental technique** demonstrated the highest levels of microleakage, with 40% of specimens exhibiting dye penetration up to two-thirds of the cavity depth (score 2) and 40% showing penetration to the full depth of the cavity (score 3).

The **Split incremental** and **U-shaped incremental techniques** exhibited intermediate results. The **Split incremental technique** showed a moderate amount of microleakage, with approximately 50% of specimens scoring 1, indicating mild dye penetration. The **U-shaped incremental technique** performed slightly worse, with more specimens showing moderate microleakage (score 2).

Table 1: Table No. 1: Descriptive data of Micro-leakage assessment among various composite placement techniques in Class V restorations.

Group		Micro-leakage scores* 0	1	2	3	4	Total
Split Horizontal	Frequency (n)	0	10	0	0	0	10
	Percentage (%)	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%
Horizontal Incremental	Frequency (n)	0	2	4	4	0	10
	Percentage (%)	0.0%	20.0%	40.0%	40.0%	0.0%	100.0%
U shaped	Frequency (n)	0	2	8	0	0	10
	Percentage (%)	0.0%	20.0%	80.0%	0.0%	0.0%	100.0%
Mat Incremental	Frequency (n)	6	4	0	0	0	10
	Percentage (%)	60.0%	40.0%	0.0%	0.0%	0.0%	100.0%
Total	Frequency (n)	6	18	12	4	0	40
	Percentage (%)	15.0%	45.0%	30.0%	10.0%	0.0%	100.0%

Table No. 2: Comparison of Micro-leakage between various composite placement techniques in Class V restorations.

Group	N	Mean Rank	Median	df	x^2 value	95% C.I. Lower Bound	95% C.I. Upper Bound	P value
Split Horizontal	10	15.50	1.00	3	26.667	0.000	0.003	0.000*
Horizontal Incremental	10	30.70						
U shaped	10	27.50						
Mat Incremental	10	8.30						

*p value significant at 0.05.

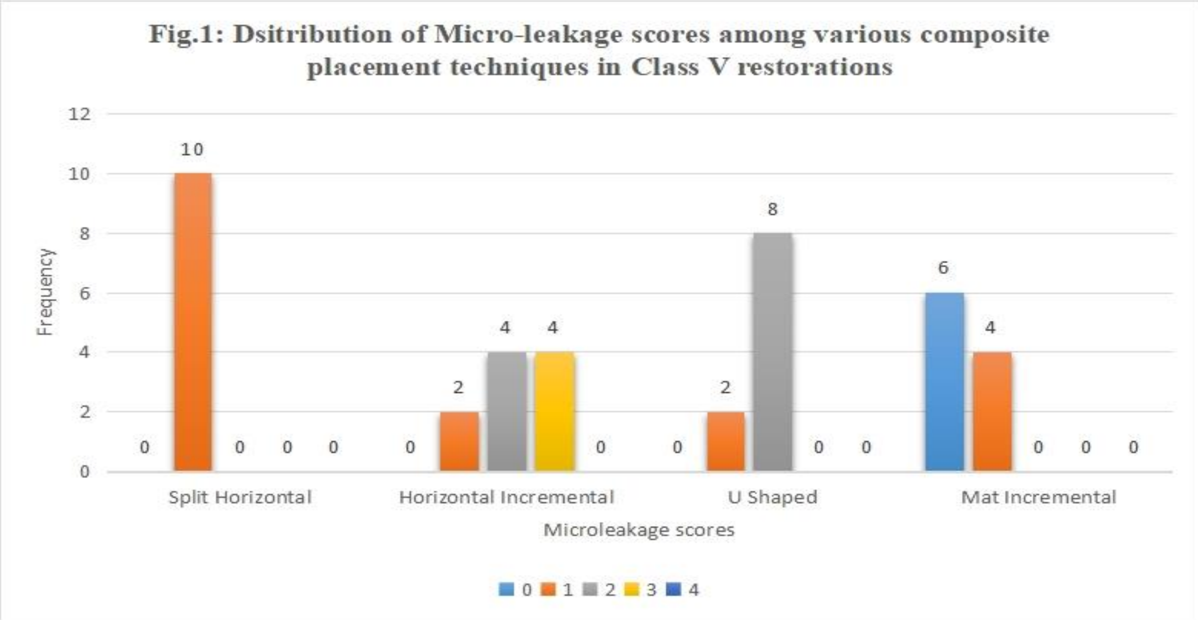


Figure 2: Horizontal Incremental Technique.

