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Fluoride in pit and fissure sealants: is it a feasible combination?

Flúor em selantes de cicatrículas e fissuras: uma combinação viável?

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Abstract

Dental sealants work on the principle of blocking caries susceptible pits and fissures of teeth thus rendering them caries resistant. Fluoride is another agent that is effective in reducing dental caries. However added benefits of fluoride can be achieved through its topical application. These effects can further be amplified by extended exposure of tooth surface to fluoride releasing agents. Thus the concept of addition of fluoride to pit and fissure sealants was conceived. Until now two methods of fluoride incorporation in pit and fissure sealants have been formulated. First method employs addition of soluble fluoride salts to the unpolymerized resin. Second system of fluoride incorporation uses an organic fluoride compound that can be chemically bound to resin. But the mechanism of fluoride release from fluoridated fissure sealants remains speculative. Fluoride release might occur from the insoluble sealant material as a result of porosity or ion exchange procedure. Several studies have looked at benefits of such combinations, but no study has documented a clear-cut clinical benefit or potential benefit of the same, rather seems a marketing ploy. This paper reviews evidence pertaining to use of combination of fluoride and sealants for caries prevention, their feasibility and effectiveness after addition of fluoride to sealants through in vitro and in vivo studies.

Keywords: Dental caries. Fluoride. Glass ionomer cements. Pit and fissure sealants.

Resumo

Selantes dentários usam o princípio de bloqueio de fóssulas e fissuras suscetíveis à cárie, tornando-as resistentes à cárie. O flúor é outro agente eficaz na redução da cárie dentária. No entanto, os benefícios adicionais do flúor podem ser alcançados por meio da sua aplicação tópica. Esses efeitos podem ser potencializados por uma exposição prolongada da superfície do dente a agentes de liberação de flúor. Assim, o conceito de adição de flúor a selantes de fóssulas e fissuras foi introduzido. Até agora, dois métodos de incorporação de flúor em selantes de fóssulas e fissuras foram formulados. O primeiro método emprega a adição de sais de fluoreto solúveis na resina não polimerizada. O segundo utiliza um composto de flúor orgânico, que pode ser quimicamente ligado à resina. Mas o mecanismo de liberação de flúor de selantes de fissuras fluoretados permanece desconhecido. A liberação de flúor pode ocorrer a partir do selante insolúvel como resultado de porosidade ou de um processo de troca iónica. Vários estudos analisaram os benefícios de tais combinações, mas nenhum estudo documentou um benefício real ou potencial do mesmo, em vez disso, parece ser mais uma jogada de marketing. Este artigo de revisão traz comentários relativos à utilização da combinação de flúor e selantes para prevenção de cáries, sua viabilidade e eficácia após adição de fluoreto em selantes utilizando estudos in vitro e in vivo.

Palavras-chave*: Cáries. Flúor. Cimento de ionômero de vidro. Selantes de fóssulas e fissuras.*

Introduction and literature review

Oral diseases are progressive, cumulative, and become more intricate to treat with advancement. While dental caries is an infectious transmissible disease with children being at the highest risk, primary prevention can reduce this risk. The concept of primary prevention of disease involves techniques and agents to prevent the onset of disease, to reverse the progress of the disease, or to arrest the disease process. The agents or methods of primary prevention of caries include fluorides, pit and fissure sealants, plaque control and dietary analysis to control the consumption of fermentable carbohydrates (1-3).

The pit and fissures present on the teeth surfaces pose the highest threat for caries initiation and progression that account for more than 50% of caries incidence. Occurrence of caries in such inaccessible areas conceived the concept of interventional procedures to occlude such areas of teeth and making them more caries resistant. Tortuous and irregular course of occlusal pits and fissure along with other contributory factors such as lack of salivary access, close proximity of fissure base to the dentinoenamel junction along with remnants of debris and pellicle in fissures increase their caries susceptibility by many folds (4).

