Pit and Fissure Sealant: Then, Now, and Next Steps

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Abstract

This paper discusses the role of Herschel S. Horowitz in pit and fissure sealant research, and the data from a literature review of the subject presented at the Memorial Symposium to Herschel Horowitz. The vast body of literature presently available to students and practitioners in the area of preventive dentistry is due in large part to pioneers who forged the path in modern preventive materials such as fluorides and sealants. Uniquely, Herschel S. Horowitz stood out for his contributions to the scientific literature in both fluorides and pit and fissure sealants. His work has contributed to millions of children growing into adulthood with less disease than they would have without the benefits that Herschel Horowitz pioneered. From a careful and thorough review of the literature of peer-reviewed publications on pit and fissure sealant, it is clear that sealants are safe, effective, and underused.

For those with a penchant for preventive dentistry, Herschel Horowitz is a legend in our time. All are familiar with his huge body of work in fluorides, particularly in school-based fluoride programs. Not so many, perhaps, think of Hersh Horowitz for his work with pit and fissure sealants. But in 1975, when planning a clinical trial in pit and fissure sealants, it was the Horowitz et al. Kalispell study (1) that I looked up to as a model and guide for my work in this field. The Kalispell study was the classic study of the times in pit and fissure sealant research. While others at this symposium will discuss Horowitz's work in fluorides, my task is to discuss pit and fissure sealant, and it is fitting that this discussion of sealant as a preventive agent be dedicated to the memory of Herschel S. Horowitz.

Discussion

Buonocore's classic study of 1955 marked the start of a major revolution in the clinical practice of dentistry (2). The first clinical benefit from Buonocore's work was the introduction of the first dental pit and fissure sealant, Nuva-Seal (L.D. Caulk) in February 1971, along with its curing initiator and ultraviolet light source, the Caulk Nuva Lite. However, it took several more years before the sealant technique, and other clinical innovations that have resulted from Buonocore's work, began to be adopted in clinical dentistry to any significant degree. Even now, more than 30 years after the introduction of pit and fissure sealants to the dental marketplace, the profession has not embraced the procedure to the extent that available scientific data would lead one to expect.

While authors had previously attempted to find conservative ways of treating occlusal pits and fissures—such as Wilson, who used zinc phosphate cement (3); Bödecker, who proposed enamel fissure eradication (4); and Kline and Knutson, who used ammoniacal silver nitrate to treat pits and fissures (5)—none achieved any great measure of success. An invasive operative procedure, the prophylactic odontotomy, introduced in the 1920s (6) by Hyatt, remained the treatment of choice for many clinicians well into the 1970s. But with Buonocore's visionary procedure came the ability, as he predicted in 1955, to successfully prevent caries by sealing pits and fissures with a bonded resin material.

By the mid-1970s, many early clinical studies showed excellent retention and great promise in terms of potential caries prevention (7). It was recognized in the 1970s that one of the deficiencies of early sealants was the difficulty in assessing sealant presence with the clear resin materials used. Thus, in 1976, 3M Dental Products introduced the first colored sealant, Concise White Sealant, a chemically cured material, white in color from the addition of titanium dioxide, that was still on the market as of a short time ago. Whether this roughly 25-year duration marks the great longevity of a fine material, or a lack of innovation in development of new sealants (certainly as compared to the dentin bonding systems)—or perhaps a combination of both factors—is a matter of opinion. In 2001, both 3M (now 3M ESPE) and Ivoclar Vivadent introduced new sealants with color-changing capability. Whether there is any clinical benefit to color change or it is merely a cosmetic marketing tactic remains to be seen.

There are literally hundreds of reports documenting and discussing the retention of pit and fissure sealants. Apart from the early reports already mentioned, the first report over a significant period of time was Horowitz's landmark Kalispell study (1). In the five-year report of this study, the authors reported 42 percent complete retention at five years (8). Horowitz also noted that teeth with sealant partially missing had a lower incidence of caries (7%) than paired unsealed control teeth that were not sealed (41% caries). Thus, from the results of this pioneering clinical trial, one can conclude that even partially sealed teeth are considerably less susceptible to caries than unsealed teeth. Horowitz concluded, "The findings of this study clearly show that when this pit and fissure sealant is retained, it is effective in preventing caries in sealed tooth surfaces." Charbeneau et al. also commented on partially lost sealant, noting "Sealant loss from a surface did not appear to initiate pit and fissure caries..." (9).

