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Review Article

Recent advances in pit and fissure sealants used in pediatric dentistry: A narrative review

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Abstract

Pits and fissures on the occlusal surfaces of teeth are particularly vulnerable to dental caries due to their deep, narrow morphology, which tends to retain plaque and is challenging to clean effectively. As a result, these areas are more susceptible to decay compared to smoother tooth surfaces. In addition to maintaining good oral hygiene and the use of fluoride, sealing pits and fissures is recognized as a key preventive measure against dental caries. The application of sealants over these areas has proven to be a highly effective method for reducing caries incidence. A variety of sealant materials are available, with resin-based sealants, composites, and glass ionomer cements being the most commonly used. The long-term effectiveness of sealants relies on routine dental check-ups and reapplication when necessary. This review discusses recent advancements in pit and fissure sealant technology, with a focus on applications in pediatric dentistry.

Keywords: Dental caries, Pit and fissure, Pit and fissure sealant, Preventive dentistry.

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1. Introduction

The occlusal surfaces of newly erupted posterior teeth are particularly susceptible to caries formation. Studies have shown that approximately 90% of carious lesions in children occur in the pits and fissures of permanent posterior teeth. This high incidence is largely attributed to the anatomical complexity of these surfaces, which promotes plaque retention and stagnation, making them difficult to clean effectively and creating an ideal environment for cariogenic bacteria to thrive.[1] Nango classified occlusal pits and fissures into five major types depending on their morphology: U, V, I, K, and Y. The shallow fissures, which have a V or U form, have been shown to be caries-resistant and self-cleaning. The deepest fissure morphology is found in I or K-type fissures, which have the most complex branch pattern and are therefore the most vulnerable to caries.[2] Topical fluoride therapy, community water fluoridation, plaque reduction, and dietary sugar restriction are of caries prevention techniques that have limited effect on pits and fissures; more potent therapies are required. In pediatric dentistry, fissure sealants (FSs) have been used to prevent dental caries since the 1960s. The American Academy of Pediatric Dentistry (AAPD) stated that fissure sealants reduce caries by 76%. As a conservative preventive measure, sealants are applied to the pits and fissures of teeth that are prone to cavities. The sealant forms a physical barrier that prevents bacteria from accessing their food source by bonding to the tooth micromechanically. An optimal fissure sealant must have the following requisities: Viscosity allowing penetration into deep and narrow fissures even in maxillary teeth, adequate working time, rapid cure, good and prolonged adhesion to enamel, resistance to wear, minimum irritation to tissues, cariostatic action. Age range for sealant application: 3-4 years for primary molars sealant application, 6-7 years for first permanent molars, 11-13 years age for second permanent molars and premolars.[3] There are now a variety of glass ionomer sealants and resin-based products on the market. The

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materials differ from one another in terms of their fluoride-releasing capacity, polymerisation process, and filler content. Retention is the main factor that determines a resin-based sealant's effectiveness, followed by the sealant's cariostatic action.[4] Sealants are evaluated using Simonsen's and Deery's criterion. Recurrent caries or the advancement of caries beneath the restoration is minimal if the sealant is completely preserved. Bonding to enamel with the etch-and-rinse system is a reliable technique. The resin-based sealant material penetrates the uneven microporous enamel surface created by phosphoric acid etching, which also eliminates impurities. According to Griffin, applying a sealant can reduce the median annual caries progression by 9%.[5]

Preventive resin restorations (PRRs), which combine restorative and preventive techniques to improve oral health, are an essential method in the management of occlusal cavities. In PRRs, carious tissues are removed selectively, and a resin-based composite is applied. The composite is sealed to stop further decay. Based on the extent and depth of the lesion PRR classified in to 3 types – Type A, B, C. For all unprepared pits and fissures, a pit and fissure sealant must be used to restore minimal exploratory preparations. This is known as the Type-A PRR by Simonsen.[6]

Adhesive systems under sealants are one of the materials and methods that have been developed to increase the longevity of pit-and-fissure sealants. Self-etch adhesive methods do not require enamel/dentin acid etching, rinsing, or drying, they simplify the bonding process and substantially reduce on clinical application time and technique sensitivity. Additionally, due to its shorter chair time and fewer surgical procedures, self-etch adhesives might be advantageous for treating paediatric patients.[7]

2. Search Strategy for Review

This review was done by searching electronic databases like PubMed, Scopus, Web of Science which were published in english language between 2001 and 2024 using terms pit and fissures, pit and fissure sealant, preventive dentistry, dental caries, recent advances in dental sealants. About 104 publications were searched and 40 were included in the review for critical evaluation process.