Incidence, risk assessment and prevention strategies

Dental caries is transmissible and multifactorial diseases in which *Streptococcus mutans* bacteria create a primary oral infection (5). Dental caries can occur at any age after teeth erupt into the oral cavity, but the individuals at highest risk are children. According to the national center for health statistics (1997) six out of ten children have one decayed tooth by the age of five, while over 50% of 5 to 9 year olds and more than 78% of 17 years old have at least one cavity or filling in the occlusal portion of the tooth (6). According to Harris and Garcia-Godoy (5), 95% of all carious lesions occur on the occlusal surfaces of teeth. The occlusal surfaces of teeth comprise 12% of total number of tooth surfaces, which means the pit and fissures of the occlusal surfaces of teeth are eight times more susceptible to decay as the smooth surfaces of the teeth (7). The teeth at highest risk for carious lesion are the first and second molars, and 90% of all dental caries in school children occurs in pits and fissures of the occlusal surface of the molars (5).

Sealant application is a conservative preventive measure that can be accomplished without anesthesia or drilling of the tooth structure. Sealants can be placed on sound teeth and over incipient caries (8). Sealants are plastic resinous materials developed from enamel bonding techniques in dentistry of the mid 1970's (9). Sealants are usually applied as a liquid that is allowed to flow into occlusal pits and fissures and then allowed to harden (1). The cariostatic properties of sealants are ascribed to their ability to obstruct pits and fissures preventing bacterial colonization and fermentation of carbohydrates to produce acids at cariogenic concentration.

Early application of sealants on caries susceptible pits and fissures before caries initiation is the key to prevent caries. Thus pit and fissure sealants have emerged as economical and adequate means of caries preventive modality for maintaining dental health (10). Another therapeutic agent which is found to be effective in reducing caries is fluoride. With the development of knowledge regarding mechanism of action of topical fluorides, it was observed that fluoride releasing agents, when available at low concentrations and delivered through a controlled release agent or device over long period of time with frequent exposures; have highest effectivity (11). However the benefits that can be achieved through topical fluorides depend strongly on duration of exposure of tooth surface to fluoride releasing agents. Thus the concept of addition of fluoride to restorative material and by the time to pit and fissure sealants was brought forward.

At present, both fluoridated and non-fluoridated resin sealants are available in market with comparable success rates for prevention of caries. But the basic concept of addition of fluoride to resin sealants still remains questionable when non-fluoridated sealants are having the same pace to provide caries preventive efficacy. Besides this, when fluoridated resin sealants are to be considered, the properties of these sealants should bear to compare and replace conventional one are: (a) better or at least comparable retention rates with conventional sealant, (b) constant fluoride release for a prolonged period of time and (c) function as reservoir of fluoride ions to provide fluoride to enamel and promote fluoroapatite formation in enamel (12).

Keeping all these points in consideration, literature regarding feasibility of addition of fluoride to sealants was reviewed under the following headings:

1) development of pit and fissure sealants;
2) methods of fluoride incorporation to pit and fissure sealants;
3) feasibility of fluoride addition to sealants to impart anti-cariogenic property;
4) effectiveness of fluoride releasing sealants.

History of development of pit and fissure sealants according Roberson et al. (13)

Since pit and fissures being the most caries prone areas of teeth, numerous procedures had been proposed for decreasing the vulnerability of these areas to caries. Attempts started with M.H. Webb's concept of extension for prevention of occlusal caries to eliminate non-carious fissures, which was subsequently popularized by G.V. Black. In 1923 Hyatt advocated Prophylactic odontotomy with the placement of small amalgam or copper cement restoration in pit and fissure of newly erupted teeth before the appearance of clinical sign of decay. Gore in 1939 used polymers of cellulose nitrate in organic solvents as sealant to fill the surface enamel made porous by the actions of acids in the saliva. Howe proposed application of ammonical silver nitrate solution to sterilize tooth surfaces. The material was reported to reduce caries dramatically by means of diffusion into enamel and dentin increasing caries resistance by forming complexes with protein components and depositing reduced silver.

