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Pit and Fissure Sealants in Caries Prevention: Materials, Clinical Effectiveness, And Modern Approaches

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Abstract

Pit and fissure sealants are widely recognized as an effective preventive measure against occlusal caries, particularly in children and adolescents. Due to the complex morphology of occlusal surfaces, these areas are highly susceptible to plaque accumulation and demineralization. This review aims to evaluate the clinical effectiveness of different sealant materials, application techniques, and recent advancements in sealant technology. The findings indicate that proper application and material selection significantly influence long-term retention and caries prevention. Modern developments, including bioactive and antimicrobial sealants, offer additional benefits and may enhance clinical outcomes.

Keywords: Pit and fissure sealants, caries prevention, bioactive materials, retention, minimally invasive dentistry.

Introduction

Dental caries remains one of the most prevalent chronic diseases worldwide and continues to represent a significant public health burden despite substantial progress in preventive dentistry. Its multifactorial etiology involves complex interactions between dental biofilm, dietary carbohydrates, host susceptibility, and time. Although overall caries prevalence has decreased in some populations due to fluoride exposure and improved oral hygiene practices, occlusal caries in posterior teeth remains a persistent clinical challenge.

The occlusal surfaces of molars and premolars are particularly susceptible to caries development due to their intricate anatomical morphology. Deep pits, narrow fissures, and irregular grooves create a favorable microenvironment for plaque accumulation and bacterial colonization. These areas are often inaccessible to conventional mechanical cleaning methods, such as toothbrushing, which limits effective biofilm removal. As a result, acids produced by cariogenic microorganisms can accumulate within these confined spaces, leading to localized demineralization of enamel and the initiation of carious lesions.

In response to these challenges, pit and fissure sealants were introduced as a targeted preventive intervention aimed at modifying the ecological conditions within susceptible occlusal surfaces. Sealants function by forming a micromechanical bond with etched enamel, thereby creating a durable physical barrier that prevents the penetration of microorganisms, fermentable substrates, and acids into fissures. By effectively isolating these high-risk areas from the oral environment, sealants interrupt the caries process at an early stage and significantly reduce the likelihood of lesion development.

Over the past decades, numerous clinical studies have confirmed the effectiveness of fissure sealants in reducing caries incidence, particularly among children and adolescents with elevated caries risk. Their success is largely dependent on long-term retention and proper clinical application, including adequate isolation, surface preparation, and material selection. Furthermore, the evolution of dental materials has led to the development of advanced sealant systems, including fluoride-releasing, bioactive, and nanotechnology-enhanced formulations, which provide additional preventive benefits beyond mechanical sealing.

Given the continuous advancements in material science and preventive strategies, there is a growing need to critically evaluate the current evidence regarding fissure sealants. Therefore, this article aims to provide a comprehensive review of contemporary sealant materials, analyze their clinical performance and retention characteristics, and discuss recent innovations that may influence future directions in preventive and minimally

invasive dentistry.

Method

A narrative review of the scientific literature was conducted to assess the current evidence regarding the effectiveness and clinical application of pit and fissure sealants in caries prevention. A comprehensive search strategy was implemented using major electronic databases, including PubMed, Scopus, and ScienceDirect. The search covered publications from January 2015 to December 2025 to ensure the inclusion of the most recent and clinically relevant studies in this field.

Search queries were developed using a combination of controlled vocabulary and free-text keywords, including "fissure sealants," "pit and fissure sealing," "caries prevention," "resin-based sealants," and "glass ionomer sealants." Boolean operators (AND, OR) were applied to optimize search sensitivity and specificity. Additionally, manual screening of reference lists from selected articles was performed to identify further relevant publications not captured during the initial database search.

The selection process was carried out in multiple stages. Initially, titles and abstracts were screened to exclude irrelevant studies. Subsequently, full-text articles were evaluated according to predefined inclusion and exclusion criteria. Only studies providing substantial data on sealant materials, retention rates, or caries-preventive effectiveness were included in the final analysis.

Clinical trials and in vitro studies investigating pit and fissure sealants, studies specifically evaluating sealant retention, longevity, or caries-preventive efficacy, peer-reviewed articles published in English, studies with clearly described methodology and measurable outcomes

Case reports, narrative opinions, and non-peer-reviewed publications, studies not directly related to fissure sealing or occlusal caries prevention, articles lacking methodological transparency or sufficient data reporting, duplicate publications or studies with overlapping datasets

Data extraction focused on key variables, including type of sealant material, application technique, follow-up duration, and reported clinical outcomes such as retention rate and caries incidence. Due to heterogeneity in study design and outcome measures, a qualitative synthesis approach was adopted rather than a meta-analysis.

Results and Discussion

Pit and fissure sealants function by establishing a micromechanical and, in some cases, chemical barrier over susceptible occlusal surfaces, thereby preventing bacterial colonization and the accumulation of fermentable substrates within pits and fissures. Following acid etching, the enamel surface develops micro-porosities that facilitate resin penetration and the formation of resin tags, ensuring durable adhesion.

By effectively sealing these anatomically complex areas, sealants isolate the underlying enamel from the oral environment, disrupting the ecological conditions necessary for cariogenic biofilm activity. This interruption halts the diffusion of acids into enamel and prevents further demineralization, thereby arresting the caries process at a reversible stage.

In addition to their physical barrier function, certain sealant materials exhibit therapeutic properties through the controlled release of fluoride, calcium, or phosphate ions. These ions contribute to the remineralization of adjacent enamel and enhance resistance to acid attacks. Consequently, modern sealants serve not only as passive barriers but also as active participants in caries prevention.

