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Ahmed Salahh
Dental Collage, Bhimavaram, Andhra Pradesh, India

Corresponding Author:
Ahmed Salahh
Dental Collage, Bhimavaram, Andhra Pradesh, India

Dental sealants: A comprehensive review of the literature

Ahmed Salahh

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Abstract
Dental sealants are a preventive measure used to protect teeth from dental caries, particularly in the pits and fissures of occlusal surfaces. They act by forming a protective barrier that prevents bacteria and food particles from getting trapped in the pits and fissures, thereby reducing the risk of caries. Sealants are safe to use, with no significant adverse events reported in clinical trials. Overall, dental sealants are a valuable preventive measure in pediatric dentistry, offering significant benefits in caries prevention, long-term efficacy, cost-effectiveness and safety.

Keywords: Dental sealants, physical properties, caries prevention

Introduction
Dental sealants are a preventive measure used to protect teeth from dental caries, particularly in the pits and fissures of occlusal surfaces [1]. Sealants are typically applied to the molars and premolars of children and adolescents, where the risk of caries is highest due to the difficulty in cleaning these areas effectively [2]. Sealants act by forming a protective barrier that prevents bacteria and food particles from getting trapped in the pits and fissures, thereby reducing the risk of caries [3].

Dental sealants are a preventive dental treatment involving the application of plastic material to the occlusal surfaces of molars and premolars [4]. Their primary role is to prevent dental caries in children and adolescents by sealing the deep pits and fissures where food particles and bacteria can accumulate, making these areas difficult to clean effectively [5]. The American Dental Association (ADA) and the American Academy of Pediatric Dentistry (AAPD) recommend the use of pit-and-fissure sealants on the occlusal surfaces of primary and permanent molars in children and adolescents to prevent dental caries [5].

Types of dental sealants
There are four primary types of dental sealants, each with distinct mechanical characteristics and clinical features [6]:

- **Resin-based sealants:** They are made from urethane dimethacrylate (UDMA) or bisphenol A-glycidyl methacrylate (bis-GMA) monomers, polymerized by chemical or light activation [7]. Usually, they have high shear bond strength, high microhardness, and superior retention rates [8]. Furthermore, these types of sealants effectively reduce caries incidence by up to 76% over 2-3 years, preferred for their durability and retention [5].
- **Glass ionomer sealants:** Glass ionomer sealants are formed from an acid-base reaction between fluoro aluminosilicate glass powder and polyacrylic acid solution [9]. They have lower shear bond strength and microhardness than resin-based sealants but higher fluoride release [10]. They are beneficial in moist environments and have lower retention rates but are effective in caries prevention due to fluoride release [11].
- **Polyacid-modified resin sealants:** These sealants combine resin-based materials with the fluoride-releasing properties of glass ionomer sealants [12]. They have intermediate properties between resin-based and glass ionomer sealants and provide both mechanical strength and fluoride release, though they are less commonly used [5].

- **Resin-modified glass ionomer sealants:** These are glass ionomer sealants with added resin components. Compared to traditional glass ionomer sealants, they have improved working time and reduced water sensitivity [13]. Furthermore, they have a similar fluoride release to glass ionomer sealants, with better handling properties [14].

The clinicians select the type of sealants based on clinical scenarios, patient needs, and the ability to maintain a dry field during application [5]. The American Dental Association and the American Academy of Pediatric Dentistry recommend resin-based sealants for their superior retention and effectiveness [5]. Research indicates that resin-based sealants are effective in preventing caries in children and adolescents. Moderate-quality evidence shows a significant reduction in caries incidence when sealants are used compared to when no sealants are applied [15]. On the other hand, glass ionomer sealants have been evaluated, but the evidence regarding their effectiveness is less conclusive [15].

Resin-based and glass ionomer sealants have distinct mechanical characteristics and properties that make them suitable for preventing dental caries in children and adolescents.

Retention rate

The retention rates of different dental sealants vary significantly based on the type of material used. Resin-based sealants generally exhibit superior retention compared to glass ionomer sealants. Studies have shown that resin-based sealants can maintain high retention rates over extended periods, which is crucial for their effectiveness in caries prevention [12, 16]. According to a meta-analysis by Kühnisch *et al*., auto-polymerizing sealants have a 5-year retention rate of 64.7%, while resin-based light-polymerizing sealants show a higher 5-year retention rate of 83.8% [17]. Fluoride-releasing sealants also demonstrate good retention, with a 5-year rate of 69.9% [17]. In a more recent study, primed sealants had a 2-year pooled retention rate estimate of 43.2%, which was significantly lower than auto-polymerizing (80.8%) and light-polymerizing sealants (68.4%) [18]. Fluoride-releasing and light-polymerizing sealants had the highest 3-year pooled retention rate estimates [18]. Additionally, a randomized clinical trial comparing conventional resin sealants and nanofilled resin sealants found that at 18 months, nanofilled resin sealants had a complete retention rate of 67.2%, compared to 55.2% for conventional resin sealants [19]. Another study reported that moisture-tolerant resin-based sealants had a higher retention rate (72%) compared to conventional resin-based sealants (50%) at 12 months [20].

