

Review Article

Evaluating the effectiveness of dental sealants in caries prevention and tooth protection

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ABSTRACT

Dental sealants are a proven preventive measure against dental caries, particularly on occlusal surfaces of molars and premolars, which are prone to decay. By forming a protective barrier over pits and fissures, sealants inhibit the accumulation of food particles and colonization by cariogenic bacteria. Resin-based sealants, known for their high retention and mechanical durability, are widely used, while glass ionomer sealants provide additional benefits through fluoride release, promoting remineralization and caries prevention even in areas not directly covered by the material. The effectiveness of sealants depends on factors such as the choice of material, application techniques, and environmental conditions during the procedure. Acid etching and proper isolation are critical to achieving optimal adhesion, while innovations in light-curing technologies have further enhanced sealant performance. Long-term studies highlight the importance of regular follow-up to monitor retention, address microleakage, and repair or replace worn sealants. Despite their benefits, challenges such as cost, patient compliance, and material degradation over time limit the broader application of sealants. Emerging concerns over potential biocompatibility issues, such as bisphenol A release, have prompted the development of safer alternatives. Advances in bioactive sealants and minimally invasive application techniques hold promise for improving outcomes, especially in high-risk populations. Sealants remain a cornerstone of preventive dental care, significantly reducing the risk of caries when properly applied and maintained. Tailored strategies to enhance awareness, improve access, and optimize application protocols can expand their role in reducing the global burden of dental diseases. Future innovations in materials and techniques are expected to address existing challenges, ensuring that dental sealants continue to play a vital role in promoting oral health.

Keywords: Dental sealants, Caries prevention, Fluoride release, Resin-based sealants, Bioactive materials

INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases worldwide, affecting both children and adults. Despite advancements in oral healthcare, the prevention of caries remains a critical focus for dental professionals.

Among various preventive strategies, the use of dental sealants has garnered significant attention for its ability to provide a physical barrier against cariogenic microorganisms and food particles, particularly on occlusal surfaces prone to decay. These sealants are thin coatings applied to the chewing surfaces of molars and

premolars, which are most vulnerable to pit-and-fissure caries due to their anatomical complexity.¹

Dental sealants offer a non-invasive and cost-effective approach to caries prevention, with their effectiveness supported by numerous clinical trials and systematic reviews. The American Dental Association (ADA) and the Centers for Disease Control and Prevention (CDC) advocate for the routine use of sealants, especially in populations at high risk for dental caries, such as school-aged children and socioeconomically disadvantaged groups.² Despite this, the uptake of sealants remains suboptimal in many regions, highlighting the need for increased awareness and accessibility. The effectiveness of dental sealants is influenced by multiple factors, including the material used, application techniques, and patient-specific variables. Resin-based sealants are widely used due to their superior mechanical properties and retention rates; however, glass ionomer sealants offer advantages in patients with limited cooperation or in settings where moisture control is challenging.³ Furthermore, advances in adhesive dentistry and light-curing technologies have improved the longevity and clinical performance of sealants, making them an integral part of preventive dental care.

Evidence from longitudinal studies has demonstrated the efficacy of sealants in reducing caries incidence by as much as 80% within the first two years of application, with significant benefits persisting for up to four years.⁴ However, concerns regarding sealant retention and potential microleakage have led to ongoing research aimed at optimizing materials and application protocols. Additionally, debates continue over the use of sealants in cases where non-cavitated lesions are already present, as some clinicians argue that sealing such lesions may promote caries arrest rather than progression.

REVIEW

Dental sealants play a critical role in modern preventive dentistry by providing a protective barrier against caries on susceptible tooth surfaces. Studies have demonstrated their efficacy in significantly reducing the risk of occlusal caries, particularly in children and adolescents. The effectiveness of sealants is primarily attributed to their ability to block cariogenic bacteria and prevent the accumulation of food debris within the pits and fissures of molars and premolars. Resin-based sealants, in particular, have shown high retention rates and superior longevity, making them a preferred choice among dental practitioners.⁵

Despite their proven benefits, the clinical success of sealants depends on several factors, including the quality of application, material properties, and patient compliance with follow-up care. Moisture control during application is crucial, as sealants placed under suboptimal conditions may exhibit compromised retention and increased risk of microleakage. Glass ionomer sealants, which can be

applied in moist environments, are an alternative, though their retention rates are generally lower compared to resin-based counterparts.⁶ Further research is warranted to explore innovations in sealant materials and techniques that could enhance their durability and effectiveness. Continued education for practitioners and public health initiatives can also help improve the adoption and utilization of sealants in high-risk populations.