Numerous materials have been attempted in the past to shield occlusal surfaces against severe pits and cracks. Cueto created the first sealing agent, methyl cyanoacrylate, in the middle of the 1960s, but it was never put on the market.[8] Hunter observed in 1803 that caries is frequently seen on the molar's hollow areas. Wilson documented the use of dental cement (zinc phosphate) in pits and fissures to stop cavities in 1895. In 1923 Hyatt advocated the early insertion of small restorations in deep pits and fissures before carious lesions had the opportunity to develop.[9] He termed this procedure prophylactic odontotomy. Again, this operation is more of a treatment procedure than a preventive approach. In order to make the occlusal areas more self-cleaning, Bodecker proposed in 1929 that deep fissures may be widened with a large round bur.[10] This procedure is known as enameloplasty. Ammonical silver nitrate was used by Kline and Knutson in 1942 to treat pits and fissures.[11] In 1950, Ast et al. tried using zinc chloride and potassium ferrocyanide topically to seal or increase the caries resistance of fissures.[12] They also tried using copper amalgam packed into fissures. Buonocore reported the first successful usage of resin sealants in the 1960s. Glycidyl Methylacrylate Sealants using Bisphenol A. Nowadays, Bisphenol A-glycidyl methylacrylate, or Bis-GMA, is the preferred sealant. It is a blend of methyl methacrylate and bis-GMA. Pit and fissure sealants were recognised by the ADA in 1971 under specification number 39. The first commercial sealer to be successfully introduced to the market was Nuva-Seal in 1972.

UV light was used to commence the first generation of sealants, autopolymerization was used for the second generation, and visible light was used for the third generation. Sorting commercial products into filled and unfilled sealants is desirable because some sealants contain fillers. The filled sealants include various fillers used in composite resins, as well as tiny glass beads and quartz particles. To make it easier for the fillers to combine with the Bis-GMA resin, they are coated with substances like silane. The sealant's resistance to wear and abrasion is increased by the fillers. Due to their increased abrasion resistance, the occlusion should be examined, and following placement, the sealant height could need to be modified. However, unfilled sealants typically do not require occlusal correction and wear more quickly. In 1978 Simonson used preventive resin restoration, in 1986 Gracia –Godoy uses preventive glass ionomer restorations. Scientists Cooley et al. studied fluoride-releasing sealants made of Bis-GMA resin, a modified urethane, in the lab. In 2002 pulpdent launched embrace wet bond pit and fissure sealant.[13]

3. Discussion

Paediatric restorative dentistry consensus conference 2002 article from the American Academy of Paediatric Dentistry strongly advises children and adolescents to have their permanent molars sealed. This advocacy draws from a review of nine randomised controlled trials that followed people with permanent molars for two to three years. The prevalence of dental caries revealed a roughly 76% decrease in occlusal caries.[14] Armamentarium used for pit and fissure sealant application as shown in (**Figure 1**). The steps involved in applying pit and fissure sealants are as follows (**Figure 2**): A rotary brush is used to clean the tooth. Rubberdam isolation is the best method for achieving the best moisture control. For acid etching, 37% phosphoric acid is utilised. The teeth will have the distinctive chalky white enamel frosty look after being rinsed and dried. Applying the pit and fissure sealant and allowing it to cure. The sealant is examined for excess and polymerisation voids. Occlusion was corrected as needed.