Factors influencing the retention rate of dental sealants are the type of sealant, the clinical procedure, proper isolation, environmental factors, application technique, and others. The use of bonding agents can significantly improve retention [21]. For example, the use of etch-and-rinse adhesives has been shown to yield better retention rates compared to self-etch adhesives [21]. Proper isolation techniques, such as using a rubber dam, can affect retention, particularly for fluoride-containing light-cured resin-based sealants [22]. Early eruption stage and patient behavior can also influence sealant retention. Early eruption is a significant risk factor for sealant failure [23]. Behavior, salivary problems, and visually apparent variations in enamel were also found to be significant risk factors for sealant failure of occlusal sealants [23]. Retention of sealants is crucial for their effectiveness. The success of a sealant largely depends on how well it penetrates the occlusal surface. The fissure type significantly influences the sealant's ability to penetrate, the specific sealant used, and the application methods employed [24].

Successful sealant retention primarily depends on the material's ability to penetrate the pits and fissures of the occlusal surface. The morphology of these fissures plays a significant role in how well the sealant penetrates [25]. A recent study found that the greatest penetration depth occurred in U- and V-shaped fissures, while I- and IK-shaped fissures exhibited the least penetration [26]. Both glass ionomer cement (GIC) and resin sealants demonstrated similar results, indicating that, in some cases, the morphology of the fissures may impact penetration depth more than the type of sealing material used [26].

Shear Bond Strength

The shear bond strength of dental sealants can vary significantly depending on the sealant type and the enamel surface preparation. Glass ionomer-based sealants tend to have lower shear bond strength (lower than 5 MPa) compared to resin-based sealants [27]. Resin-based sealants typically have higher shear bond strength, contributing to better retention and durability on the tooth surface [28]. Conventional resin-based sealants generally exhibit the highest shear bond strength, mainly when used with prior acid etching, while self-etching/self-adhesive and Glass ionomer sealants tend to have lower shear bond strength.

Microhardness

Sealants exhibit higher microhardness, which enhances their resistance to wear and mechanical forces during mastication [28]. A recent study revealed varying microhardness values for different sealants [28]. Among the tested sealants, UltraSeal XT® hydro™ showed the highest mean change value in microhardness, while Aegis Pit and Fissure sealant exhibited the lowest [29].

The hardness of a material contributes significantly to the effectiveness of fissure sealants by offering resistance against deforming forces. This property is closely linked to yield strength, fracture resistance, and the modulus of elasticity. Ideally, a fissure sealant should possess a high hardness value [29]. Acid-based glass ionomer cement (GIC) can chemically bond to tooth structures and release fluoride over time. However, the mechanical properties of glass ionomer fissure sealants tend to be relatively weak. Employing the thermo-curing method has been shown to increase their durability. Thermo-curing acid-based GIC fissure sealants enhances surface hardness, ultimately improving their longevity and clinical performance [30]. According to a recent study, Clinpro sealant displayed the lowest microhardness value before undergoing thermal cycling, measuring 18.27 ± 1.24 Vickers Hardness Number [29]. This finding is consistent with results from other studies [31]. Glass ionomer sealants exhibit lower microhardness, making them less resistant to mechanical wear compared to resin-based sealants [28].

Fluoride releasing properties

The fluoride-releasing properties of different types of pit and fissure sealants vary significantly. Conventional resin-based sealants generally release minimal fluoride. However, some resin-based sealants are formulated to include fluoride-releasing components. For example, studies have shown that fluoride-containing resin sealants like Clinpro can release fluoride, but the amount is typically lower than glass ionomer-based sealants [32, 33]. Self-etching/self-adhesive sealants release fluoride, but the release rate and total amount are generally lower than glass ionomer-based sealants. The fluoride release from these sealants can be sustained over time, but it is not as significant as that from glass ionomer-based sealants [33].

One of the key benefits of glass ionomer sealants is their ability to release fluoride, which can help in the remineralization of enamel and provide additional caries protection [32, 34]. Glass ionomer sealants like Fuji VII exhibit the highest fluoride release among the different types of sealants [32]. This high fluoride release contributes to their anti-demineralization efficacy on adjacent unsealed enamel surfaces. Glass ionomer sealants can release fluoride continuously over an extended period, which enhances their cariostatic properties [34].