Resin-based sealants remain the gold standard in clinical practice due to their superior retention rates and favorable mechanical properties. These materials are typically composed of bis-GMA or urethane dimethacrylate resins and require meticulous moisture control during application to ensure optimal bonding.

The success of resin-based sealants largely depends on proper enamel conditioning through phosphoric acid etching, which enhances micromechanical retention. When correctly applied, these sealants can provide long-term protection against occlusal caries.

Glass ionomer sealants offer distinct advantages in clinical situations where moisture control is challenging, such as partially erupted molars or pediatric patients with limited cooperation. Unlike resin-based materials, glass ionomers exhibit chemical adhesion to tooth structure and are less technique-sensitive.

A key feature of these materials is their ability to release fluoride over time, which contributes to ongoing remineralization and inhibition of bacterial activity. Although their retention rates are generally lower compared to resin-based sealants, their cariostatic effect compensates for this limitation.

Recent advancements in dental materials have led to the development of bioactive sealants capable of interacting dynamically with the oral environment. These materials release calcium, phosphate, and fluoride ions in response to environmental changes, promoting remineralization and enhancing enamel resistance.

Bioactive sealants represent a shift toward therapeutic materials that not only provide mechanical protection but also actively contribute to tissue repair and biofilm modulation. Their potential to improve long-term clinical outcomes makes them a promising area of ongoing research.

Extensive clinical evidence supports the effectiveness of pit and fissure sealants in reducing the incidence of occlusal caries. Studies have demonstrated that properly applied sealants can reduce caries risk by up to 70–90% in high-risk populations.

Retention rate is a critical determinant of clinical success, as the protective effect of sealants is directly related to their ability to remain intact over time. Partial or complete loss of sealant material may lead to renewed exposure of

fissures to cariogenic factors.

Furthermore, clinical effectiveness is highly dependent on operator technique, including adequate cleaning of the tooth surface, proper isolation from saliva contamination, and precise application of the material. Regular follow-up and reapplication, when necessary, are essential components of long-term preventive care

The longevity and effectiveness of fissure sealants are influenced by multiple clinical and material-related factors:

- **Moisture contamination**: Salivary contamination during application significantly compromises adhesion and reduces retention

- **Inadequate enamel etching**: Insufficient etching results in poor micromechanical bonding

- **Occlusal stress and wear**: Mechanical forces during mastication may lead to gradual material degradation

- **Operator technique**: Clinical skill and adherence to protocol are critical for optimal outcomes

In addition, patient-related factors such as oral hygiene, dietary habits, and caries risk status also influence sealant longevity. Continuous monitoring and maintenance are therefore essential for sustained effectiveness.

Pit and fissure sealants offer several well-established advantages: Minimally invasive approach that preserves natural tooth structure, high efficacy in preventing occlusal caries, particularly in children and adolescents, cost-effectiveness in both individual and public health settings, ease of application and patient acceptance.

These characteristics make sealants a cornerstone of modern preventive dentistry.

Despite their clinical benefits, fissure sealants have certain limitations: Technique sensitivity, particularly for resin-based materials, risk of microleakage in cases of incomplete adaptation or partial loss, dependence on regular clinical monitoring and maintenance, variability in long-term performance across different materials.

Addressing these limitations requires improvements in material design and standardization of clinical protocols.

Future developments in fissure sealant technology are expected to focus on the creation of advanced materials with enhanced functionality. These include self-adhesive systems that reduce technique sensitivity, as well as antibacterial sealants capable of inhibiting biofilm formation.

Nanotechnology-enhanced materials are being активно investigated for their ability to improve penetration into microstructures and provide sustained ion release. In addition, the development of “smart” materials with controlled and stimuli-responsive behavior may enable more precise and individualized preventive strategies.

The integration of these innovations into clinical practice has the potential to further improve the effectiveness of fissure sealing and expand its role in minimally invasive dentistry.

Conclusion

Pit and fissure sealants continue to represent a fundamental component of contemporary preventive dentistry, providing a highly effective and minimally invasive approach to the control of occlusal caries. Their ability to create a durable physical barrier over anatomically susceptible surfaces allows for the interruption of cariogenic processes at an early, reversible stage, thereby preserving the structural integrity of enamel and reducing the need for restorative interventions.

Ongoing advances in dental material science have significantly enhanced the performance characteristics of sealants, including improved adhesion, increased wear resistance, and the incorporation of bioactive properties such as fluoride and calcium-phosphate ion release. These innovations have expanded the clinical indications for sealant use and contributed to more predictable and long-lasting preventive outcomes. In particular, the development of bioactive and nanotechnology-enhanced sealants reflects a shift toward therapeutic materials that actively participate in remineralization and modulation of the oral environment.

However, the clinical success of fissure sealants remains highly dependent on proper application technique, including effective isolation, adequate enamel conditioning, and precise material placement. Equally important is the implementation of regular follow-up protocols to monitor sealant integrity and ensure timely maintenance or reapplication when necessary.

In this context, pit and fissure sealants not only serve as a preventive measure but also as an integral element of minimally invasive dentistry and risk-based patient management. Their routine use, particularly in high-risk populations, can significantly reduce caries incidence and support long-term oral health outcomes.

In conclusion, fissure sealants remain a reliable, evidence-based preventive strategy, and their continued evolution through material innovation and improved clinical protocols is expected to further strengthen their role in modern therapeutic dentistry.

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