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Microleakage Assessment of Flowable Composites and Hydrophilic Sealant: A Stereo Microscopic Study

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Abstract **Objectives:** Dental cavities are a prevalent issue that, if untreated, can escalate into severe complications. Minimally invasive treatments, such as fissure sealants, have been developed to prevent early-stage cavities from progressing. Traditional sealants, however, often fail due to moisture contamination during application. To address this, hydrophilic sealants were designed to perform effectively in moist environments. A critical determinant of their success is the ability to create a durable, tight seal along the edges. **Methods:** This study used 20 extracted, caries-free, sound molars, randomly divided into two groups: Group I (hydrophilic sealants) and Group II (flowable composites). Tooth sectioning was performed mesiodistally using a low-speed diamond cutting blade. The specimens were immersed in 1% methylene blue solution at room temperature for 24 hours to assess dye penetration and the microleakage was evaluated using a stereomicroscope following Ovrebo and Raadal guidelines (1990). **Results:** Hydrophilic sealants demonstrated superior performance in microleakage prevention, with a significantly higher number of samples scoring zero for dye penetration compared to flowable composites. Statistical analysis using the Mann-Whitney U test ($p < 0.05$) confirmed that Group I exhibited less dye penetration, highlighting the enhanced sealing ability of hydrophilic sealants. **Conclusion:** Hydrophilic sealants exhibit better sealing efficacy and reduced microleakage compared to flowable composites, particularly under moist conditions. Their superior penetration and adaptability make them a promising option for long-lasting dental restorations. Future research should focus on larger sample sizes, long-term clinical performance and optimizing application techniques for diverse clinical scenarios.

Key Words Dental caries, flowable composites, hydrophilic sealants, microleakage, stereo microscopy, dental adhesives, marginal sealing

INTRODUCTION

Dental restorative materials have undergone remarkable advancements over the years, aiming to achieve optimal aesthetics, durability and biocompatibility while addressing persistent clinical challenges such as microleakage [1]. Microleakage, the infiltration of oral fluids, bacteria and other substances between the dental restoration and tooth structure, significantly impacts the longevity and success of restorations, leading to secondary caries, post-operative sensitivity and restoration failure [2]. This study seeks to assess the microleakage of flowable composites and hydrophilic sealants, two materials that have gained considerable attention for their distinct properties and applications, using stereo microscopy [3].

Flowable composites, characterized by their low-viscosity resin-based formulation, are widely utilized for small cavity restorations, liners and enamel defect repairs [4]. Their flowable nature facilitates better adaptation to cavity walls and improved marginal sealing. However, challenges such as polymerization shrinkage and differences in thermal expansion between the composite material and tooth structure can compromise their sealing ability, leading to potential microleakage [5].

Hydrophilic sealants, on the other hand, are designed to bond effectively to moist surfaces, making them particularly advantageous for sealing pits and fissures in teeth [6]. Their hydrophilic properties enhance adhesion in challenging moist environments, often surpassing the limitations of other

sealants and composites in such conditions [7]. While promising, the effectiveness of hydrophilic sealants in preventing microleakage and ensuring long-term restoration integrity requires further investigation.

Stereo microscopy provides a detailed three-dimensional evaluation of the tooth-restoration interface, making it a valuable tool for assessing microleakage [8]. This method involves staining the tooth-restoration interface with a dye and analyzing the extent of dye penetration, thereby offering critical insights into the sealing efficacy of restorative materials [9]. Although alternative imaging techniques such as confocal microscopy provide enhanced resolution, stereo microscopy remains a widely accepted and cost-effective method for such assessments [10].

The aim of this study is to compare the microleakage performance of flowable composites and hydrophilic sealants using stereo microscopy [11]. By analyzing dye penetration at the restoration interface, this research seeks to provide actionable insights into the clinical performance of these materials and inform strategies for their application and formulation improvement [12]. The null hypothesis posits that there is no statistically significant difference in microleakage between hydrophilic sealants and flowable composites when evaluated using stereomicroscopic methods.

Understanding the microleakage behavior of these materials is crucial for advancing restorative dentistry practices and ensuring the longevity of dental restorations [13]. This study contributes to the development of more effective and reliable restorative options, addressing critical gaps in the current understanding of their performance under varying clinical conditions.

