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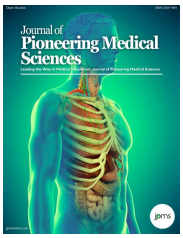

Assessment of Dye Penetration and Penetration Depth of Hydrophilic Sealant and Flowable Composite

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Abstract **Objectives:** Pit and fissure sealants provide a protective barrier against microbial infiltration and plaque accumulation, effectively reducing the risk of occlusal caries. However, microleakage remains a significant challenge, influencing sealant efficacy. This study evaluates and compares the penetration depth and microleakage of hydrophilic sealants and flowable composites under in vitro conditions. **Methods:** Twenty extracted third molars with deep pits and fissures were randomly divided into two groups. Acid etching was performed using 37% orthophosphoric acid, followed by the application of either a hydrophilic sealant or a flowable composite. Samples were immersed in 1% Methylene blue dye for 24 hours to assess microleakage. After sectioning, penetration depth was measured using a stereo-microscope. Statistical analysis was conducted using SPSS software (Version 20.0, IBM Corp, Armonk, NY, USA) with the Mann-Whitney U test. **Results:** The hydrophilic sealant group exhibited significantly lower dye penetration and higher penetration depth percentages compared to the flowable composite group, indicating superior sealing properties and adaptability. **Conclusion:** Hydrophilic sealants demonstrated better performance in terms of reduced microleakage and enhanced penetration depth compared to flowable composites, making them a promising choice for fissure sealing, particularly in conditions with moisture challenges. Further studies are recommended to confirm these findings and assess long-term clinical performance..

Key Words Pit and fissure sealants, hydrophilic sealants, flowable composites, microleakage, penetration depth

INTRODUCTION

Dental caries is a bacterial condition affecting a significant proportion of the population globally and remains a major public health challenge despite advancements in preventive strategies [1]. Over recent decades, the prevalence of dental caries in children and adolescents has declined in industrialized countries, primarily due to effective preventive measures. However, occlusal caries continues to be a significant concern due to the complex morphology of pits and fissures on the occlusal, buccal, and palatal surfaces of molar teeth. These areas are highly susceptible to caries development because they readily trap food particles and dental plaque, which are difficult to remove through routine oral hygiene practices.

Pit and fissure sealants act as a mechanical barrier, preventing the accumulation of plaque and microbial infiltration in these vulnerable areas. Among preventive methods, sealant application is one of the most reliable and cost-effective approaches for reducing the risk of occlusal caries. When compared to untreated surfaces, the application of sealants significantly decreases caries incidence and is less costly than restorative treatments. Pre-application techniques, such as air abrasion, enameloplasty, or fissurotomy, may enhance sealant effectiveness; however, each tooth's unique fissure shape and depth necessitate individualized application methods.

Various materials have been developed as pit and fissure sealants, including glass ionomer, resin, flowable composites,

and more recently, giomer-based sealants. These materials have been extensively tested in vivo and in vitro, yet no single material has been universally recommended as the ideal pit and fissure sealer. The ability of sealants to flow into pits and fissures and thoroughly fill them without air entrapments is a critical factor contributing to their efficacy. Traditional sealants, often composed of bisphenol A-glycidyl methacrylate (bis-GMA), are hydrophobic, requiring a dry working environment to ensure adhesion. In conditions where isolation is challenging, hydrophilic sealants have been developed as an alternative. These sealants exhibit superior performance in moist environments, offering a practical solution for clinical conditions where dryness cannot be maintained [2]. Similarly, flowable composites have gained attention as potential sealants due to their enhanced wear resistance and bonding strength. These composites are particularly advantageous in cases with widened occlusal fissures, providing improved abrasion resistance and favourable marginal adaptability compared to conventional filled sealants.

Microleakage, the movement of bacteria, oral fluids, or ions through microscopic gaps between the tooth and restoration, is a critical determinant of sealant success. Studies have shown that lower viscosity materials exhibit better marginal adaptation, thereby reducing microleakage and enhancing sealant retention. Consequently, using low-viscosity sealing materials can improve initial sealing effectiveness and minimize long-term failure risks.

Sealant penetration depth is another key factor influencing retention and longevity. Effective penetration into the depths of pits and fissures ensures better adaptation to lateral walls and increases the sealant's durability. Factors such as fissure morphology, the material's flowability, and the interaction between the sealant and enamel affect the penetration depth [3,4]. The durability of sealants is largely contingent on their ability to prevent microleakage and maintain an effective seal over time.

The present study aims to evaluate and compare the penetration depth and microleakage of two sealant materials-hydrophilic sealants and flowable composites-under in vitro conditions. By analyzing these parameters, the study seeks to identify a more effective material for clinical application, particularly in situations where moisture control poses a challenge.

