

Sealants

The Role of Sealants in Caries Prevention Programs

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Pit and fissure sealants have been employed as an element in dental prevention programs for more than 30 years. The technique for sealant placement has evolved over time to become somewhat more invasive today. However, a meticulous technique is still required for success. Practitioners recently estimated that their one- and three-year sealant success rates were 89 percent and 78 percent, respectively. Grand medians for sealant success rates after one year in clinical trials have been reported to be as high as 83 percent for effectiveness and 92 percent for complete retention. Seven-year rates were 55 percent and 66 percent, respectively. Several changes in caries epidemiology have had an impact on the use of sealants. These changes include:

abstract

* Declines in overall caries rates in U.S. schoolchildren during the latter decades of the 20th century;

* A relative increase in the percentage of the population DMFS constituted by occlusal caries; and

* A general slowing in the rate of lesion progression.

Dentists' abilities to diagnose occlusal surface status also affect the decision to seal. Sealant cost-effectiveness can be improved by:

* Targeting at-risk populations;

* Using sealants on incipient lesions and minimally defective restorations; and

* Training more dental auxiliaries to place sealants under a dentists' supervision. Concerns about sealing over decay and the estrogenicity of sealant components are addressed. Sealant guidelines, as promulgated by the Workshop on Guidelines for Sealant Use, are reviewed; and conclusions are presented about the role of sealants in prevention programs.

The title of Michael Buonocore's 1955 paper in the *Journal of Dental Research* was unpretentious: "A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces."¹ Few but the most perceptive researchers and clinicians foresaw the revolution that his

discovery would bring to the fields of restorative dentistry, prevention, and orthodontics. Yet Buonocore's subsequent work led directly to the development of pit and fissure sealants,² then to enamel bonding, bonded orthodontic brackets, dentin bonding, crown and bridge cements, and other uses. While the techniques and materials have evolved, the sealants we apply today to prevent pit and fissure caries are direct descendants of Buonocore's "simple method."

This paper will provide an overview of current materials and techniques, sealant effectiveness and cost effectiveness, epidemiologic considerations, concerns, and decision making. It will conclude with some considerations of the role of sealants in a caries management plan.

Technique -- Then and Now

Initially, the sealant technique required prophylaxis of the tooth surfaces to be sealed, a 60-second etch with one of a variety of acids (typically 50 percent liquid phosphoric acid); variable rinse and drying times generally on the order of 30 seconds each; followed by application of an unfilled, UV light cured (later, autopolymerizing) sealant. Longer etch times were advocated for primary teeth. The technique was strictly non-invasive; in fact, that aspect of the technique was touted as one of its attractions. Concerns about inadvertently etching adjacent tooth surfaces were quickly dispelled by studies that demonstrated the remineralization of etched and otherwise untreated enamel over relatively short periods of time. No advantage was seen in applying sealant to a nonrestored portion of an occlusal surface if a restoration had to be placed in another portion of that same surface.

In current practice, etch times are down to 10 to 20 seconds, etchants are less concentrated liquids and gels (typically 37 percent phosphoric acid), and some degree of fissure preparation via rotary instruments or air abrasion is increasingly common. An almost bewildering array of filled and unfilled, tinted and clear, fluoride-releasing and nonreleasing, self-curing and visible light-cured materials is available. Other materials that have been tried as sealants include flowable composites, glass ionomer cements, and even amalgam. Bonding agents have been shown to increase sealant retention, especially on enamel that has become contaminated with saliva after etching.^{3,4} Still, national surveys indicate that sealants are underutilized in the United States. The Third National Health and Nutrition Examination Survey, conducted from 1988 to 94, found that among U.S. children ages 5 to 17, only 18.5 percent had at least one sealant.⁵