Thylstrup and Poulsen looked at caries reduction and found a 70 percent reduction in caries over one year (10). At two years, the caries reduction

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was 98 percent in sealed pairs where the material was fully retained (11). A report on Nuva-Seal, the first sealant marketed, noting an 84 percent caries decrease over one year, and 53 percent two years after application (12). The caries reduction was similar for primary and permanent enamel.

Additional studies reported retention rates of 50 percent at 48 months (13); 60 percent after 5 years (14); 85 percent after 24 months(15); 72 percent at 54 months (16); 92 percent at 2 years (17); 63 percent after 23 months (18); 67 percent after 6 years (19); 97 percent at 2 years (20); 94 percent after one year in a Guatemalan public health clinic (21); Delton sealant in a Danish school dental service 40 percent after 6–7 years with caries reduction of 32 percent for girls and 25 percent for boys (22); and 85 percent at 2 years (23).

A meta-analysis carried out by Llodra et al. showed that the overall effectiveness of autopolymerized resin was 71 percent and the authors concluded that "autopolymerizing sealants should be used" (24). Ismail and coworkers reported in an evaluation of the Saskatchewan dental program that sealed teeth experienced 46 percent fewer carious lesions than unsealed teeth four years after the application of sealants (25).

The longest studies in pit and fissure sealant retention have been reported for 10 years or longer. Wendt and Koch reported on teeth sealed over a 10-year period (the title of their paper is somewhat confusing as it sounds like it is a 10-year study, but not all teeth were sealed for 10 years; teeth were sealed on an ongoing basis and the longest retentive period for any tooth was 10 years). They found that after 8 years, about 80 percent of the sealed fissures showed total sealant retention and no caries. Another 16 percent of the sealed occlusal surfaces showed partial retention and no caries. After 10 years only 6 percent of the sealed occlusal surfaces showed caries or restorations. The authors noted the results underline that fissure sealing is an effective treatment and has a low failure rate (26). A later follow-up noted that this long-term retrospective study indicates that a structured fissure sealing program is of great benefit for oral health (27). Up to 20 years after sealant had been applied, a surprisingly high 65 percent showed complete retention, 22 percent partial retention without caries, and 13 percent caries or restoration in the occlusal fissures or buccal pits (28).

Another long study by Romcke et al. showed an overall annual sealant success of 96 percent after one year and 85 percent after 8–10 years. The authors concluded that the results support the careful application of chemically cured sealants under field conditions and the use of annual examination to allow minimal sealant maintenance (29).

A 15-year study of the single application of a colored (white) autopolymerizing pit and fissure sealant found 28 percent complete retention and 35 percent partial (noncarious) retention on permanent first molars. In a matched pair analysis, carious, or restored surfaces made up 31 percent of the surfaces in the sealed group and 83 percent in the unsealed group (30). The author predicted that with routine maintenance, the 31 percent of sealed teeth that became carious could be brought down close to nil if partially missing sealant was replaced at regular intervals.

The late Eva Mertz-Fairhurst completed several important studies in the area of pit and fissure sealant before her untimely passing. In a 1981 report in the *Journal of the American Dental Association* (16), she reported on the retention of Delton, probably the most popular sealant on the market, compared to the older ultraviolet light-initiated Nuva-Seal. While the Nuva-Seal was completely retained on 35 percent of all paired permanent molars, Delton was retained on 72 percent. Improved sealants and curing methods, along with a better understanding of the technique, was leading to improved retention rates compared to the original materials. Mertz-Fairhurst concluded, "Occlusal caries protection on permanent molars is assured if the sealant is completely retained on the tooth. Delton was four times more effective in providing protection against pit and fissure caries than Nuva-Seal."

Stephen et al. reported that 25 percent of baseline unsealed surfaces were carious compared to 15 percent of those originally sealed ($P<.001$), although for molars, the equivalent figures were 49 percent and 24 percent ($P<.001$) (31).

In a review, Weintraub reported that based on the literature reviewed, following one application of autopolymerized or visible-light-cured sealant, the median percent effectiveness declines from 83 percent after one year to 55 percent after seven years. Similarly, the median complete retention declines from 92 percent after one year to 66 percent after seven years. Conversely, the median percent of sealed first molars becoming carious and/or restored increases from 4 percent after one year to 31 percent after seven years. It was further noted that large differences in sealant effectiveness are not apparent between studies performed in fluoridated and fluoride-deficient communities (32).

Messer and coauthors showed that regardless of sealant retention, caries experience was low under partially retained or missing sealants (5%) and completely retained sealants (<1%) (33).