Mechanism of action of dental sealants in caries prevention

Dental sealants are primarily designed to prevent caries by creating a physical barrier over the pits and fissures of teeth. These surfaces are particularly susceptible to decay due to their anatomic complexity, which promotes the retention of food debris and bacteria. Sealants act by blocking these fissures, preventing colonization by cariogenic microorganisms such as *Streptococcus mutans* and *Lactobacillus species*.⁷ This mechanism is most effective when the sealant adheres securely to the enamel, creating a continuous layer that inhibits the penetration of nutrients required for bacterial metabolism and growth.

The application process of sealants involves the preparation of tooth surfaces using techniques that enhance adhesion. Acid etching is a critical step in this process, creating microporosities on the enamel surface that improve the mechanical interlocking of the sealant material. Once applied, the material polymerizes and solidifies, forming a robust barrier that reduces the diffusion of acids produced by bacterial fermentation. This acid-neutralizing effect minimizes enamel demineralization and further protects the tooth structure.⁸ Advances in adhesive dentistry have introduced light-cured sealants that ensure rapid polymerization and a higher degree of cross-linking, enhancing their resistance to wear and microleakage.

Different sealant materials exhibit varied mechanisms of action, contributing to their efficacy. Resin-based sealants, the most widely used, rely on their hydrophobic properties and high mechanical strength to create a durable barrier. Their ability to withstand the occlusal forces of chewing makes them particularly effective in protecting molars. On the other hand, glass ionomer sealants offer a unique advantage due to their fluoride-releasing capabilities. Fluoride ions released from these sealants can penetrate adjacent enamel and inhibit demineralization, even in areas not directly covered by the sealant. This property is particularly beneficial for patients with high caries risk, as it provides an additional layer of chemical protection.⁹

The retention of sealants, a critical factor in their effectiveness, depends largely on the type of material used and the conditions under which they are applied. Studies have shown that sealants placed on well-isolated and dry surfaces demonstrate better longevity and adhesion. However, in environments where moisture control is challenging, such as when treating young or uncooperative

patients, the use of moisture-tolerant sealants like glass ionomer is preferred, even if their retention rates are slightly lower.¹⁰ Longitudinal studies highlight the cumulative effect of sealants in reducing caries incidence over time. For instance, research has demonstrated that teeth sealed during early childhood exhibit lower rates of decay in adolescence, supporting the preventive and protective role of these materials. However, the long-term success of sealants is contingent upon regular follow-ups and maintenance, as wear and material degradation can compromise their integrity. This underscores the importance of routine dental visits to ensure sealants remain intact and effective in their role.¹¹

Comparative effectiveness of sealant materials

Dental sealants are available in various materials, each with distinct properties that influence their performance in preventing caries. Resin-based sealants and glass ionomer sealants are the most commonly used types, with advancements in materials continually enhancing their efficacy. Resin-based sealants are typically preferred for their durability and high retention rates. Their hydrophobic nature ensures strong adhesion to the enamel when applied under optimal isolation and dry conditions. Studies have shown that resin-based sealants can retain their effectiveness for up to five years, with proper application techniques playing a crucial role in maximizing their longevity.¹² On the other hand, glass ionomer sealants offer unique advantages, especially in environments where maintaining complete isolation is difficult. Unlike resin-based sealants, glass ionomer sealants are hydrophilic and can bond effectively to enamel in moist conditions. This makes them suitable for use in younger children or uncooperative patients. Additionally, glass ionomers release fluoride over time, which can help strengthen adjacent enamel and provide a chemical mechanism for caries prevention. Although they exhibit lower retention rates compared to resin-based sealants, their cariostatic properties compensate for this limitation in specific high-risk populations.¹³