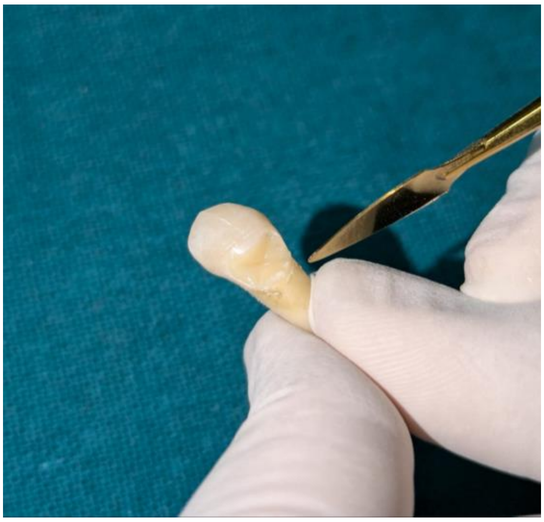
Figure 4: Split Incremental Technique.


Figure – 3: U-shaped Incremental Technique.

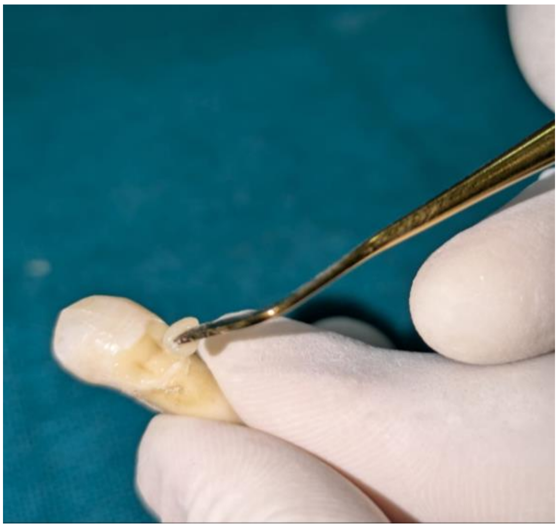
Figure – 5: Mat Incremental Technique.

Figure – 6: 0=No dye penetration, 1=Dye penetration up to one third cavity depth, 2=Dye penetration up to two third cavity depth, 3=Dye penetration up to full depth of cavity, 4=Dye penetration onto axial wall of cavity.

DISCUSSION

Microleakage is a well-known complication associated with composite resin restorations, particularly in Class V cavities. It is primarily caused by polymerization shrinkage, which leads to stresses at the interface between the tooth and the restorative material. These stresses can result in gaps or voids that allow the infiltration of fluids, bacteria, or ions, ultimately compromising the longevity and effectiveness of the restoration.[1] In clinical practice, it is critical to minimize these gaps to avoid secondary caries, postoperative sensitivity, and restoration failure. The present study aimed to determine the most effective composite placement technique for minimizing microleakage among four incremental techniques.

Polymerization shrinkage is the most significant contributor to microleakage in composite restorations.[2] In the current study, the group using the horizontal placement technique (Group I) exhibited the highest levels of microleakage. This finding is consistent with previous studies, where bulk placement techniques or large increments of composite material resulted in higher shrinkage stresses and, consequently, greater microleakage at the restoration margins.[3]

Incremental techniques, where composite material is placed in thin layers and each layer is polymerized separately, have been shown to reduce the effects of polymerization shrinkage. The incremental approach reduces the overall surface area that undergoes contraction during the polymerization process, which helps to minimize the shrinkage stress and, consequently, the potential for microleakage. Among the incremental techniques evaluated in the current study, the mat incremental technique (Group IV) demonstrated the lowest microleakage levels, followed by the split horizontal incremental technique (Group III), the U-shaped incremental technique (Group II), and the horizontal placement technique (Group I). These results suggest that incremental techniques, particularly the mat and split incremental techniques, are more effective at reducing microleakage than traditional bulk-fill methods.[4]

The split incremental technique and the mat incremental technique showed remarkable outcomes in terms of minimizing microleakage. These techniques involve breaking up the composite into smaller increments, which helps to reduce the C-factor, a critical factor in determining polymerization shrinkage stress. A low C-factor reduces the stresses at the bonded interfaces, as smaller increments undergo less contraction during polymerization.[5] In contrast, the horizontal technique, which involves placing larger increments of composite material, results in higher shrinkage stress and, as observed in this study, greater microleakage.[6]