Regarding retreatment, sealants placed in first permanent molars in 6-, 7-, and 8-year-olds required more retreatment than those in older children. Those placed initially in second molars in 11- and 12-year-olds required more reapplication than those placed in older children. It was concluded that sealants are a successful preventive procedure, but the failures of early-age placement leave some doubt as to the best time to place sealants (34).

It has been documented for decades that sealants are safe, effective, and underused. The latest data available indicate that in the United States only 15 percent of children aged 6–17 years have dental sealants (35). Another report indicates just 10 percent of the sample had sealants on their permanent molars (36).

Why there is underusage of a proven preventive material is hard to explain. Dentists continue to identify lack of insurance coverage for sealant application as a major barrier to patients receiving the service (37). Chapko promoted the two-stage, or opinion-leader, model of diffusion and suggested that new technologies can be promoted by first influencing dentists who consistently adopt early (38), while Farsi concluded that continuing education courses were more likely to change dentists' knowledge than attitude and behavior (39).

Cohen and co-workers concluded that professional organizations should take a more active role in promoting

sealants to dentists, that professional organizations and governmental agencies should increase efforts to inform patients/consumers of the benefits of sealants, that guidelines for sealant use should be developed, that state boards should permit the delegation of sealants to trained auxiliaries, and that sealant manufacturers should make more effort to advertise and promote sealants (40). In another paper, Cohen suggested that the best combination of variables predicting sealant use were preventive orientation, opinion about sealants, and patient influence (41). A study by Lang et al. suggested that dental personnel may strongly influence dissemination of information about, and utilization of, pit and fissure sealants (42). Romberg and co-workers noted that variables significantly associated with sealant use included availability of insurance, ability to delegate sealant procedures, and patient income and acceptance (43).

In a Colorado study, it was shown that a relatively high percentage of Colorado dentists are utilizing sealants on a frequent basis. Major reasons for limited usage or nonutilization of sealants relates to lack of insurance coverage and concern regarding sealing in of caries (44).

Attitudes toward certain procedures are frequently born in dental school. In another report, Cohen noted that the students' projected sealant use in practice was explained best by the combination of student attitudes toward sealants and their evaluation of the overall preventive orientation of their dental school (45).

One of the concerns with adding sealant coverage to third party dental programs was the concern about overtreatment. Corbin et al. looked at the effect of third party plans and showed that sealants can be added to third party dental programs with little overall risk of inappropriate use or abuse (46). Newbrun noted that dental sealants, which are highly effective in protecting pits and fissures when applied soon after the teeth erupt, will be more widely used in the future when insurance plans will pay for prevention (47). In the 13 or so years that have passed, little increase in usage has been ascertained.

Selwitz and others, in an analysis of 16 factors thought to be related to sealant presence, revealed that parents were more likely to obtain dental sealants for their children if dentists or their staffs recommended them, if the parents were knowledgeable about dental sealants, if the parents were more highly educated, and if the parents had dental insurance coverage. Yet they were surprised to discover that parents were less likely to obtain dental sealants for their children if they heard about them from mass media. The latter finding was unexpected and may have been influenced by conflicting or negative opinion expressed by some dental practitioners through mass media or other channels of communication (48).

It remains a clear and disappointing fact that, despite the proven benefits, pit and fissure sealant treatment is offered to just a small percentage of the at-risk population.

Penetration of sealant is, in my opinion, a key factor in improving sealants of the future. Irinoda and co-workers showed that a low viscosity sealant penetrates better and forms a resin-impregnated layer with enamel, whereas the higher viscosity sealants tested did not penetrate enough to ensure that the acid-etched enamel was infiltrated sufficiently by the sealant to ensure good marginal seal (49). This finding runs contrary to the manufacturers' tendency today to promote filled sealants or flowable materials for sealant application. There is no evidence that these filled sealants will be better; what evidence there is tends to show that they will not be retained as well (50,51). Barnes et al., on the other hand, found that viscosity and flow characteristics have no effect on sealing ability or void formation (52). The effect of a sealant that penetrates better than conventional sealants would be interesting to study clinically over the long term. My best prediction is that the sealant that penetrates the best, all other factors remaining equal, is the sealant that will be retained the longest and therefore the sealant that will prevent the initiation, or the spread, of caries the longest.