Zinc chloride and potassium ferrocyanide solutions were also reported to be effective in reducing caries. The concept application of impregnating solutions was based on theory that the primary route for initiation of caries was by proteolytic action of organisms on organic structures in enamel. Numerous dental cements such as zinc phosphate and copper cement were used to block pits and fissures mechanically. Kline and Knutson used ammonical silver nitrate to treat pits and fissures (14).

Development of occlusal sealants

In recent years, interest in non-operative methods for increasing resistance of pits and fissures has focused on developing polymeric materials, capable of adhering to tooth structure and "seal" caries prone areas. Methyl methacrylate was invented in 1933 followed by composite based Methyl methacrylate in 1951 that opened new vistas for different methods in dentistry. Haggers in the same year proposed the possibility of dentin resin bonding. In 1955, Buonocore discovered the technique of acid etching to increase adhesion of resin material to the enamel surface, that brought a breakthrough in sealant research (15).

A major breakthrough in this field was the development of a new cross-linking, thermo-setting di-methacrylate monomer (BIS-GMA) by Bowen. Flow characteristics of Bis-GMA were improved by diluting it with methyl methacrylate or other co-monomer to be used as sealant. This product mixture had less polymerization shrinkage, a lower coefficient of thermal expansion and better bonding with enamel. Further advancements in polymerization techniques of Bis-GMA were achieved with ultraviolet and visible light, depending on the chemical catalyst added to the mixture. Development of another very similar di-functional molecule UDMA (Urethane di-methacrylate) replaced the bisphenol-A backbone of sealants with a linear isocynate. Both BIS-GMA and UDMA were diluted with low viscosity TEGDMA to reduce viscosity (13).

In 1973, UV-cured composite sealants were replaced by auto-polymerizing resin. In 1980`s visible light cured composite sealants were introduced with advantage of easy manipulation. Meanwhile other adhesive materials like glass ionomer sealants and its allied modifications like resin modified glass ionomer sealants, compomers with or without fluoride, auto-polymerizing or light cured were developed. Other materials like diluted composite, has also been used as an acceptable alternative to an UV light polymerized sealant with advantages of simpler polymerization procedure, an apparently better wear resistance due to filler particles and easier recognition because of slight discoloration (15).

Methods of fluoride incorporation in pit and fissure sealants

Until now two methods have been developed to incorporate fluoride in pit and fissure sealants. First method utilizes addition of fluoride in form of soluble salt to the unpolymerized resin that releases fluoride ions after salt dissolution, following sealant application (16).

Another system of fluoride incorporation uses an organic fluoride compound that can be chemically bound to resin. Fluoride ions from such formulations are released by means of ion exchange procedure with other ions in the system. (16, 17) In this method (anion exchange systems), fluoride constitutes only a small amount of the total structure, and is replaced rather than lost.

Method 1: soluble fluoride salts added to unpolymerized resins

Because of advantage of topical fluorides, attempts were made to combine fluorides and resin sealants so as to improve caries preventive effects of pit and fissure sealants. Polyurethane fluoride-containing sealant material was the first to be formulated that would release fluoride on the enamel surface for an extended period of 24h to 30 days. Using several fluoride salts like NaF, acidulated NaF and Na2PO3F in ex-vivo studies observed that greatest fluoride uptake was observed in the acidulated NaF solutions (18).

Swartz, Phillips et al. (19) attempted to add fluoride to four sealants in form of two component system included in their study and determine feasibility of the same for enhancing its anti-cariogenic property similar to silicate cement. Two of these were commercially available products Nuva Seal (LD Chaulk Co., Milford, DE.), Epoxylite 9075 (Lee Pharmaceuticals, El Monte, Calif.) and the third was an experimental formulation (S.S. White, Philadelphia, Pa.) Initial tests were conducted with one sealant (Nuva-Seal) and two fluoride compounds, NaF and sodium fluorosilicate. The NaF salts were added by dispersing and vigorous mixing to the sealant in amounts of 2, 5, 10, and 15% by weight. In this study they investigated the fluoride release from the fluoride-containing resins, its uptake by intact enamel from fluoride resin and effect on enamel acid solubility. Results of the study had shown high deviations both in the enamel acid solubility and fluoride uptake tests on intact teeth as a result of its inherent solubility variations and initial fluoride content.