The success of incremental techniques in reducing microleakage can be attributed to several factors. One of the key factors is the reduction in the C-factor. The C-factor refers to the ratio of bonded to unbonded surfaces in the cavity. A high C-factor, such as that seen with bulk placement techniques, results in greater shrinkage stress and higher microleakage levels.[7] By placing composite resin in smaller increments, the C-factor is reduced, allowing for more uniform contraction of the material and a better seal at the restoration margins. This approach minimizes the gap formation at the tooth-restoration interface, leading to less microleakage.

Additionally, incremental placement techniques help to achieve better adaptation of the composite material to the cavity walls, which is crucial for achieving a good marginal seal. A good marginal seal is essential for the longevity of the restoration, as it prevents the infiltration of bacteria and fluids into the cavity and protects the tooth from secondary caries.[8] The split incremental and mat incremental techniques, by reducing the overall shrinkage stress at the margins, enhance the bond between the composite and the tooth structure, contributing to a more effective seal and less microleakage.

The results of the current study also highlight the importance of enamel etching and the adhesive system used in conjunction with the placement techniques. Acid etching, particularly with phosphoric acid, is a well-established method for creating microporosities on the enamel surface, improving the micromechanical bond between the composite resin and the tooth structure. Khosarvi et al. demonstrated that acid etching significantly improves the marginal seal of composite restorations by increasing the surface area for bonding, which reduces microleakage.[9] The enhanced bond strength achieved through acid etching helps to reduce the gap formation at the tooth-restoration interface, contributing to lower microleakage levels in the split and mat incremental techniques, which used acid-etched enamel surfaces.

Furthermore, the addition of filler particles to adhesive systems may contribute to the success of incremental techniques. Studies by Cangul and Ghavamnasiri have shown that fillers in adhesive systems increase the modulus of elasticity and rigidity, which helps to reduce the polymerization shrinkage of the adhesive. This reduction in shrinkage stress further prevents microleakage and enhances the bond between the composite and the tooth structure.[10] The adhesive system's effectiveness, combined with the reduced C-factor achieved through incremental placement, is likely responsible for the lower microleakage observed in the split and mat incremental techniques in this study.

The findings of this study are consistent with those of previous research comparing different incremental techniques for Class V restorations. For example, Usha et al. compared oblique layering and split incremental techniques and found that the split incremental technique resulted in less microleakage.[11] Similarly, Rani Somani et al. observed that the mat incremental technique demonstrated significantly lower microleakage compared to other techniques.[12] The present study supports these findings, further confirming the superiority of the mat and split incremental techniques in minimizing microleakage.

The mat incremental technique, in particular, introduces a novel approach to reducing polymerization shrinkage by cutting the composite increments into smaller square portions. This strategy further reduces the C-factor by creating new unbonded surfaces, which minimizes the stresses at the bonded interfaces and margins, resulting in lower microleakage. This technique, which effectively divides larger increments into smaller, more manageable portions, significantly reduces the shrinkage stresses at the cavity margins and thus minimizes microleakage.[13]

The clinical implications of this study are important for improving the long-term success of Class V restorations. By using incremental techniques, especially the mat and split incremental techniques, clinicians can significantly reduce the occurrence of microleakage, thereby enhancing the longevity and durability of composite restorations. This is particularly important in Class V cavities, which are located in areas of the tooth that are more susceptible to contamination and decay. Furthermore, the results suggest that the split and mat incremental techniques can be incorporated into clinical practice to provide more reliable outcomes for patients, reducing the need for re-treatment and improving patient satisfaction.[14]

CONCLUSION

In conclusion, the **Mat incremental technique** is the most effective method for reducing microleakage in Class V composite restorations, followed closely by the **Split incremental technique**. These findings suggest that optimizing the incremental technique is a promising approach to improving the clinical success and longevity of composite restorations, particularly in challenging areas such as the cemento-enamel junction. Future studies incorporating clinical outcomes and long-term evaluations will be beneficial to confirm these results in vivo.

Limitations

This study was conducted in vitro, which may not fully replicate the complexities of the oral environment. Additionally, this study focused solely on microleakage as the measure of restoration success, without evaluating other important factors such as wear resistance, bond strength, or clinical performance over time.

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