Etchant penetration goes hand in hand with sealant penetration. If we are to use penetrating agents within sealants, then we also must provide a way to etch the fissure walls as deeply as possible. The present trend of using self-etching adhesives may well be of enormous benefit if applied to pit and fissure sealant. In one study, none of the commercially available etchants studied were able to penetrate further than 17 percent of the total fissure depth in the fissure model. A surfactant-containing etchant was tested and showed complete penetration within about 1 minute and had a significantly lower surface tension and contact angle than the other products tested. Only the surfactant-containing etchant could produce a retentive pattern on the entire wall enamel of the fissure with the exception of locations blocked by debris and plaque. Surfactant-containing etchants with a low viscosity can penetrate completely into fissures and can produce an increased retentive and wettable surface which significantly increased sealant penetration into deep fissures (53).

If sealants are gradually lost over time (as all sealants are to some degree), they should be repaired when deficient if they are to be effective (54).

There is an interesting dichotomy in how sealants are used in different parts of the world. In the United States the trend today seems to be to use far more caution in applying sealant to questionable areas (carious or not). It seems that the oxymoronic invasive diagnosis is the order of the day, with aluminum oxide air abrasion and small burs leading the way. In other parts of the world, sealants are not applied until caries is diagnosed visually (without invasive treatment). There it is recognized that well-applied sealants will prevent spread of an incipient lesion, as the literature shows. Why this is so hard to get across in the United States is hard to fathom.

Clearly, our powers of diagnosis are limited, particularly where pit and fissure caries is concerned. Innovative new diagnostic tools such as the DIAGNOdent (KaVo) promise objective, rather than subjective, diagnosis of pit and fissure caries (55,56). In a recent paper, Takamori et al. expanded the use of the laser fluorescence system into detecting caries under sealants, an intriguing use indeed. They showed that this laser diagnosis system (DIAGNOdent) makes it easy to detect the existence of caries under a pit and fissure sealant during a routine checkup (57). However, the technique did not work on white sealants and the opacity of the titanium dioxide may be the confounding factor at play.

The philosophical discussion then

revolves around whether the subjectively caries-free fissures should be cleaned and sealed, or aggressively (invasively) opened (enameloplasty) prior to sealing with small burs or aluminum oxide abrasive systems, or whether the fissures should be left untreated, or maybe preventively treated with application of a fluoride varnish? The relatively viscous fluoride varnishes would, however, not penetrate the fissures to an ideal degree.

In some European countries, particularly the Scandinavian countries, routine application of pit and fissure sealant to caries-free teeth is seen as overtreatment. This approach is supported by the study of Heller et al. "Initially sound tooth surfaces were unlikely to become decayed in five years, and did not benefit greatly from the application of sealants. Within the limitations of this study, there were clear efficiencies in sealing incipient, but not sound, surfaces. The targeting of teeth with incipient caries for sealants is therefore recommended" (58). Others would prefer to investigate the surfaces prior to sealing: the results support the practice of opening up questionably carious fissures and removing caries (if present) before sealing (59).

In this philosophy of conservative pit and fissure management, the effect would be to leave all caries-free fissures unsealed until there is evidence of caries and only then seal the fissures. This is apparently an effort to minimize overtreatment of teeth that would never become carious and thus conserve valuable resources and manpower. However, in so doing, many teeth will become carious before sealing and this becomes an ethical dilemma. Is it ethical to allow a disease to occur before instituting proven, effective preventive procedures?

Applying sealant to small carious lesions is certainly justifiable—the literature is clear on this subject (60,61). However, when the sealant wears down and a fissure that was previously sealed becomes partially uncovered and the oral fluids are free once again to migrate down the fissure, under the sealant, and thus possibly interact with the bacteria in the dormant carious lesion once again, the caries process would once again become active. Depending on when the sealant is reapplied, the resulting damage could be limited or severe. It would seem to me to be more prudent to seal caries-susceptible, caries-free teeth and, once caries is diagnosed, to remove the caries and place a preventive resin restoration (62,63). Of course, if we had etchants and sealants or a combined self-etching adhesive sealant that penetrates to the base of all fissures, this would be of lesser concern.

It has been suggested that sealants should be a targeted treatment for just the high-risk patients. Graves et al. stated in 1986, "The dental profession should shift its emphasis from the early restoration of fissured-surface defects to an expanded use of sealants for those with reduced decay and focus resources on a minority of the population with high caries levels who receive limited care" (64).

Chewing gum containing xylitol has been shown to prevent caries to a similar degree as sealants. Alanen et al. found that sealants and xylitol chewing gum are equal in caries prevention. After 5 years, no statistically significant differences between the sealant and xylitol groups were found (65).