Park et al. (20) compared Fluro-Shield, Prisma-Shield and Delton pit and fissure sealants to each other through shear bond strength, scanning electron microscopy and microleakage. They concluded that the shear bond strength in Fluro-Shield and Prisma-Shield was significantly higher than in Delton, better adaptation to the etched enamel with Fluro-Shield and Prisma-Shield than with Delton, and no significant difference in microleakage among the three pit and fissure sealants.

Loyola-Rodriguez and Garcia-Godoy (21) estimated the antibacterial activity and the fluoride release, of FluroShield, Helioseal and a new fluoride containing sealant Teethmate F. Only Teethmate F showed inhibition activity against all strains of *Mutans Streptococci* tested; there was no significant difference in the inhibition between strains of *S. Mutans* and *S. Sorbinus*. Teethmate exhibited higher fluoride release than FluroShield during the 7-day study period. During 2 days after setting, these materials showed their highest concentration of fluoride release, which decreased to approximately 50% (below 0.1 PPM F^-) at 7 days.

Rock et al. (22) came to similar results regarding fluoride release, in vitro, from FluroShield in comparison to a GIC material Baseline. They also found 70% complete retention of FluroShield in first permanent molars, in vivo, after a 3-year follow-up.

In another clinical study, Jensen et al. (23) evaluated the retention and salivary fluoride release of FluroShield compared to its non-fluoride analogue PrismaShield. There was no significant difference in retention between the two sealants at 6 and at 12 months. However, fluoride release was significantly increased when compared to the baseline values, only at the 30 min post-sealant sampling interval.

Rock et al. (22) found 70% complete retention of FluroShield applied to contralateral caries-free first permanent molars in 86 children aged 7-8 years, after a 3-year follow-up. Lygidakis and Oulis (24) evaluated the retention rate and the caries increment differences between FluroShield and Delton. The sealants were applied in a half-mouth design to all 4 caries-free first permanent molars of 112 children aged 7-8 years. At a 4-year follow-up, the complete retention for FluroShield was 76.5% and for Delton 88.8% - the difference being statistically significant.

Morphis and Toumba (25) evaluated the retention rates of three different sealants: a conventional sealant Delton, its recently marketed fluoride-containing analogue Delton Plus, and an experimental fluoride-containing sealant, which was prepared by adding fluoride-glass powder to Delton. The sealants were applied to 104 permanent molars in children aged 6-16 years, in a randomized way. Results showed no significant difference in retention among the three sealants after a 1-year follow-up.

Method 2: organic fluoride compounds chemically bound to resin (anion exchange systems)

In order to avoid the problem of possible dissolution of fluoride salts incorporated into sealant materials, fluoride ions were incorporated as a mobile charge unit into an inert sealant material, i.e., acrylic anion-exchange resin system (26, 27). These resins had relatively high fluoride content and exchange fluorine ions from the sealant materials for hydroxyl and chlorine ions in the oral environment (26). In these resins the fluoride containing monomer was t-butyl-amino-ethyl-methacrylate hydrogen fluoride (t-BAEMA: HF), which copolymerized readily with other acrylic monomers. Thus the organic portion of the fluoride salt was covalently bound into the insoluble polymer network structure of the resin. An ion from saliva diffused into the resin, exchanged with fluoride ion, which then diffused out and was released, with probably insignificant decrease in the strength of sealant (28).