METHODS

This research employed an in-vitro study design to evaluate the microleakage of hydrophilic sealants and flowable composites. The sample size was calculated using G*Power software Version 3.1.9.6, based on the study conducted by Eliacik BK *et al.* employing apriori power analysis with an alpha error of 0.005 and 95% power.

Sample Selection and Preparation

Twenty extracted human molars with deep pits and fissures were selected for the study. Teeth were thoroughly cleaned to remove foreign particles and debris and were stored in a 0.1% thymol solution to prevent bacterial growth until the study began. Each tooth underwent a detailed visual examination using a dental explorer to confirm the absence of caries. The selected teeth were then randomly divided into two groups:

- Group I: Treated with hydrophilic sealants
- Group II: Treated with flowable composites

Experimental Procedures

The *in-vitro* analysis was conducted in the White Research Lab at Saveetha Dental College under controlled conditions to minimize variability.

Figure 1: Group I-Flowable composite

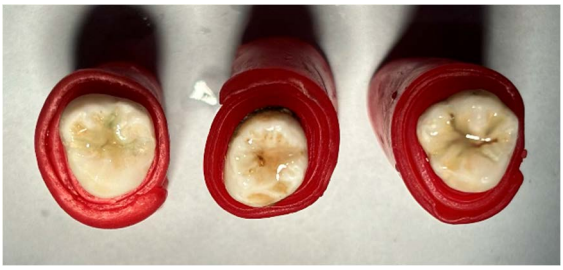

Figure 2: Group II- Hydrophilic Sealant

Acid Etching:

- The occlusal surfaces of all samples were etched using 37% orthophosphoric acid for 15 seconds and then rinsed thoroughly with distilled water.
- For hydrophilic sealants, the samples were gently dried to retain a shiny or glossy appearance, ensuring the presence of slight moisture (Figure 1).
- For flowable composites, samples were dried completely until a frosty or glacial white enamel surface was achieved (Figure 2).

Dye Immersion: Both groups were immersed in 1% rhodamine methylene blue dye for 24 hours at room temperature to allow dye penetration into potential microleakage pathways (Figure 3).

Thermocycling: Following dye immersion, the samples were subjected to a thermocycling procedure between 5°C and 55°C for 1500 cycles. Each cycle involved a 15-second immersion at each temperature with a 10-second dwell time, simulating the thermal stresses experienced in the oral environment (Figure 4).

Tooth Sectioning and Evaluation: The treated teeth were sectioned mesiodistally using a low-speed diamond cutting blade to expose the occlusal-restoration interface. The sectioned halves were analyzed under a stereomicroscope to assess the extent of dye penetration, following the Ovrebo and Raadal scoring criteria for microleakage evaluation (Figures 5 and 6).

Statistical Analysis

Data were analyzed using SPSS software version 20.0 (IBM Corp, Armonk, NY, USA). Frequency and percentage