The use of combinations of preventive techniques—such as fluoride-containing varnishes, chewing gum containing xylitol, or agents that stimulate remineralization of demineralized enamel and sealants in a multipronged attack—should be studied further.

Croll has come up with perhaps the most innovative application of a pit and fissure sealant technique to date. He described a method of placing a reinforced resin-bonded sealant. He applies a dentinal bonding agent to etched enamel (or uses the new self-etching adhesives) and compresses a posterior composite into the fissures. "When the beneficial properties of resin-bonded sealants are combined with those of preventive resin restorations, the outcome is perhaps the "quintessential sealant" (66).

In a paper where almost 1,500 references involving pit and fissure sealant or other ancillary techniques were reviewed, the following conclusions can be drawn from the available scientific evidence. The etching agent of choice for pit and fissure sealant application is 35–37 percent orthophosphoric acid. The clinical technique for pit and fissure sealant application involves strict attention to detail and to perfect isolation for maintenance of a dry field. Dry brushing, rotary brushing with pumice paste, air polishing, and air abrasion have all been used to clean the enamel surface prior to etching. Air polishing appears to offer the best surface preparation technique. Etching time has shortened over the years to 15 seconds for both permanent and primary enamel. Trained auxiliaries are equally competent at sealant application. Pit and fissure sealant is well documented in terms of retention and caries prevention.

Fluoride-containing sealants have not shown superiority to regular sealant. With regard to using sealant as one component in an intensive preventive program, one study found that basic prevention leads to virtually the same preventive effect as intensive prevention treatments, while another found that providing intensive prevention to high-risk populations was a benefit. Glass ionomer sealants have failed miserably in comparison to resin-based sealants, showing very poor retention. The major benefit of resin sealants, that of excellent retention and thus physical blocking of the fissure system, appears much more important for caries prevention than the transient benefit of fluoride release over the short time glass ionomer sealants are retained. Even though some claim remnants of the glassionomer sealant may inhibit caries for longer time periods, this does not compensate for the poor retentive properties of the material.

Unfilled sealants perform better than filled sealants. Colored or clear resin sealant is a matter of personal preference; however, it has been shown that the ability to assess retention properly in colored sealants is much less error prone than with clear sealants. Use of an opaque color may interfere with the potential for laser fluorescent diagnosis of caries under a sealant. This may eventually become a valuable adjunct procedure in the follow-up routine of sealants placed years earlier, and thus the opaque white sealant may not be ideal (57).

Autocured sealant appears to have equivalent documentation of performance compared to visible-light-cured sealant. The data is unequivocal that sealant can safely be placed over incipient caries and that the lesion will remain dormant as long as the sealant eliminates contact of the oral fluids

(and thus the nutrient source) with the cariogenic bacteria. The claim from some advocates of aggressive invasive exploration of apparently caries-free, or minimally carious, fissures that bacteria remaining viable within the confines of a sealed fissure can continue to produce acid from nutrients from the dentinal tubules is unsubstantiated.

Pit and fissure sealant can be regarded as cost effective or not cost effective, depending on the study design and results (primarily the retention of the sealant). It seems that even if the data show that sealant treatment is more costly than restoring surfaces that would have become carious in the absence of sealant, one must remember the intangible benefits of preventing disease and preventing loss of tooth structure. Application of sealant, from a maximally cost-effective view, is best applied to high-risk patients. While safe and effective and (according to some studies) cost effective, sealants are an extremely underused preventive treatment. Various rationalizations have been proposed to explain the incongruity of the underuse of a known successful preventive treatment.

One study raised concern about the safety of monomers leaching out of one particular sealant. Other more recent studies have refuted this concern and the present scientific position as expressed by the American Dental Association is that parental concern about the alleged estrogenicity of sealants is unfounded based on the presently available evidence. The use of an intermediate bonding layer, or the incorporation of the benefits of the advances of the past decade in dentin bonding agents into newly formulated pit and fissure sealants, is perhaps the most exciting new potential development for the future of pit and fissure sealant materials. The use of a caries-detecting laser fluorescence system as a routine baseline caries-assessment aid, prior to sealant application, and more recently as a follow-up observation, deserves further study.

The vast body of literature that is presently available to students and practitioners in the area of preventive dentistry is due in large part to pioneers who forged the path in modern preventive materials such as fluorides and sealants. Uniquely, Herschel S. Horowitz stood out for his contributions to the scientific literature in both fluorides and pit and fissure sealants. His work has contributed to millions of children growing into adulthood with less disease than they would have had without the benefits Herschel Horowitz pioneered.

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