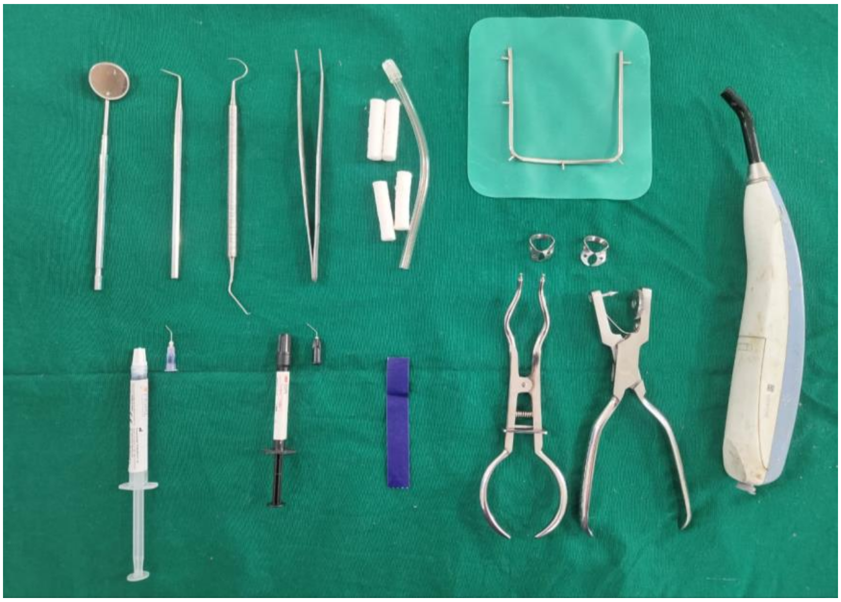

Figure 1: Armamentarium used for pit and fissure sealant application

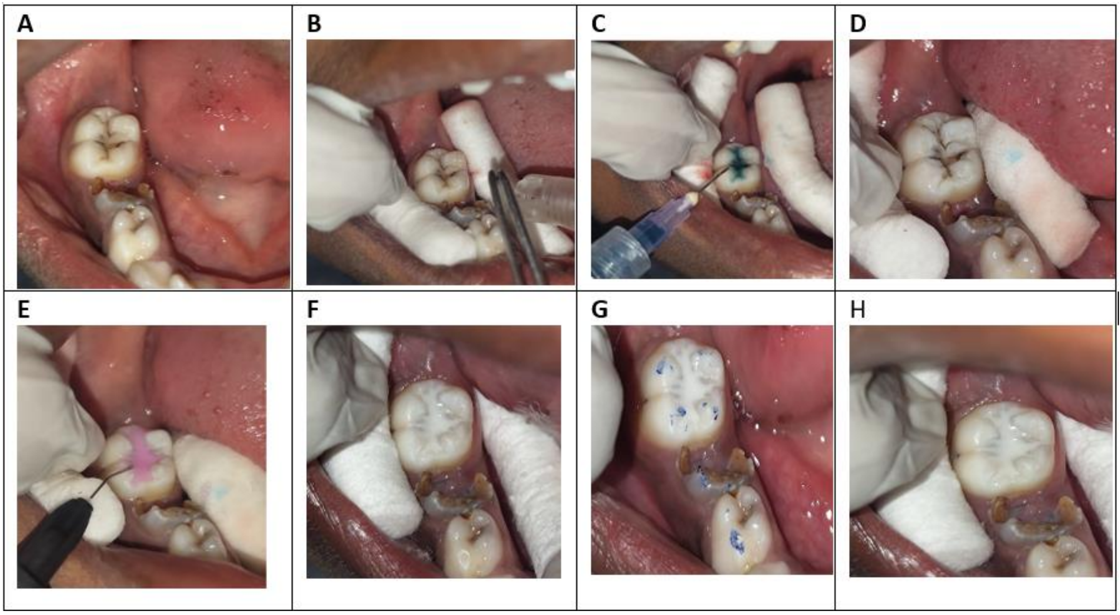

Figure 2: A): Deep, stained pit and fissures, **B):** Isolation with cotton rolls, **C):** Application of etchant, **D**): Tooth appears frosty after being etched, washed, and dried. **E**): Sealant application, **F):** After curing of sealant, **G):** High points are checked by articulating paper; **H):** After highpoints removal

3.1. Resin based pit and fissure sealants

The first generation of resin-based sealants (RBS) were created by polymerising the material's initiators using UV light Ex: Nuva-Seal®. Auto-polymerizing resin-based sealants (ARBS) or chemically-cured sealants were the second generation; an activator, tertiary amine, is mixed with one component and applied to another. The reaction produces free radicals that initiate the polymerization of the resin sealant material. Setting time is of 1-2 min.[15] Third generation comprises visible light-polymerizing resin-based sealants (LRBS). Here the visible light activates photoinitiators that are present in the sealant material and are sensitive to visible light in the wavelength region of around 470 nm (blue region). Takes less than 10 to 20 seconds to set. The material does not set until it is exposed to the polymerising light, and the working time is extended.[16] The fluoride-releasing resin-based sealants (FRBS) are the fourth generation. The filler content of sealants affects their physical properties, flowability, and resistance to wear. In theory, unfilled sealants may have superior retention because of their low viscosity, which allows them to enter the crevices more deeply. It is not necessary to make occlusal modifications. Nonetheless, it has been shown that a high wear resistance and low shrinking rate require filler content, which improves longevity.[17] Applying coloured sealants makes it simpler to view the sealant, and evaluating retention with a white sealant at later times is significantly quicker than with a clear sealant.