METHODS

Sample Size Estimation: This randomized in vitro experimental study utilized a total of 20 extracted third molars. The sample size was determined based on the study conducted by Saini *et al.* [5] using G*Power software (Version 3.1.9.6). A priori power analysis was performed using a t-test, incorporating differences in the mean and standard deviation values of Tetri N Flow and Helioseal F groups.

Ethical Approval

The study protocol received ethical clearance from the Saveetha Institutional Research Review Board (SRB/SDC/UG-2038/24/PHD/337) before commencing the experimental phase.

Pretreatment of Tooth Samples

Twenty intact maxillary or mandibular third molars without caries were selected. The samples were cleaned thoroughly to remove saliva, debris, calculus, and soft tissue using an ultrasonic scaler. After cleaning, the teeth were air-dried and stored in normal saline at room temperature until the intervention phase. Standardized tooth morphology was ensured to minimize variability.

Randomization

A simple randomization technique using a coin flip was employed to allocate the samples into two groups:

- **Group I:** Ultraseal XT Hydrophilic sealant
- **Group II:** Flowable composite (Ivoclar)

Intervention

The experimental phase was conducted in the White Research Lab, Saveetha Dental College. The occlusal surfaces of the teeth were etched with 37% orthophosphoric acid, following the manufacturer's protocol for both groups.

- **For Group I (Hydrophilic sealant):** The teeth were mildly dried, leaving a moist surface to achieve a glossy appearance
- **For Group II (Flowable composite):** The teeth were dried to exhibit a frosty white appearance

A periodontal probe tip was carefully moved through the pits and fissures during sealant application to prevent air entrapment and void formation (Figure 1).

Immersion in Dye and Thermocycling Process

To assess dye penetration, the samples were immersed in 1% Methylene blue solution for 24 hours at room temperature (Figure 2). Subsequently, thermocycling was performed, simulating oral conditions with temperatures cycling between 5°C and 55°C. Each cycle included a 15-second dwell time at each temperature and a transition time of 10 seconds, with a total of 1500 cycles.

Tooth Sectioning and Microleakage and Penetration Depth Assessment

The teeth were sectioned buccolingually through the central fossa using a low-speed diamond cutting blade. Each section was visualized under a stereo microscope at 10x magnification, and images were captured (Figures 3 and 4). The Ovrebo and Raadal scoring criteria [6] were adopted to evaluate dye penetration.

The penetration depth of the sealing material was measured using images imported into CorelDraw software at 100% magnification. Measurement tools within the software were utilized to estimate the depth of penetration. The deepest concavity or upper meniscus of the sealing material was identified as the top of the fissure. The material penetration percentage was calculated by dividing the length of the sealing material by the total depth of the fissure, expressed as a percentage of occlusal groove sealing.

Figure 1: Figures depicting Group I and Group II samples after sealant intervention

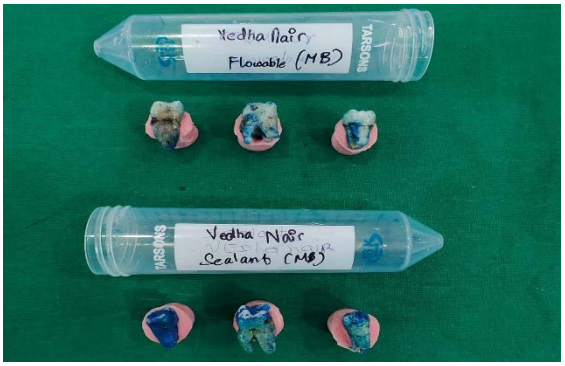

Figure 2: Methylene Blue dye penetrated tooth samples

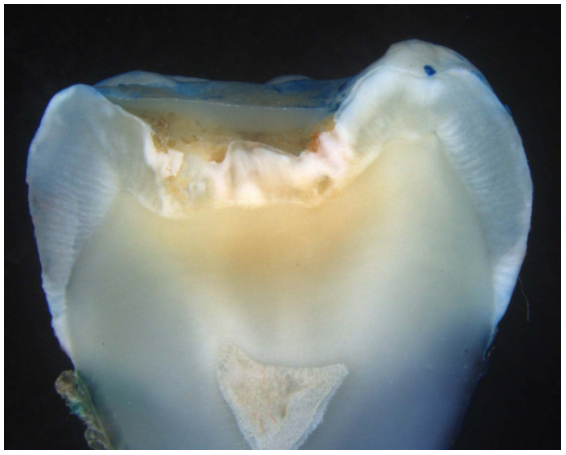

Figure 3: Stereo microleakage image of group I. sample shows score 1

Outcome Analysis

The data were analyzed using SPSS software (Version 20.0, IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequency, percentage, mean, and standard deviation, were computed. Group differences were analyzed using the Mann-Whitney U test.