The possibility of making fluoride-releasing sea¬lants with organic resin was explored at an early stage and became one of the major focuses of effort. The initial results demonstrated that the material was too hydrophilic so that the physical properties deteriorated. In addition, color stability was poor and one of the components glycidyl methacrylate (GMA) proved to be both toxic and mutagenic (29). Reformulation of this 'first generation' resin was accomplished by replacing GMA with EGDMA (ethylene glycol dimethacrylate). The properties were much improved and the 'second generation' resin was neither toxic nor mutagenic (30).

As a first step towards this end it was determined that the fluoride monomer could be dissolved in a commercial sealant (Delton) without significantly changing its rate and degree of polymerization; a potential for 1-year fluoride release (0-03 mg/g/day) with 10% polymer loading was found ex vivo, while physical properties remained similar to the sealant alone. Based on these results new formulations ('third generation resins') were devised by the same authors that were less hydrophilic (31). Evaluation of these materials is currently in progress. Kadoma et al. (32) attempted to copolymerize methacryloyl fluoride (MF) with methyl methacrylate (MMA), yielding long lasting topical fluoride materials. The fluoride in the copolymers was present as acid fluoride covalently bonded to carbonyl groups, and fluoride ions were slowly released by hydrolysis in aqueous solution with adjustable rate of release through variable copolymer composition.

Research of the anion exchange system-sealant is in progress but, to date, no commercial product is available (33). Despite the fact that no anti-caries clinical studies have been reported (34), in vitro studies indicate that a fluoride releasing sealant substantially reduces the amount of enamel demineralization adjacent to it (23). However, the main problem with the existing fluoride releasing sealants is that they give no lasting effects on salivary fluoride concentration levels (22, 23, 35).

Feasibility of fluoride addition to sealants to impart anti-cariogenic property

Several studies have looked at the benefits of combining pit and fissure sealant application with fluoride treatment of one kind or another, or of adding fluoride to a sealant. However, no studies have documented a clinical benefit with fluoride-releasing resin sealant, and while one can contemplate the potential benefit, the short time duration of very low level fluoride release from resin sealant would raise doubts about whether any clinical benefit is likely.

Feasibility of use of fluorides with sealants and fluoridated sealant

Of the two methods that were developed to incorporate fluoride in pit and fissure sealants, the first one that utilized soluble fluoride salts for addition in unpolymerized resin, it was observed that fluoride ions leached from within the substance of resin sealants possibly compromise the integrity of the resin (16). This method has been questioned, because fluoride release resulting from the dissolution of a soluble salt might weaken the sealant in situ, thereby reducing its usefulness as a preventive agent (28). In the second method that utilized system of an organic fluoride compound incorporated as a mobile charge unit into an inert sealant material. This organic fluoride compounds were chemically bound to resin yielding an anion-exchange resin system. These resins had relatively high fluoride content and exchange fluoride ions from the sealant materials for hydroxyl and chlorine ions in the oral environment (26).

In 1990, a commercially available sealant with fluoride was marketed that purportedly released fluoride. This product (Fluoro-Shield) was a visible light-cured resin containing 2% NaF and 50% by weight inorganic filler (35). Cooley et al. (35) evaluated ability of FluroShield (LD Chaulk/Dentsplay, Milford, USA) light cured resin containing 2% NaF and a nonfluoride sealant HelioSeal (Vivadent Co., Liechtenstein, UK) to penetrate fissures, resist microleakage and release fluoride. No significant difference was observed between two sealants regarding fissure penetrating ability, but FluroShield was found to have significantly more leakage. All specimens of the FluroShield released fluoride over the 7-day test period; there was a 'burst effect' in which larger amounts of fluoride were released on the first and the second day and then the release tapered off. Fluoride release was decreased by approxi¬mately one-half for each of the first three days.

However, because the data was obtained from a laboratory model, the results could not directly predict clinical caries reduction through the use of FluroShield. The addition of fluoride to resin sealant seems to be more of a marketing benefit than a clinical benefit. Additionally, attempts to treat etched enamel with acidulated phosphate fluoride prior to sealant application resulted in reduction in bond strengths with all sealants tested (36). In an analysis of fluoride release from fissure sealants, Garcia-Godoy found that all the fluoridated sealants tested released measurable fluoride throughout the test period in a similar pattern. However, the greatest amount of fluoride was released in the first 24 hours after mixing, and the fluoride release fell sharply on the second day and decreased slowly for the last days (37).

