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Confocal Assessment of Microleakage of Hydrophilic Sealants and Flowable Composites

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Abstract **Objectives:** Dental caries is a highly prevalent chronic condition that, if left untreated, can result in severe oral health consequences, including pain, infection and tooth loss. Micro-invasive treatments for dental caries, such as fissure sealants, are effective in arresting incipient caries in pits and fissures. However, conventional sealants face challenges such as technique sensitivity and failure under moisture contamination. Hydrophilic sealants were introduced to address these limitations, offering better adaptability in moist environments. Marginal sealing is a critical factor in determining the longevity and success of restorative treatments. **Methods:** The study utilized 20 extracted sound molar teeth free from caries and developmental defects. The samples were randomly divided into two groups of 10 each: Group I (Ultra-seal XT Hydro hydrophilic sealants) and Group II (Flowable composite). Mesiodistal sectioning was performed using a low-speed diamond cutting blade and the sections were immersed in 0.1% rhodamine B isothiocyanate dye at 37°C for 24 hours. Dye penetration was assessed using confocal laser scanning microscopy. Microleakage was evaluated following Ovrebo and Raadal guidelines (1990). **Results:** Group I (hydrophilic sealants) exhibited significantly less dye penetration compared to Group II (flowable composites), as determined by the Mann-Whitney U test ($p = 0.041$). The results indicated that hydrophilic sealants demonstrated superior marginal sealing, reducing microleakage more effectively than flowable composites. **Conclusion:** Hydrophilic sealants showed better performance in preventing microleakage than flowable composites, particularly in moisture-prone conditions. These findings suggest that hydrophilic sealants are a valuable choice for enhancing the longevity and effectiveness of restorative treatments, with potential implications for improving clinical protocols and patient outcomes. Future research should explore the long-term durability, cost-effectiveness and real-world applications of these materials..

Key Words Hydrophilic sealants, flowable composites, dental caries, confocal microscopy, microleakage, adhesive dentistry

INTRODUCTION

Dental caries, a widespread chronic disease, is characterized by the progressive demineralization of tooth structure due to acidic by-products of bacterial metabolism. As a major public health issue globally, dental caries significantly impacts oral and general health, leading to pain, infection and tooth loss if untreated. Its prevalence and consequences necessitate effective preventive and restorative strategies to mitigate the global burden of this disease and improve health outcomes [1].

The prevention and management of dental caries heavily rely on restorative materials that not only fill cavitated lesions but also form a strong bond with the tooth structure, preventing further decay and ensuring restoration longevity [2]. Pits and fissures on occlusal surfaces are particularly susceptible to caries formation due to their complex morphology, contributing to higher rates of cavitation compared to smooth surfaces [3]. To address these challenges, interventions such as pit and fissure sealants, resin infiltration, remineralizing agents and flowable composites are utilized [4].

Resin-based sealants and composite materials have become pivotal in modern restorative dentistry due to their ability to bond effectively to enamel and dentin. Sealants, particularly hydrophilic varieties, act as protective barriers, minimizing the risk of cariogenic bacterial penetration in pits and fissures, where caries frequently initiate [5-7]. Flowable composites, on the other hand, offer both functional and aesthetic benefits for restoring carious lesions, with their lower viscosity facilitating adaptation to the tooth structure [8]. However, the effectiveness of these materials is often challenged by microleakage, a critical issue in adhesive dentistry [9].

Microleakage refers to the penetration of bacteria, fluids and contaminants between the restorative material and the tooth surface. This phenomenon can lead to secondary caries, sensitivity and eventual restoration failure [10]. It is influenced by factors such as polymerization shrinkage, improper adhesion and marginal gaps. For sealants and flowable composites, inadequate bonding to enamel or dentin can result in the ingress of saliva and bacteria, increasing the risk of underlying decay [11]. Flowable composites, while easier to apply in small cavities or as liners, are particularly susceptible to polymerization shrinkage, which may exacerbate microleakage by creating marginal gaps [12].