The introduction of resin-modified glass ionomer sealants has further blurred the lines between the two traditional materials. These hybrid sealants combine the fluoride-releasing capability of glass ionomers with the enhanced mechanical properties of resin. This dual mechanism provides both chemical and physical protection, making

them a versatile option for a broader range of clinical scenarios. Clinical trials have demonstrated that resin-modified glass ionomers achieve better retention rates than conventional glass ionomers while maintaining the fluoride release those benefits high-carries-risk patients.¹⁴ In addition to traditional sealants, newer materials such as bioactive sealants have emerged, designed to interact with the tooth structure actively. These materials release ions, such as calcium and phosphate, to promote remineralization in areas susceptible to decay. Bioactive sealants offer a promising approach for patients with early non-cavitated lesions, potentially halting the progression of caries while providing a protective barrier. Although their long-term effectiveness is still under investigation, preliminary studies suggest that they may outperform traditional materials in preventing caries progression in high-risk cases.¹⁵

Material selection ultimately depends on several factors, including the patient’s caries risk, age, and ability to cooperate during the procedure. For patients in low-carries-risk categories or those who can maintain proper oral hygiene, resin-based sealants may be the material of choice due to their superior longevity. Conversely, for high-risk patients or those with challenges in maintaining a dry field during application, glass ionomer or resin-modified glass ionomer sealants may offer a more practical solution. These considerations underscore the importance of tailoring the material choice to the individual needs of the patient to achieve the best outcomes. Table 1 present a comparison of the different sealants with their advantages and limitations.

Application techniques and their impact on outcomes

The effectiveness of dental sealants is closely linked to the techniques employed during their application. Proper application ensures optimal adhesion and minimizes potential issues such as microleakage and early failure. Key steps in the application process include surface preparation, isolation, and curing, all of which contribute to the overall success of the sealant in preventing caries. The most critical aspect of application is maintaining a dry field to ensure adhesion between the sealant material and the enamel surface. Moisture contamination during any stage can significantly reduce retention and increase the risk of failure.¹⁶

Table 1: Comparison of sealant materials.

Sealant material	Key advantages	Limitations	Best suited for
Resin-based sealants	High retention, durable, excellent adhesion	Requires dry field, BPA concerns	Low-risk patients with optimal conditions
Glass ionomer sealants	Fluoride release, moisture tolerance	Lower retention rates, less durable	High-risk patients or young children
Resin-modified glass ionomer sealants	Combines fluoride release with improved retention	Higher cost, moderate retention	Patients needing fluoride release with longer retention
Bioactive sealants	Promotes remineralization, active ion release	Limited long-term studies, costlier	Patients with early non-cavitated lesions or high caries risk

Acid etching is a standard preparatory step in sealant application, where phosphoric acid is used to create microporosities on the enamel surface. These microscopic irregularities enhance mechanical retention by allowing the sealant to bond securely with the tooth. The duration and concentration of the etching agent must be carefully controlled, as under-etching may fail to create sufficient retention, while over-etching can weaken the enamel structure. Studies have shown that a 15-20 second etching time with a 37% phosphoric acid solution is most effective for resin-based sealants.¹⁷

Isolation of the tooth during application is another crucial factor. Rubber dams and cotton rolls are commonly used to prevent saliva contamination, which can interfere with sealant bonding. Rubber dams, in particular, are preferred in clinical settings where complete isolation is essential.

However, they may not be feasible in younger or uncooperative patients, where alternative techniques such as high-suction evacuation and careful placement of cotton rolls can be effective substitutes. The use of moisture-tolerant materials, such as glass ionomer sealants, is also beneficial in these cases, as they do not require absolute dryness for adhesion.¹⁸

Curing techniques have advanced significantly with the advent of modern light-curing units. High-intensity light-emitting diode (LED) curing systems have largely replaced traditional halogen lamps due to their shorter curing times and consistent output. The angle and distance of the curing light also play a pivotal role; improper positioning can result in incomplete polymerization of the sealant, leading to weak adhesion and reduced longevity. Recent innovations in curing technology, such as polywave LED units, offer enhanced efficiency by emitting a broader spectrum of light to activate various photoinitiators used in sealant formulations.¹⁹

Beyond these technical aspects, operator experience and adherence to manufacturer guidelines are critical determinants of sealant success. Improper handling, such as applying too thick a layer or inadequate mixing in the case of dual-component sealants, can compromise the final outcome. Training and regular calibration of clinicians performing sealant applications have been shown to improve consistency and success rates.