Feasibility of glass ionomer materials as sealants

The logical assumption that a material that releases fluoride, such as glass ionomer cement, would provide an added benefit to the retentive blocking of the fissure. However there is no data that supports the use of glass-ionomer sealant in preference to resin sealant. Use of glass ionomer materials as pit and fissure sealants is not encouraging in terms of retention, but appears somewhat more positive for caries prevention. Glass ionomer (polyalkenoate) cements have documented high levels of fluoride release (38); the caries-preventive effect of glass ionomer sealant depends on both retention of the sealant and fluoride release (39).

Williams et al. (40), concluded that Polyalkenoate cements probably should be regarded as 'fluoride depot' materials rather than fissure sealants when used in this context. However, used as a pit and fissure sealant, the traditional glass-ionomer cements have shown very poor retention rates (41) as well as leakage even when fully retained (42). Seppä et al. (11), suggested that fissures sealed with glass ionomer are more resistant to demineralization than control fissures, even after macroscopic sealant loss. This may be the result of the combined effect of fluoride released by glass ionomer and residual material in the bottom of the fissures (43).

Raadal et al. (44) and Rock et al. (22) used different types of glass ionomers in their analyzing studies ranging from cavity liners of low-viscosity, resin-modified to medium viscosity glass ionomer. It wouldn't be surprising to know that, because of the very low retention rate, low viscosity cavity liners resin-modified glass ionomer cement showed a low caries preventive effect in comparison with light-cured resin composite sealants. Resin sealants have been tested many times with various glass ionomer materials, sometimes in direct comparison with resin materials. However there is no data that supports the use of glass-ionomer sealant in preference to resin sealant.

In the interesting study by Mejare and Mjör (45), 61% of the glass ionomer sealants were lost within 6-12 months and 84% after 30-36 months. Although total loss was recorded clinically for the majority of the glass ionomer sealants, some retained sealant was observed in the tooth replicas in 93% of them. The clinical evaluation of the resin-based sealants showed an average complete retention rate of 90% after 4.5-5 years. The corresponding figure with the replica technique was 58%. Caries was recorded in 5% (n = 8) of the resin based and in none of the glass ionomer sealed surfaces (45). In the eight surfaces with caries, six of the surfaces were registered after 6 to 12 months, which is probably too soon to be certain caries was not present at sealant application time. This study proved to be a stepping-stone in supporting glass ionomer cement as beneficial form in caries preventive perspective despite of poor retention. However, the small numbers do not allow such a conclusion to be drawn. As the authors themselves concluded, "Any conclusions about a possible long term caries-preventive effect [of glass-ionomer sealant] cannot be drawn from the present results".

The poor retention rates of glass ionomer sealants make cost effectiveness a significant issue in considering their usage. Kervanto-Seppälä et al. (46) in Finland showed that glass ionomer sealants, whether resealed or not, cannot be as cost-effective as resin-based sealants, when the expense of placement in time (and thus costs) is used as the basis of efficacy. At 12 months, only 20% of the sealants were clinically evident (47). So it is clear is that the caries-preventive effect of glass ionomer sealant depends on both retention of the sealant and fluoride release (39).

Thus, traditional glass ionomer cements have essentially been abandoned as fissure sealants since their retention is vastly poorer than the resin sealants. However, it has been speculated, if not shown to be of statistical significance, that the fluoride-releasing effect of the glass-ionomer materials may infer some caries protective effect even after the apparent loss of the material in the pits and fissures (43, 45). Thus the studies published concluded that the resin-based sealant is not only superior in terms of retention, but also in caries prevention where retention plays a major role (44, 48).