RESULTS

The dye penetration scores for both groups are illustrated in Figure 5. In the hydrophilic sealant group (Group I), four tooth samples exhibited a score of 0, indicating no dye penetration. Eleven samples had a score of 1, with five samples belonging to Group I and six to the flowable composite group (Group II). One sample from Group I and three samples from Group II exhibited a score of 2. Only one sample in Group II had a score of 3, while none of the samples in Group I exhibited this highest level of dye penetration.

The comparison of microleakage scores between the groups is shown in Figure 8. The mean rank for Group I was 7.75, whereas for Group II, it was 13.25, indicating significantly lower microleakage in Group I compared to Group II. The Mann-Whitney U test confirmed this difference to be statistically significant ($p = 0.022$), highlighting the superior performance of the hydrophilic sealant in minimizing microleakage (Table 1).

The penetration depth of the sealing material is presented in Figure 6 and Table 2. The mean penetration depth percentage for Group I (hydrophilic sealant) was 82.22±1.31, whereas for Group II (flowable composite), it was 79.44±1.36. The Mann-Whitney U test yielded a p-value of 0.001, indicating a statistically highly significant difference

Table 1: Comparison of Dye penetration scores between the Groups

Groups	Mean Rank	Mann whitney U test value	p-value
Group I	7.75	22.50	0.022*
Group II	13.25		

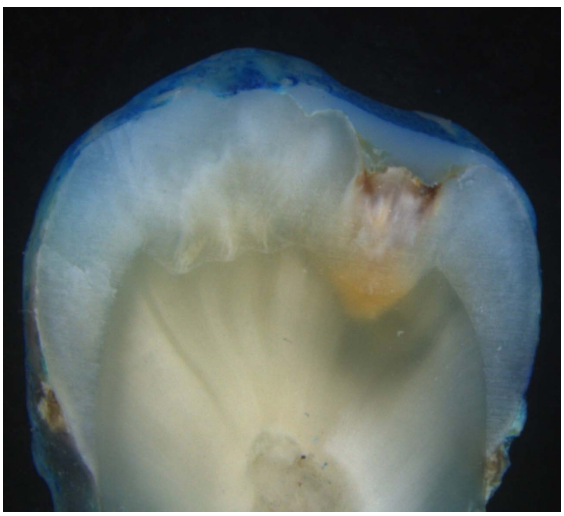

Figure 4: Stereo microleakage image of group II

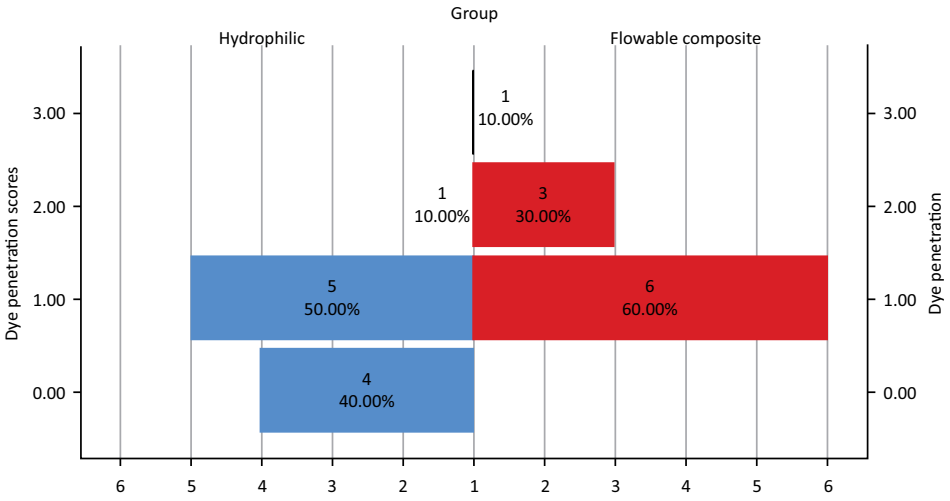

Figure 5: Distribution of dye penetration scores between the groups

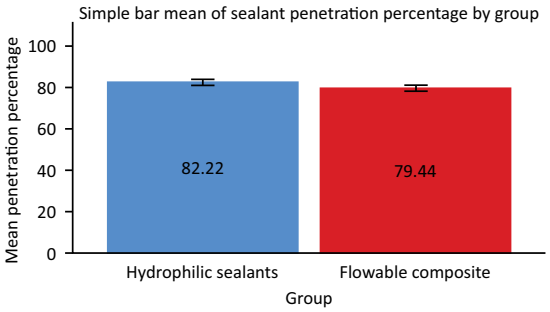

Figure 6: Distribution of sealing material penetration depth between the groups

between the two groups. These results underscore the superior penetration ability of the hydrophilic sealant compared to the flowable composite.