Additionally, using a coloured sealant makes it much simpler to document retention over extended periods of time.[18] The most recent trend in sealant marketing is to include a colour change in either the polymerised phase (Helioseal Clear Chroma; Ivoclar Vivadent, Amherst, NY, USA) or the curing phase (Clinpro, 3M ESPE, St. Paul, MN, USA). The Helioseal material, on the other hand, turns green when exposed to visible light. An interesting study comparing the usefulness of transparent and coloured (opaque) sealants was conducted by Rock et al. While the overall identification error rate for clear resin was 23%, it was only 1% for opaque resin. There was a substantial difference ($p < 0.0001$).[19]

3.2. Glass ionomer based pit and fissure sealants

The acid-base interaction between a fluoroaluminosilicate glass and a polyacrylic acid solution produces glass ionomer sealant (GIS). These sealants have poorer retention rates than RS and little resistance to masticatory pressures. Compared to resin sealants (RS), GIS is easier to apply, it can be administered without pretreatment and uses a chemical reaction to bond the teeth. Furthermore, adhesion and fluoride release are made achievable by GIS, which is not moisture sensitive. However, RS releases very little or no fluoride. According to Markovic et al., GIS has a low long-term retention rate; nonetheless, in 65% of permanent molar fissures, this material prevented the formation of cavities.[20] GI sealants can be classified into low viscosity and high viscosity types. low-viscosity GIS, such as Fuji III GI sealant applied on pit and fissures in thin consistency and it has poor physical properties. It has now been replaced by a more recent version, like the Fuji Triage (VII) (GC, Tokyo, Japan), which is made to emit more fluoride and has improved physical characteristics. Gloved index finger coated with petroleum jelly is used with pressure to apply high viscosity glass ionomer sealants. When resin is incorporated with glass ionomer, it is called a resin-modified glass ionomer (RMGI). It has also been used as a pit and fissure sealant material. The setting reaction of this type of sealant is initiated by the photoactivation of the resin component, followed by the acid-based reaction for the ionomer component. It's resin component has enhanced its physical characteristics in comparison to conventional GI. Compared to normal GI, RMGI actually has a longer operational life and is less water sensitive.

3.3. Polyacid based resin modified pit and fissure sealants (Compomer)

Compomer, another name for polyacid-modified resin-based composite material, has been applied as a fissure filler. It combines the fluoride-releasing ability of the GI sealant with the beneficial qualities of a visible light polymerised resin-based sealant. In comparison to GI sealant material, a polyacid-modified resin-based sealant is less water soluble, less technique-sensitive, and has superior adhesion properties to enamel and dentin. After 24 months, a total retention rate of 58.4% for Dyract Flow was noted in a clinical research by Vanessa Pardi et al.[21] After a year, De Luca-Fraga and Pimenta found that the overall retention rate for Dyract was 95.9%.[22]

3.4. Glass carbomer pit and fissure sealants

Glass carbomer cement for example, GCP Glass SealTM are carbomized, monomer-free, nano-glass restorative cements made from a traditional glass ionomer material that contains fluorapatite and hydroxyapatite nanoparticles.[23] Glass carbomer has better chemical and mechanical qualities than conventional glass ionomer cements, including resistance, flexural strength, wear, remineralisation power, and command setting—with an LED curing device. According to reports, Shear bond strength of glass carbomer is on par with or even greater than that of traditional glass ionomer cement. These materials may have the ability to change into materials that resemble enamel and apatite. Bayrak G.D *et al.*, showed glass carbomers emit fluoride at a greater rate than traditional glass ionomers. The steps involved in the process are as follows: The enamel was conditioned for 20 seconds with an EDTA solution, rinsed, dried but not desiccated, and isolated with cotton rolls; glass carbomer material was applied; GCP gloss was then applied with a pellet onto the sealed surface and light-cured for 60 seconds using a polymerisation unit. A study by Liana Beresescu *et al.*, demonstrated that glass carbomer retention is significantly inferior than that of resin-based materials, but it was nevertheless successful in preventing the development of new caries and was on par with traditional resin-based sealants.[24]

3.5. Moisture tolerant pit and fissure sealant

Conventional hydrophobic sealants have been shown to decrease bonding strength and increase microleakage in saliva-contaminated fissures. With the recent advancements in resin-based sealant technology, hydrophilic sealants that can withstand moisture have been introduced. Its hydrophilic resin chemistry is very different from the hydrophobic bis-GMA resins used in conventional sealants. To make it moisture tolerant, sophisticated moisture-activated acid-integrating chemistry is combined with di, tri, and multifunctional acrylate monomers.[25] Commercially available resin dental sealants with hydrophilic chemistry Embrace WetBond, Ultraseal XT hydro, Smartseal and Loc.