In addition, advancements in minimally invasive dentistry have introduced techniques such as air abrasion and laser etching for surface preparation. These methods offer alternative approaches to mechanical preparation, with potential benefits in terms of patient comfort and reduced enamel loss.²⁰

Long-term benefits and challenges in sealant use

The long-term success of dental sealants lies in their ability to maintain protection against caries over extended

periods, despite various factors that may compromise their performance. Numerous studies have demonstrated that sealants significantly reduce the incidence of caries, particularly in molars, for years after application. This protective effect is largely due to the ability of sealants to create a physical barrier that prevents the infiltration of bacteria and food particles into the pits and fissures of teeth. However, retention rates and effectiveness over time are influenced by factors such as material choice, application technique, and patient compliance with follow-up care.²¹

The durability of resin-based sealants has been well-documented, with many studies reporting retention rates exceeding 80% after two years of application. When properly applied, these sealants can provide consistent protection for five years or more. Despite this, gradual wear and microleakage over time can reduce their effectiveness. Environmental factors such as chewing forces and temperature fluctuations in the oral cavity contribute to the degradation of the sealant layer, particularly in high-stress areas like the molars. Regular follow-up visits are essential to assess the integrity of sealants and perform repairs or reapplications when necessary.²²

Glass ionomer sealants, while advantageous for their fluoride-releasing properties, tend to have lower retention rates compared to resin-based alternatives. However, their ability to release fluoride over time offers an additional mechanism for caries prevention, even after partial loss of the material. This characteristic is particularly beneficial for high-risk populations, such as children with limited access to regular dental care. The fluoride release creates a localized environment that inhibits demineralization and supports remineralization of enamel, providing ongoing protection even under suboptimal retention conditions.²³

A major challenge in the long-term use of sealants is patient compliance with follow-up care. Sealants require periodic evaluation to ensure they remain intact and functional. Inadequate follow-up can result in unnoticed wear, microleakage, or complete loss of the sealant, leaving the tooth vulnerable to caries. Additionally, the cost of reapplication or repair may discourage some patients from seeking regular dental care. Public health programs that promote the use of sealants in school-based or community settings often face difficulties in ensuring long-term follow-up, particularly in underserved populations.⁹

Another emerging concern is the potential release of bisphenol A (BPA) from certain resin-based sealants. Although the levels of BPA released are minimal and generally considered safe, this issue has raised questions about the long-term biocompatibility of sealant materials.

As a result, manufacturers have developed BPA-free formulations to address these concerns and ensure patient

safety. However, more research is needed to understand the implications of long-term exposure to sealant materials and their potential effects on oral and systemic health.²³ Despite these challenges, the benefits of dental sealants in caries prevention far outweigh their limitations. Continued advancements in sealant materials and application techniques are expected to enhance their longevity and effectiveness. Patient education and public health initiatives can further improve compliance with follow-up care, ensuring that sealants provide sustained protection against dental caries over the long term.

CONCLUSION

Dental sealants remain a cornerstone in preventive dentistry, offering significant protection against caries when applied effectively. Their success is influenced by material choice, application techniques, and regular maintenance. Advancements in materials, including fluoride-releasing and bioactive sealants, promise to enhance their longevity and effectiveness. Continued education and public health initiatives are essential to maximize their potential in reducing the global burden of dental caries.