Effectiveness of fluoride releasing sealants

After addition of Na2PO3F to polyurethane; it was concluded that this preparation reduced enamel acid solubility, increased fluoride uptake in enamel and released fluoride up to 1 month (18). Swartz and Phillips et al. (19) in their attempt to add fluoride to sealants observed that, under the test conditions, the physical properties of the resins (tensile strength, water absorption, hardness and resistance to tooth¬brush abrasion) were not grossly impaired by the addition of fluoride salts nor were enamel-resin bond strength or microleakage. But researchers observed difficulty of achieving and maintaining a uniform dispersion of the fluoride salt in test materials. Distribution of fluoride added to sealant was found to be more even in viscous type than in more fluid type sealants. Factors such as differences in the degrees of polymerization, not only of various materials but also in the same material from one specimen to another affected the amount of available fluoride. The rate of release of fluoride from the sealants was found similar to the pattern of release from restorative resin in that the greatest amount of fluoride was released during the first day or two, after which the amount rapidly diminished. Researchers were doubtful about such pattern of fluoride release in terms of providing same degree of protection against caries as GIC and silicate cements, where fluoride is leached from the material at a continuous rate throughout the life of the restoration. Based on the previous study, el-Mehdawi et al. (49) studied, in vitro, fluoride release of an ultraviolet fissure sealant (Nuva-seal - L. D. Caulk Div., Dentsply, Int. Inc., Milford, De, USA) throughout a 3-week period by adding several concentrations of NaF to the sealant, that was found to decrease over the 3-week study period, while the quantity of fluoride ions increased when the concentration of the fluoride salt in the sealant increased.

In a study retention rates and caries increments between a fluoride-containing filled sealant (FluoroShield) and a conventional (non fluoridated) sealant (Delton®, Ash/Dentsply,York, PA) was compared over four years in a regular biannual preventive program including topical gel application, the fluoride-containing filled sealant (FluoroShield) appeared to have a lower complete retention rate when compared with conventional one (Delton). However, total sealant loss and caries increment was similar in both groups (14, 24).

An in vitro analysis of fluoride release by pit and fissure sealant showed that sealant may provide additional protection against caries formation in cuspal incline enamel and smooth surfaces adjacent to sealed pits and fissures (although caries in such areas clinically is rare). Perhaps, more importantly, sealant may act as a fluoride reservoir with long-term release of fluoride into the immediately adjacent oral environment (50). However the key questions still remain unanswered for the evidence of equal retention rates between conventional sealants and fluoridated one; for in-vitro fluoride release and reduced enamel demineralization. That's why researchers have further advocated necessity of some more in vivo experiments to ensure the clinical longevity of fluoride sealant retention and to establish the objective of greater caries inhibition through the fluoride released in saliva and enamel (33).

Discussion

In 1990s, Arends and Christoffersen (51) and Featherstone (52) proposed that dental caries could be prevented on superficial layers of enamel by inhibiting demineralization under common ions such as calcium and phosphate and by promoting remineralization under fluoride ions on the surface. They also stated that significant remineralization occurred even at very low concentrations of fluoride ions (0.03-0.05 ppm) in the oral cavity. Following such recommendations and considering evidences of some previous in vitro experimental studies (18, 19) sealant manufacturers came with innovative concept of addition of fluoride ions to dental sealants. However fluoride release rates and periods of contact of fluoride containing pit and fissure sealants with calcified dental tissues are clinically important in establishing to what extent dental caries can be prevented and whether they will recur in the boundary.

In 1983 a National Institute of Health Consensus Panel (53) considered the available information on pit and fissure sealants and concluded that,

> The placement of sealants is a highly effective means of preventing pit and fissure caries. Expanding the use of sealants would substantially reduce the occurrence of dental caries in the population beyond that already achieved by fluorides and other preventive resources.

The role of fluoride released from dental materials in caries prevention has been well established in the dental literature. Frequent supply of F- at low concentration decreases the enamel demineralization and accelerates the remineralization process. Fluoride released from various dental materials plays a promising role in caries prevention. Thus the ability of a dental material to act as a fluoride reservoir is a distinct advantage in caries resistance, both at the enamel restorative interface and adjacent to the outer enamel surface near the fluoride-releasing dental material (54).