Additionally, material properties such as viscosity play a critical role in adaptation to the tooth surface. Poor adaptation, coupled with inadequate moisture control or improper adhesive protocols, can significantly compromise the bond strength and sealing ability of restorative materials. These factors emphasize the importance of optimizing clinical procedures and material selection to minimize microleakage and ensure restoration longevity.

Emerging technologies such as confocal laser scanning microscopy (CLSM) have advanced the evaluation of microleakage in restorative materials. CLSM enables high-resolution imaging and detailed analysis of material-to-tooth interactions, providing valuable insights for improving clinical outcomes [8,9]. Recent studies underscore the importance of comparing hydrophilic sealants and flowable composites to understand their relative effectiveness in moist conditions, where hydrophilic sealants are believed to perform better due to their superior adaptability [13].

To ensure comprehensive and reproducible evaluations, guidelines such as those established by Ovrebo and Raadal provide standardized methods for microleakage assessment. These include the use of dye penetration techniques to quantify leakage and rank the sealing abilities of dental materials [13]. However, further research is necessary to address gaps such as the long-term durability of these materials, their cost-effectiveness and their application in diverse clinical settings.

This study aims to compare the microleakage of hydrophilic sealants and flowable composites using confocal microscopy, contributing to a better understanding of their performance in restorative dentistry. The findings are expected to inform material innovations and enhance clinical protocols, particularly in challenging environments such as those with high moisture content.

METHODS

Study Design and Sample Size Derivation: This study employed an experimental, randomized 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 mean values from a prior study [14]. An a priori power analysis was conducted with 95% statistical power and a 0.05 alpha error. Based on the t-test family and differences between two independent groups, the calculated sample size was 10 teeth per group, yielding a total of 20 samples.

Ethical Clearance

Ethical approval for the study was obtained from the Saveetha Institutional Research Review Board (SRB/SDC/UG-2004/24/PHD/335). The study adhered to ethical guidelines for the use of extracted human teeth in laboratory research.

Tooth Samples

Twenty extracted third molars with deep pits and fissures were selected for this study. Each sample was thoroughly cleaned and examined visually and with palpation using a dental explorer to confirm the absence of caries and developmental defects. Only teeth with sound occlusal surfaces and deep pits and fissures were included in the study. To ensure uniformity, storage conditions of the teeth were standardized to minimize potential variability.

Randomization

The samples were randomly allocated into two groups using computer-generated random numbers:

- Group I: Ultraseal XT Hydrophilic Sealant
- Group II: Flowable Composite (Ivoclar)

Sealant Placement

The experimental phase was conducted in a controlled laboratory environment at Saveetha Dental College. Standard acid-etching techniques were applied to all samples using 37% orthophosphoric acid.

For Group I (Hydrophilic Sealant)

The etched tooth surfaces were gently dried, ensuring a marginally moist surface with a shiny appearance, as per manufacturer guidelines.

For Group II (Flowable Composite)

The etched tooth surfaces were dried to achieve a white, glacial appearance of the enamel.

Sealant application followed manufacturer protocols for both groups to ensure consistency in the procedure (Figure 1).

Dye Penetration and Thermocycling

To simulate clinical conditions, all samples were immersed in 0.1% rhodamine B isothiocyanate dye at 37°C for 24 hours