Antibacterial properties

The antibacterial properties of different types of dental sealants vary based on their composition and the incorporation of specific antibacterial agents. Conventional resin-based sealants can be enhanced with antibacterial agents such as quaternary ammonium monomers (e.g., dimethylamino dodecyl methacrylate) and nanoparticles (e.g., silver nanoparticles). Studies have shown that resin-based sealants modified with these agents exhibit significant antibacterial activity against Streptococcus mutans and other cariogenic bacteria by reducing bacterial growth, metabolic activity, and biofilm formation [35]. Self-etching/self-adhesive sealants can also be modified to include antibacterial agents. For example, the incorporation of zinc methacrylates or di-n-butyl-dimethacrylate-tin has been shown to provide strong anti-biofilm efficacy against various oral bacteria without impairing the mechanical properties of the sealant. These modifications help prevent the formation of cariogenic biofilms [36]. Glass ionomer sealants inherently possess antibacterial properties due to their fluoride release, inhibiting bacterial growth. Additionally, modifications with bioactive components such as porous hydroxyapatite or bioglass can enhance their antibacterial effects. These modifications have been shown to improve the antibacterial properties of glass ionomer sealants, making them effective in reducing bacterial colonization and biofilm formation [37, 38].

Alkalizing potential

The alkalizing potential of dental sealants varies based on their composition and the presence of bioactive components. The alkalizing potential of dental sealants can influence their longevity by affecting their ability to resist demineralization and support remineralization, impacting their retention and effectiveness over time. Resin-based sealants generally do not have significant alkalizing potential unless modified with bioactive components like 45S5 bioactive glass (BAG). Studies have shown that resin-based sealants containing BAG can increase pH levels due to the release of calcium and phosphate ions, which contribute to their alkalizing properties [39, 40]. This helps prevent demineralization and enhances remineralization, potentially improving their longevity [39, 40].

Glass ionomer sealants inherently possess alkalizing properties due to their composition. Glass ionomer sealants release fluoride, calcium, and phosphate ions, which can increase the pH and contribute to their alkalizing effect. Studies have shown that resin-modified glass ionomer cement (RMGIC) enriched with bioactive fillers like 45S5 bioglass exhibits even higher alkalizing activity [41]. This alkalizing effect helps maintain a higher pH environment, which is less conducive to bacterial growth and demineralization [12]. Glass ionomer sealants have been shown to have lower retention rates compared to resin-based sealants. However, their continuous ion release and alkalizing potential can still provide significant caries-preventive benefits over time [34].

Wear resistance

Resin-based sealants generally have the highest wear resistance. For example, resin-based sealants like ClinPro Sealant and GrandioSeal have demonstrated superior wear resistance in comparative studies. In a study evaluating wear behavior, resin-based sealants showed lower wear rates than other sealants, with flowable composites presenting the lowest wear [42]. In contrast, glass ionomer cement exhibits the highest wear rates among the different types of sealants. For example, Fuji Triage presented the highest wear in comparative studies. Despite their higher wear rates, glass ionomer-based sealants are valued for their fluoride release and cariostatic properties [12].

Viscosity of Dental Sealants

The viscosity properties of dental sealants vary significantly, categorizing them into three types: low viscosity, moderate viscosity, and high viscosity. Resin sealants are typically non-Newtonian and shear-thinning, meaning their viscosity decreases as the shear rate increases. They also exhibit thixotropy, allowing them to flow under pressure while remaining stable once applied. For example, Clinpro and Delton FS+ are known for their low viscosity, which facilitates easy application and effective penetration into pits and fissures.

Glass ionomer sealants generally have a higher viscosity compared to resin-based sealants. High-viscosity glass ionomer cements, such as Ketac Molar Easymix, are designed to be pressed into pits and fissures, enhancing their retention but potentially limiting their flow and penetration capabilities. The viscosity of glass ionomer sealants is influenced by the powder-liquid ratio and the presence of additives like porous hydroxyapatite.

Self-etching and self-adhesive sealants have a moderate viscosity, with their flow properties affected by their composition and the presence of bioactive components. These factors can also impact their ability to penetrate fissures effectively. A recent study analyzed the viscosity of Grandio Seal, a resin-based pit and fissure sealant, and assessed how temperature changes affected it [46]. The findings revealed that heating the material to 41 ºC or 51 ºC before use significantly decreased its viscosity, improving its penetration into pits and fissures [46]. This enhanced flowability contributes to better retention on the occlusal surfaces of molars. The more effectively a sealant can flow and fill the microroughness in the enamel after etching, the stronger the micromechanical adhesion it achieves.

Remineralizing abilities

Certain sealants possess remineralizing properties, which help repair early carious lesions. Bioactive sealants containing calcium and phosphate ions, such as BeautiSealnt, have demonstrated significant abilities, reducing enamel demineralization and promoting remineralization [47].

Conclusion

In summary, dental sealants are a safe and effective way to prevent dental caries in children and adolescents, particularly when applied to the chewing surfaces of molars. They possess strong mechanical properties and demonstrate long-term clinical effectiveness, making them a valuable and cost-effective option for caries prevention.

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