3.6. Giomer based pit and fissure sealants

In contrast to the resin-based sealants, glass-ionomer sealants showed noticeably higher microleakage scores. A resin-based fissure sealer that contains surface reaction-type pre-reacted glass-ionomer (S-PRG) filler was recently introduced to overcome this limitation. Using pre-reacted glass-ionomer (PRG) technology, fluoroaluminosilicate glass reacts aqueously with a polycarboxylic acid to generate a glass ionomer phase on glass particles. Fluoride can be used to recharge the S-PRG filler. Composite resin containing S-PRG filler has antibacterial activity due to the release of metal ions from the composite, which releases several types of ions (F, Si, and Sr) into either distilled water or lactic acid solution. Self-etch adhesive combines etching, priming, and bonding in a single step, saving enamel and minimising chair side time, especially in youngsters who are uncooperative. GIOMER-based pit and fissure sealer uses self-etch primer to eliminate phosphoric acid etch and rinse. [20] According to a study by S. Ntaoutidou et al., the clinical performance of the dental sealant comprising S-PRG filler applied with a self-etching primer was inferior in terms of retention. At the 18-month recall, its noticeably greater loss did not result in more carious occlusal surfaces.

3.7. Pit and fissure sealant with amorphous calcium phosphate (ACP)

Amorphous calcium phosphate (ACP) is a novel light-cured pit and fissure sealer. By boosting the tooth's natural repair process, it can release calcium and phosphate ions and remineralise tooth structure.[21]The insitu study by Silva et al. shows that sealants with fluoride and/or ACP had a greater remineralising capacity than the control group. Aegis provided either more efficient or similar remineralization than the other sealants.[28] Materials containing amorphous calcium phosphate offer numerous benefits over those that release fluoride. Compared to products that release fluoride, those containing ACP deposit a lot more minerals overall and deliver them deeper into the lesion.[29] Because of its high solubility, ACP dissolves as Ca and PO4 ions, which locally supersaturates the region and encourages the production of HAP.[30] Materials that include ACP are "smart" in that they only release Ca and PO4 ions when the pH falls below 5.5 and stop when the pH rises.[31]

3.8. Fluorescing pit and fissure sealants

This sealant removes the uncertainty associated with applying sealants and verifying application on recall visits. For instance, Delton Seal-N-Glo Illuminating Pit & Fissure Sealant is an opaque, fluoride-containing sealant that is 38 percent full and administered via syringe. Using a UV pen light, Seal-N-Glo emits a blue/white fluorescence. During patient recall appointments, the fluorescent glow offers the simplest method to check margins and confirm retention. It also gives doctors a visual confirmation of the sealant margins at the moment of placement.

A randomised control trial comparing the retention rates of fissure sealants utilising Isolite with rubber dam and cotton roll isolation procedures was carried out by Rahif E. Mattar et al. in 2023. The findings indicate that there are no appreciable variations in the retention rate of pit and fissure sealant among the three isolation procedures.[32]

3.9. Ormocer based pit and fissure sealant

Organically modified ceramic (Ormocer) material is more aesthetically pleasing and has a high abrasion resistance, much like natural teeth. Monomer molecules, which make up ormocers, lessen the effects of wear, shrinkage, and leaching of an oestrogenic chemical bisphenol-A.[33] Saravanan SM *et al*., compared ormocer and compomer based pit and fissure sealant on permanent molars aged 7-9 years which showed a retention rate of 88.3% in ormocer group and 73.8% in compomer group at 9months interval significant differences were noted.[34]

3.10. Cost effectiveness of pit and fissure sealants

Simonsen found that, over a ten-year period, it is 1.6 times more expensive to repair the carious lesion in the first permanent molars in the unsealed group of children aged 5 to 10 who live in a fluoridated area than it is to prevent, with a single application of pit and fissure sealant, the greater number of lesions observed if pit and fissure sealant is not performed.[35] Especially for high-risk persons, using a sealant is more cost-effective than not applying one since, over a period of four to five years, the cost of restoration was much higher than the incremental cost-utility ratio and incremental cost-effectiveness ratio.[36]