Glass ionomer cement (GIC) is one such material introduced nearly about 35 years ago as an alternate fissure sealant system containing fluoride that is released slowly over a period of time into the surrounding enamel and yield cariostatic effects for prevention of pit and fissure caries. The main advantage of GIC is its ability to bond chemically to enamel and dentin without etching, making it much easier to handle (55). F- release from glass ionomer cement occurs by means of three discrete mechanisms: surface wash off, diffusion through pores and cracks and bulk diffusion (56). A sustained F- release in surrounding dental structures and tooth microenvironment can be explained through the mechanism of diffusion of water into the material forming hydrogen ions, that attack fluoride-containing glass particles, releasing fluoride. Ionomeric materials being more permeable to water enhance fluoride diffusion and release (57).

On the other hand, Glasspoole et al. (58) observed no significant inhibition of demineralization between fluoridated as well as non-fluoridated resin sealants. Such findings could be explained on the basis of differences in the composition between ionomeric and resinous materials, resulting in subsequent differences in fluoride releasing profiles, the matrix of resinous sealants is much less hydrophilic, making fluoride release more difficult (59). Depending on the environment, all pit and fissure sealants may act differently due to other variables like preparation of fissures, enamel etching and conditioning, application of bonding agents and contamination of prepared surfaces of fissures (19).

The mechanism of fluoride release from fluoridated fissure sealants remains speculative. For example, release might occur from the insoluble sealant material as a result of porosity (16). It might also occur because the fluoride ion or the fluoride-glass is not tightly bound to the polymerized resin molecules. Release in fluoride-glass containing sealants may also be due to fluoride-glass grains depositing on the surface of the resin (26). Fluoride may have been released in several in-vitro systems that have been studied from the unpolymerized air-inhibited layer on the surface of the specimens. Unpolymerized resin probably would not be of benefit to the enamel, in the clinical situation because it contacts the enamel only minimally and also would be worn away almost immediately after sealant placement (15). Despite the fact that no anti-caries clinical studies have been reported (34), in vitro studies indicate that a fluoride releasing sealant substantially reduces the amount of enamel demineralization adjacent to it (23). However, the main problem with the existing fluoride releasing sealants is that they give no lasting effects on salivary fluoride concentration levels. (22, 23, 35)

Conclusion

Our review of guidelines and position statements revealed concerns about the methods of incorporation of fluorides in various types of pit and fissure sealants and release of fluoride from sealants in general use. Dental concerns, however, are specific about feasibility of fluoride addition to sealants and their effectiveness to impart anti-cariogenic property.

Because the literature on this topic is extensive and complex, it merits a much larger review of all the issues around sealants, including all dental concerns. Most of the studies done till now are in-vitro and results obtained are recorded under laboratory conditions that utilized distilled water or artificial saliva as experimental surrounding medium.

Fluoride release that occurs in such conditions are unidirectional ie. from sealant specimen into tooth or experimental surrounding medium. Release of fluoride from fluoride materials into artificial hu¬man saliva has been shown to be significantly less than into water. However the scenario is totally different in in-vivo condition. In the oral cavity, it is probable that some of the fluoride release is available for ionic substitution of the mineral phase of the enamel from dental sealants and some from saliva or other oral tissue fluids.

Based on our review of literature, we recommend one of the following procedures to accomplish this task: In addition to determining the fluoride ion release from sealants in-vitro, long term clinic-epidemiological studies and in vivo experiments are necessary in order to evaluate the factors of concentration, rate and duration of fluoride release. In spite of the above evidences through numerous in vitro and clinical studies between fluoridated and non fluoridated pit and fissure sealants for equal retention rates, caries preventive efficacy and reduced enamel demi¬neralization, any statement for additional benefits of fluoridated over non-fluoridated fissure sealants should be made with caution.

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