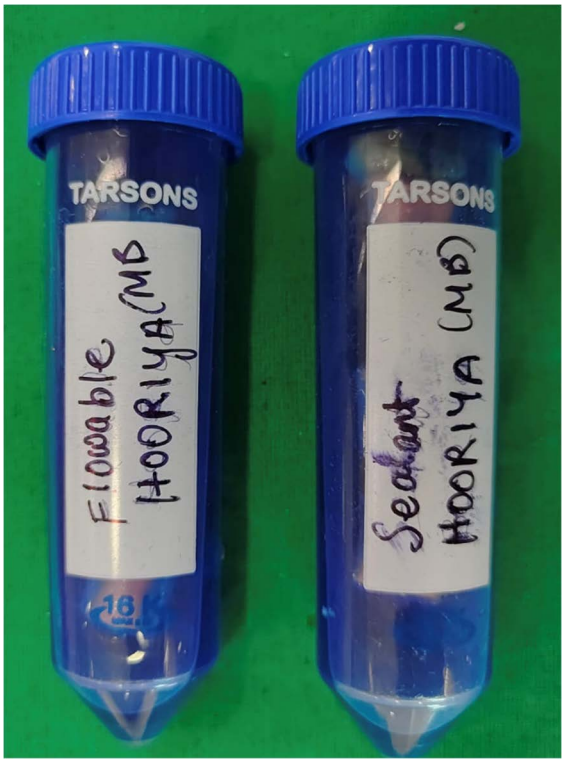

Figure 3: Dye Immersion

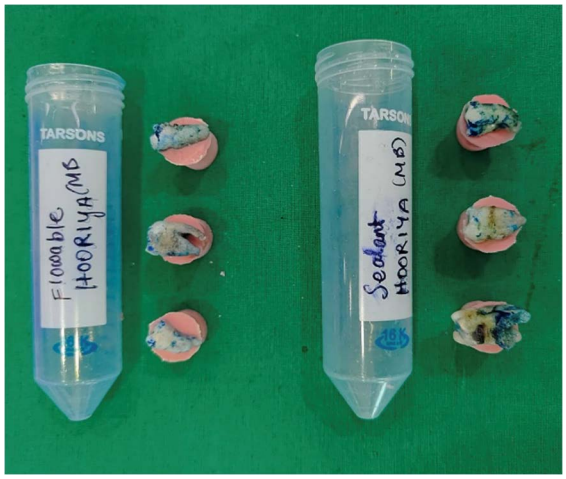

Figure 4: Dye Penetrated Samples

distributions of the microleakage scores were calculated for both groups. Comparisons between groups were performed using the Mann-Whitney U test, with a significance level set at $p<0.05$.

RESULTS

The microleakage scores demonstrated significant differences between the two tested groups. In Group I (hydrophilic sealants), four samples recorded a microleakage score of 0, indicating no dye penetration, compared to only one sample

Figure 5: Microleakage Image of Group-1

Figure 6: Microleakage Image of Group-II

Table 1: Comparison of microleakage scores between the Groups

Groups	Mean Rank	Mann whitney U test value	p-value
Group I	8.85	33.50	0.04
Group II	12.15		

in Group II (flowable composites). A score of 1, signifying minimal dye penetration, was observed in three samples from Group I and four samples from Group II. Conversely, a score of 2, indicating moderate dye penetration, was observed in three samples in Group I and five samples in Group II. The mean rank values for Group I and Group II were 8.85 and 12.15, respectively.

The statistical analysis was performed using the Mann-Whitney U test to evaluate the difference in microleakage scores between the two groups. The test yielded a value of 33.50 with a p-value of 0.04 (Table 1), which is statistically significant. These findings indicate that hydrophilic sealants exhibited superior sealing ability compared to flowable composites, as evidenced by reduced dye penetration. The results support the hypothesis that hydrophilic sealants are more effective in minimizing microleakage under the tested conditions.

DISCUSSION

This study compared the effectiveness of flowable composites and hydrophilic sealants in minimizing microleakage in dental restorations using stereo microscopy. Flowable