Burt noted that cost-effectiveness of sealants would be enhanced by using trained auxiliaries to apply sealant to the fullest extent allowed by law, Applying the most recently developed sealants in which retention rates appear to be most favorable, and their application in areas where proximal caries is low.[37]

3.11. Estrogenicity of pit and fissure sealant

The most widely used monomers in resin composites and pit and fissure sealants are bisphenol A dimethacrylate and bisphenol A glycidyl dimethacrylate, both of which are derived from bisphenol A. Dental sealants do not contain bisphenol-A (BPA) directly; rather, it is a chemical that is added to the finished product only when the basic ingredients do not completely react.38 The Olea study implicated bisphenol-A dimethacrylate (BIS-DMA) as an estrogenic component and validated the estrogenicity of BPA. Additionally, although the researchers had not discovered these monomers in the patients' saliva before to the application of the sealants, they did find them in the saliva of human subjects one hour after the sealants were applied.[39] However, report by ADA and American academy of pediatric dentistry did not support the occurrence of adverse effects after sealant placement and describes BPA effect as small transient effect.It should also remembered that none of the dental sealants that carry the ADA seal release detectable BPA.

3.12. Recent studies

Choi JW *et al*., conducted invitro study which aimed to evaluate the antibacterial, physicochemical, and mechanical properties of pit and fissure sealants containing different weight percentages of zinc oxide nanoparticles (ZnO NPs). They concluded Significant variations in antibacterial activity were observed between pit and fissure sealants containing 4 wt.% ZnO NPs. Experiments on pH change, zinc ion release, depth of cure, water sorption and solubility, and flexural strength showed that the addition of ZnO NPs had no detrimental effects on the mechanical and physicochemical characteristics of the sealants.[40]

Kumar JS *et al.*, conducted a systematic review on evaluating retention and caries prevention efficacy of hydrophilic and hydrophobic pit and fissure sealant which concludes Hydrophilic sealants exhibit superior short-term retention and similar caries prevention efficacy compared to hydrophobic sealants.[41]

Chiu HHC *et al.*,(2025) conducted clinical study on two preventive interventions Glass ionomer fissure sealant (GIS) and fluoride varnish (NaF V) on dental anxiety (DA), cooperativeness and pain level in pre-school children when applied to primary second molars in outreach settings. Four hundred and thirteen children were recruited for the study. Results showed NaF V application is associated with less Dental anxiety and more cooperative behaviour in pre-school children compared to GIS application although similar pain levels were recorded.[42]

Yassin SM *et al.*, conducted a systematic review which aimed to see the impact of nanofillers on the physicomechanical properties of resin-based pit and fissure sealants (RBS).which concludes the inherent nature of the nanomaterial used, its morphology, concentration, and volume used were the primary parameters that determined the nanomaterial's success as a filler in RBS. The use of nanofillers that were non-agglomerated and well dispersed in the resin matrix enhanced the physicomechanical properties of RBS.[43]

Hafez ME *et al*., conducted an invitro study to evaluate the effect of sonic oscillation on penetration depth and marginal adaptation of resin-based fissure sealants. Thirty-six extracted human third molars were randomized into three groups Helioseal F, Sonic-HF, unfilled-resin-based sealant (Clinpro). They concluded sonic activation of resin-based sealant increased penetration depth into fissures and marginal adaptation to the enamel wall without decreasing filler load or compromising sealant mechanical properties.[44]

Memarpour M *et al.*, conducted a systematic review in vitro literature on shear bond strength (SBS) and microleakage of pit and fissure sealant materials in contaminated (water, human, or artificial saliva) and non-contaminated conditions which concludes Surface contamination decreases the bond strength between contaminated enamel and both unfilled and filled resin-based sealants, which affects the clinical effectiveness of sealants.[45]

A randomized controlled trail conducted in 2024 by Elmokanen, M.A *et al.*, to assess the retention rate of giomer S-PRG filler containing pit and fissure sealant applied with or without etching showed 69% retention of giomer sealant with acid etching when compared to giomer sealant without etching after 12 months.[46]

4. Conclusion

1. Sealant application is a preventive conservative approach involving the introduction of sealants into the pits and fissures of caries prone teeth.
2. It is a technique-sensitive procedure that needs to be carried out in a setting with controlled moisture levels.
3. Though the effectiveness and caries-preventive effect of pit and fissure sealants have been extensively demonstrated in the literature, they are still underused globally. Therefore, pit and fissure sealants are recommended for patients with deep pits and fissures.

5. Source of Funding

None.

6. Conflict of Interest

None.

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