DISCUSSION

Pit and fissure sealants are widely recognized as a critical preventive measure for occlusal caries. An ideal sealant material must exhibit properties such as biocompatibility, retention, resistance to wear, and effective sealing against microleakage [7-10]. In this study, Group I (hydrophilic sealant) demonstrated significantly less dye penetration and better penetration depth compared to Group II (flowable composites). These results align with findings from Sharma *et al.* [2], who reported that hydrophilic sealants have superior marginal integrity and retention due to their low viscosity and wetting properties.

Similarly, Askarizadeh *et al.* [11] and Panse *et al.* [12] found that hydrophilic sealants exhibit the least microleakage under moist conditions compared to hydrophobic counterparts. However, studies by Khogli *et al.* [13] highlighted that improper application techniques, such as insufficient isolation, could lead to increased microleakage in hydrophilic sealants. Techniques like bur enameloplasty were suggested to improve outcomes in such cases.

Kakaboura *et al.* [14] observed that low-viscosity resin composites perform better in shallow and wide fissures, whereas unfilled resin sealants are more effective in deep and narrow fissures. The use of hydrophilic bonding agents combined with hydrophobic sealants was also noted to enhance material penetration in challenging fissure morphologies. These findings underscore the importance of tailoring sealant material and technique based on fissure anatomy.

Contrary to the findings of this study, Ku *et al.* [16] reported that hydrophilic sealants such as Wetbond™ and Ultraseal XT® hydro showed higher microleakage compared to Clinpro on moist enamel. These discrepancies highlight the variability in outcomes based on application techniques, environmental conditions, and material formulations. Schlueter *et al.* [17] further emphasized that certain moisture-tolerant hydrophilic sealants might perform poorly over extended periods compared to traditional hydrophobic sealants, suggesting a need for long-term clinical evaluations.

Resin-based sealants share similar chemistry with composites but require lower viscosity for deeper penetration into conditioned enamel surfaces [18]. Hatirli *et al.* [19] demonstrated that unfilled resin-based sealants like Clinpro exhibit superior penetration depth, while Gisour *et al.* [20] reported that self-adhering flowable composites achieve better retention and marginal integrity due to their simplified application process.

Corona *et al.* [21] also noted that flowable restorative systems outperform conventional sealants in terms of retention, particularly in primary teeth, with excellent outcomes over a one-year follow-up. These findings highlight the potential for using flowable composites as an alternative to traditional sealants in specific clinical scenarios.

The results of this study provide compelling evidence for the efficacy of hydrophilic sealants in reducing microleakage and enhancing penetration depth, particularly in environments where moisture control is challenging. However, the variability in outcomes reported in the literature underscores the need for standardized protocols and further research to optimize sealant performance.

CONCLUSION

This study compared the microleakage and penetration depth of hydrophilic sealants and flowable composites in sealing pits and fissures to prevent occlusal caries. The findings demonstrated that hydrophilic sealants significantly outperformed flowable composites in both parameters. The superior performance of hydrophilic sealants is attributed to their low viscosity and ability to adapt better to moist environments, resulting in enhanced sealing properties and retention. These results suggest that hydrophilic sealants could be a preferable choice in clinical situations where moisture control is challenging. However, further clinical studies with larger sample sizes and longer follow-up periods are required to validate these results and assess the long-term performance of hydrophilic sealants compared to flowable composites.

Limitations

This study has certain limitations that should be addressed in future research. The small sample size (20 teeth) limits the generalizability of the findings. Additionally, the study was conducted under in vitro conditions, which do not fully replicate the complexities of the oral environment, such as saliva, masticatory forces, and thermal fluctuations. Further clinical trials with larger cohorts and long-term follow-ups are necessary to validate the in vitro results and assess their clinical applicability.

Future Scope

Future research should focus on evaluating the performance of hydrophilic sealants and flowable composites under real-world clinical conditions. Investigating their retention rates and resistance to wear over extended periods would provide valuable insights. Moreover, exploring the use of advanced materials or combinations, such as nanofilled sealants or hydrophilic-hydrophobic hybrids, could help develop sealants with superior performance characteristics. Studies assessing the cost-effectiveness and ease of application of these materials would also be beneficial for broader adoption in diverse clinical settings.

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Conflict of Interest

The authors declare no conflicts of interest related to this study. All authors have reviewed and approved the final manuscript and confirm that there are no affiliations, financial arrangements, or other involvements that could be perceived as a potential source of bias.

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