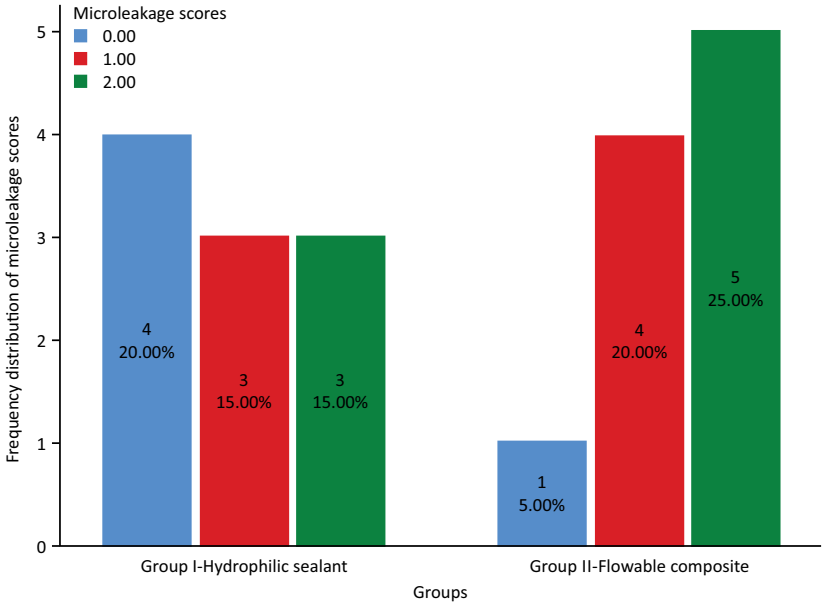

Figure 7: Frequency distribution of microleakage scores between the Groups

composites, known for their low viscosity, have been favored for their ability to adapt closely to cavity walls and improve marginal sealing. However, the results of this study confirm that flowable composites are prone to polymerization shrinkage, which creates marginal gaps and increases microleakage. This finding aligns with prior research that highlights the susceptibility of flowable composites to shrinkage stresses during curing, leading to compromised restoration integrity and increased risks of secondary caries and postoperative sensitivity [14,15].

In contrast, hydrophilic sealants demonstrated superior performance in minimizing microleakage, even under conditions with potential moisture contamination. Their hydrophilic properties allow them to form reliable bonds on moist tooth surfaces, making them particularly effective in subgingival restorations or in cases involving high salivary flow. This observation is consistent with studies that emphasize the advantage of hydrophilic sealants in clinical scenarios where achieving complete moisture isolation is difficult [16,17]. The chemical composition of hydrophilic sealants enables them to maintain adhesive properties in moisture-rich environments, enhancing the durability and effectiveness of restorations.

The clinical implications of these findings are significant. By minimizing microleakage, hydrophilic sealants reduce the risks associated with secondary caries, restoration failure and sensitivity, thus contributing to better patient outcomes. Moreover, the study underscores the importance of optimizing application techniques for these materials to maximize their potential. Proper handling, combined with practitioner training, can enhance the performance of hydrophilic sealants in real-world scenarios [18].

However, despite their advantages, hydrophilic sealants are not without limitations. Their effectiveness depends heavily on precise application and environmental conditions during placement. Addressing these factors through improved training and standardized protocols can further enhance the clinical utility of hydrophilic sealants [19].

CONCLUSION

This study demonstrates that hydrophilic sealants provide superior sealing ability compared to flowable composites, as evidenced by significantly lower microleakage scores. Their ability to bond effectively in moist environments highlights their potential as a reliable alternative for restorative applications in challenging clinical scenarios. While flowable composites remain widely used for their aesthetic benefits and ease of application, hydrophilic sealants offer distinct advantages in moisture-prone conditions. Future research should focus on long-term clinical trials, larger sample sizes and advanced imaging techniques to validate these findings and explore broader clinical applications.

Limitations

Several limitations of this study must be acknowledged. The small sample size of 20 teeth restricts the generalizability of the findings and the in vitro design does not fully replicate the complexities of clinical environments, such as the presence of saliva, temperature fluctuations and operator variability. Stereo microscopy, though effective for assessing surface-level microleakage, lacks the resolution required for detailed subsurface analysis. Additionally, the absence of long-term in vivo data limits conclusions about the durability of these restorative materials. Future studies should address these

limitations by including larger sample sizes, employing advanced imaging techniques such as confocal microscopy or micro-CT scanning and conducting long-term clinical trials. Further research should also explore hybrid materials that combine the strengths of hydrophilic sealants and flowable composites, as well as the impact of application techniques and operator variability on restoration outcomes.

Future Directions

To build on the findings of this study, future research should focus on several key areas. Long-term clinical trials are essential to evaluate the durability and effectiveness of hydrophilic sealants and flowable composites under diverse oral conditions. Investigating the development of hybrid materials that combine the strengths of these two restorative options could provide improved sealing abilities and broader clinical applicability. Additionally, studies on the role of operator training and the impact of different application techniques will help refine protocols for optimal results. Finally, exploring cost-effectiveness and scalability in various healthcare settings would contribute to the widespread adoption of these materials, ultimately improving patient outcomes.

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Conflicts of Interest

The authors declare no conflicts of interest. All affiliations and institutional support have been disclosed to maintain objectivity in this research.

Ethical Statement

This study was conducted with the approval of the Saveetha Institutional Research Review Board (SRB/SDC/UG-2024/24/PHD/336). Extracted teeth were handled in compliance with ethical guidelines, ensuring proper documentation, storage and disposal.

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