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REFERENCES

1. Simonsen RJ. Retention and effectiveness of a single application of white sealant after 10 years. *J Am Dent Assoc*. 1987;115(1):31-6.
2. Gooch BF, Griffin SO, Gray SK, Kohn WG, Rozier RG, Siegal M, et al. Preventing dental caries through school-based sealant programs: updated recommendations and reviews of evidence. *J Am Dent Assoc*. 2009;140(11):1356-65.
3. Forss H, Walsh T, Hiiri A, Nordblad A, Mäkelä M, Hv W. Sealants for preventing dental decay in the permanent teeth. *Cochrane Database Syst Rev*. 2013;3:CD001830.
4. Beauchamp J, Caulfield PW, Crall JJ, Donly K, Feigal R, Gooch B, et al. Evidence-based clinical recommendations for the use of pit-and-fissure sealants: a report of the American Dental Association Council on Scientific Affairs. *J Am Dent Assoc*. 2008;139(3):257-68.
5. Feigal RJ. The use of pit and fissure sealants. *Pediatr Dentistry*. 2002;24(5):415-22.
6. Wright JT, Crall JJ, Fontana M, Gillette EJ, Nový BB, Dhar V, et al. Evidence-based clinical practice guideline for the use of pit-and-fissure sealants: a report of the American Dental Association and the American Academy of Pediatric Dentistry. *J Am Dent Assoc*. 2016;147(8):672-82.
7. Bandi M, Mallineni SK, Nuvvula S. Retention and effectiveness of pit and fissure sealants placed with or without bonding agent in young permanent teeth: A randomized clinical trial with a year follow-up. *Indian J Dent Res*. 2020;31(6):877-82.
8. AlShahrani SS, AlAbbas MaS, Garcia IM, AlGhannam MI, AlRuwalli MA, Collares FM, et al. The antibacterial effects of resin-based dental sealants: a systematic review of in vitro studies. *Materials*. 2021;14(2):413.
9. Forsten L. Fluoride release and uptake by glass-ionomers and related materials and its clinical effect. *Biomaterials*. 1998;19(6):503-8.
10. Pardi V, Pereira AC, Mialhe FL, de Castro Meneghim M, Ambrosano GMB. A 5-year evaluation of two glass-ionomer cements used as fissure sealants. *Comm Dentistry Oral Epidemiol*. 2003;31(5):386-91.
11. Griffin SO, Gray SK, Malvitz DM, Gooch BF. Caries risk in formerly sealed teeth. *J Am Dent Assoc*. 2009;140(4):415-23.
12. Wendt LK, Koch G, Birkhed D. On the retention and effectiveness of fissure sealant in permanent molars after 15–20 years: a cohort study. *Comm Dentistry Oral Epidemiol*. 2001;29(4):302-7.
13. Alirezai M, Bagherian A, Shirazi AS. Glass ionomer cements as fissure sealing materials: yes or no?: A systematic review and meta-analysis. *J Am Dent Assoc*. 2018;149(7):640-9.
14. Molina GF, Cabral RJ, Mazzola I, Lascano LB, Frencken JE. Mechanical performance of encapsulated restorative glass-ionomer cements for use with Atraumatic Restorative Treatment (ART). *J Appl Oral Sci*. 2013;21(3):243-9.
15. Neto FR, Maeda F, Turssi C, Serra MC. Potential agents to control enamel caries-like lesions. *J Dentistry*. 2009;37(10):786-90.
16. Cvikl B, Moritz A, Bekes K. Pit and fissure sealants—a comprehensive review. *Dentistry J*. 2018;6(2):18.
17. Bevilacqua L, Cadenaro M, Sossi A, Biasotto M, Di Lenarda R. Influence of air abrasion and etching on enamel and adaptation of a dental sealant. *Eur J Paediatr Dentistry*. 2007;8(1):25.
18. Mattar RE, Sulimany AM, Binsaleh SS, Al-Majed IM. Comparison of fissure sealant chair time and Patients' preference using three different isolation techniques. *Children*. 2021;8(6):444.
19. Price RB, Felix CA, Andreou P. Evaluation of a second-generation LED curing light. *J Canad Dent Assoc*. 2003;69(10):666.
20. Kumar G, Dhillon JK, Rehman F. A comparative evaluation of retention of pit and fissure sealants placed with conventional acid etching and Er, Cr: YSGG laser etching: A randomised controlled trial. *Laser Therapy*. 2016;25(4):291-8.
21. Kitchens DH. The economics of pit and fissure sealants in preventive dentistry: a review. *J Contemp Dent Pract*. 2005;6(3):95-103.
22. Muller-Bolla M, Lupi-Pégurier L, Tardieu C, Velly AM, Antomarchi C. Retention of resin-based pit and fissure sealants: a systematic review. *Comm Dentistry Oral Epidemiol*. 2006;34(5):321-36.

23. Weintraub JA, Ramos-Gomez F, Jue B, Shain S, Hoover CI, Featherstone JD, et al. Fluoride varnish efficacy in preventing early childhood caries. *J Dent Res*. 2006;85(2):172-6.

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