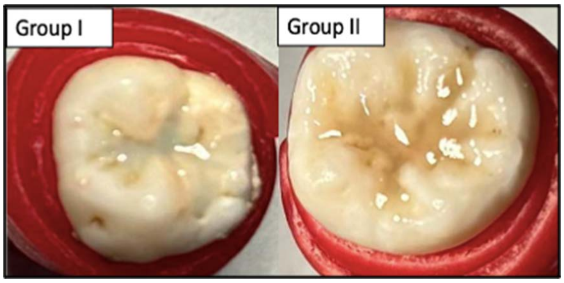

Figure 1: Group I and Group II tooth sample after intervention

Figure 2: Dye Penetrated samples

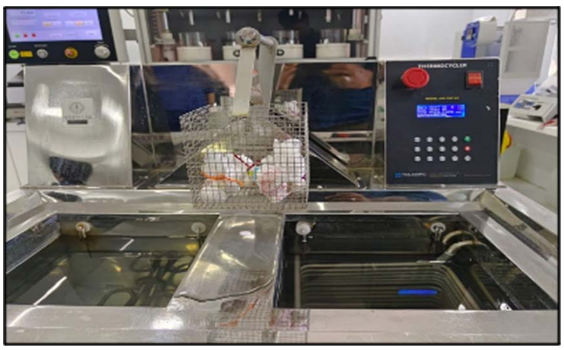

Figure 3: Thermocycling bath

(Figure 2). Following dye penetration, samples underwent thermocycling to mimic oral temperature fluctuations. The thermocycling process ranged from 5°C to 55°C, with a dwell time of 10 seconds at each temperature and 15 seconds for transitions, completing 1500 cycles (Figure 3).

Tooth Sectioning and Microleakage Assessment

Each molar was sectioned mesiodistally into two halves using a low-speed diamond cutting blade. The sections were then evaluated for microleakage under a confocal microscope (Figures 4 and 5). Microleakage was assessed using the Ovrebo and Raadal scoring criteria [15], which quantify dye penetration at restoration margins.

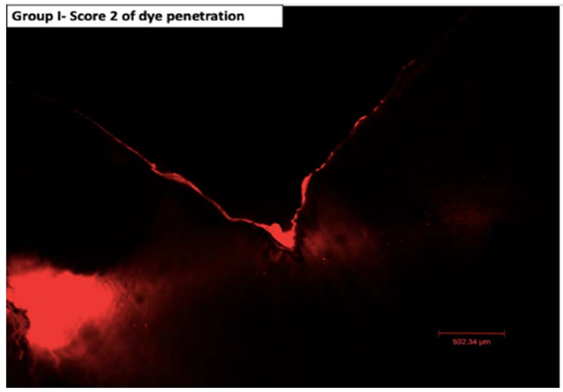

Figure 4: Confocal microleakage image of Group I

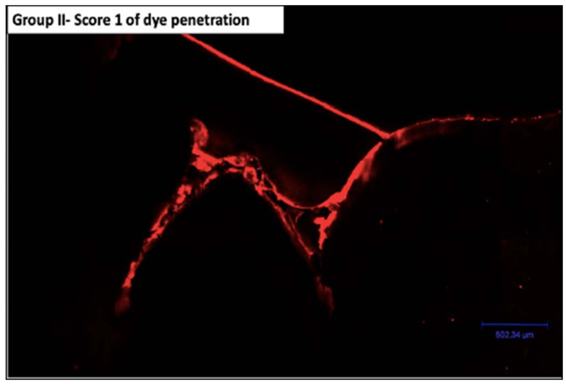

Figure 5: Confocal microleakage image of Group II

Double-Blind Assessment

To minimize bias, two calibrated examiners independently scored the samples. Both examiners were blinded to group allocation and had no prior involvement in the study. Calibration was conducted prior to the study to ensure consistency in scoring.

Statistical Analysis

Microleakage scores were analyzed using SPSS software version 20.0 (IBM Corp, Armonk, NY, USA). Data were expressed as frequencies, percentages and median values. The Mann-Whitney U test was employed to compare the two groups. A p-value of less than 0.05 was considered statistically significant, indicating meaningful differences in microleakage between the two groups.

RESULTS

The frequency distribution of microleakage scores is depicted in Figure 6. Dye penetration scores of 0 were observed in three samples from Group I (hydrophilic sealants) and one sample from Group II (flowable composites). Scores of 1 were observed in six samples from Group I and four samples from Group II. Only one sample in Group I exhibited a score of 2, compared to five samples in Group II.

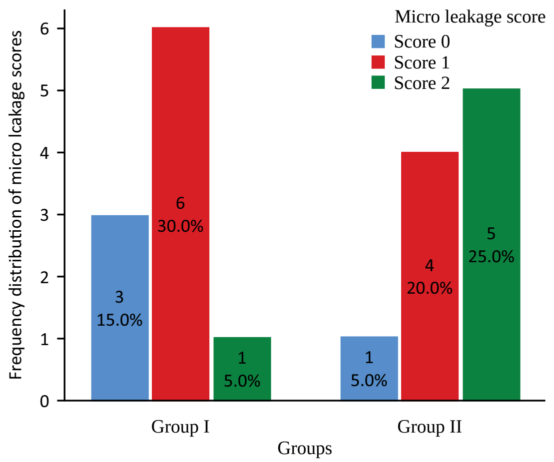

Figure 6: Distribution of microleakage scores between the Groups

Table 1: Comparison of microleakage scores between the Groups

Groups	Median	Mean Rank	Mann whitney U test value	p-value
Group I	1.0	8.20	27.00	0.041*
Group II	1.5	12.80		

The median microleakage scores for Group I and Group II were 1.0 and 1.5, respectively, with mean rank values of 8.20 for Group I and 12.80 for Group II. Statistical analysis using the Mann-Whitney U test yielded a test value of 27.00, with a p-value of 0.041. These findings indicate a statistically significant difference, with hydrophilic sealants demonstrating superior marginal sealing ability by exhibiting significantly less dye penetration compared to flowable composites (Table 1).

DISCUSSION

Microleakage remains a critical challenge in restorative dentistry due to its potential to compromise restoration longevity, cause secondary caries and lead to restoration failure. The results of this study demonstrate that hydrophilic sealants exhibit significantly less microleakage compared to flowable composites, aligning with previous findings on the superior adaptability of hydrophilic materials in moist environments [16,17].

Hydrophilic sealants' reduced microleakage can be attributed to their ability to form longer resin tags and their lower viscosity, which allow for better penetration and adhesion even in challenging clinical conditions. Conversely, flowable composites are more prone to polymerization shrinkage, leading to marginal gaps and increased microleakage [18,19]. These findings highlight the clinical relevance of hydrophilic sealants, particularly for cases involving moisture-prone conditions or high-risk patients, such as pediatric and geriatric populations.

The use of confocal laser scanning microscopy (CLSM) in this study provides a high-resolution analysis of marginal integrity, offering valuable insights into the performance of adhesive materials under thermocycling stress. Previous studies have shown that etch-and-rinse systems outperform self-etch and self-adhesive systems and the current findings reinforce the importance of selecting adhesive protocols carefully for optimizing clinical outcomes [20,21].

Limitations

This study has several limitations. The study used a relatively small sample size (n = 20), which may limit the generalizability of the findings. Future studies with larger sample sizes are needed to validate these results. The study was conducted under laboratory conditions, which may not fully replicate the complexities of the oral environment. Clinical studies are needed to evaluate real-world performance. Only one hydrophilic sealant and one flowable composite were evaluated. Exploring additional brands and formulations could provide a broader understanding of material performance. The study did not assess long-term durability or wear resistance of the materials, which are critical for determining restoration longevity.

CONCLUSION

The study demonstrated that hydrophilic sealants outperform flowable composites in minimizing microleakage, with significantly lower dye penetration scores observed in Group I. These findings underscore the clinical advantages of hydrophilic sealants, particularly in moisture-prone environments where conventional materials may fail.

The results emphasize the importance of careful material selection and meticulous application techniques to enhance restoration longevity. Future research should focus on long-term clinical trials, cost-effectiveness analyses and innovations in adhesive systems to optimize restorative outcomes and improve patient satisfaction.

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Conflict of Interest

The authors declare no conflict of interest related to this study. All affiliations and contributions were transparently reported to ensure unbiased analysis and interpretation of results.

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