Primosch and Barr⁶ recently surveyed 1,210 pediatric dental practitioners and all 55 departments of pediatric dentistry regarding their sealant placement techniques. Responses were received from 70 percent of the practitioners and 90 percent of the departments. Reported use of antisialogogues was rare, with 85 percent of the practitioners and 91 percent of the departments reporting that they never employ them. Cotton roll and/or Dri-Angle isolation, sometimes in conjunction with a saliva ejector, was preferred over a rubber dam. Among practitioners, a range of surface cleansing techniques were evident, from use of an explorer by 54 percent to air abrasion by 2 percent. Techniques taught by departments of pediatric dentistry uniformly included some means of surface cleansing, but without use of air abrasion or hydrogen peroxide. 13 percent of practitioners and schools alike did no fissure preparation, while the majority in each group used high- or low-speed rotary instruments for this purpose. Air abrasion for fissure preparation was more commonly employed in practice (18 percent) than in schools (2 percent). Clearly, however, the technique has evolved into a more invasive procedure. A wide range of etching times was reported by both groups for primary and permanent teeth (15 to 120 seconds), with mean etching times for primary and permanent teeth of 29 and 26 seconds, respectively. Practitioners reported using a wider selection of materials than did schools, and some had

adopted laser polymerization. Dental schools uniformly employed visible-light-cured materials.

Sealant Effectiveness

Practitioners in the Primosch and Barr study⁶ estimated their one-year and three-year sealant retention rates to be 89 percent and 78 percent, respectively. Sealant retention has traditionally been equated in the dental literature with effectiveness under the assumption that pit and fissure caries cannot be initiated or progress under an intact sealant. Unfortunately, there is no uniformity in the literature with regard to reporting the results of sealant studies. Studies have been conducted in optimally fluoridated and fluoride-deficient communities. Results for primary and permanent dentitions or for molars and premolars have been reported separately and combined. Some studies used multiple sites per tooth while others used the tooth as the basis for analysis. Thus, it is difficult for summaries of large numbers of studies to take these methodological differences into account.

The early trials of first-generation (ultraviolet light curing) and second-generation (autopolymerizing) sealants employed half-mouth designs in which a pair of contralateral caries-free molars of the same type were chosen; one was selected at random to be sealed while the other was left unsealed as a negative control. Percent effectiveness was calculated by various formulas that used the sealed and unsealed tooth pair as the unit of analysis. In general, these formulas determined the number of surfaces "saved" by the sealant, divided by the number of pairs with DMF control teeth. A sealant "success" occurred when the sealed tooth remained sound and its matched tooth became carious or was filled. A sealant "failure" occurred when the sealed tooth became carious while its matched tooth remained sound. When "ties" occurred, they were not entered into the calculation of net gain. As noted by Burt and colleagues⁸ however, a sealed tooth that decays is still a failure even if the matched tooth becomes carious as well.

Weintraub⁷ evaluated 20 studies that evaluated the percent effectiveness of first- and second-generation sealants. Studies were conducted in fluoridated and nonfluoridated communities using predominately permanent first molars. The grand medians for effectiveness ranged from 83 percent after one year to 55 percent after seven years (**Figure**). One small study that included 10-year followups reported 68 percent effectiveness. Most of the studies reported results after only one application of sealant, though sealant effectiveness was increased if they were repaired or replaced as required. There are other factors that can influence percent effectiveness; but, in general, sealants were more effective in optimally fluoridated communities compared to fluoride-deficient communities, and less effective in primary teeth (two studies) than permanent teeth.

Half-mouth designs were employed up until the mid-1970s, when a marketed sealant received full acceptance from the American Dental Association Council on Dental Materials and Devices. At that point, denial of sealant usage was considered unethical. Study designs changed to focus on sealant longevity, or retention, as the benchmark for effectiveness. This approach was based on findings from the earlier studies that effectiveness was directly related to retention.

Weintraub⁷ reported the grand medians derived from 50 retention studies of second- and third-generation (visible light cured) materials placed on primary and permanent teeth in fluoridated and nonfluoridated communities. Grand medians for the studies ranged from 92 percent complete retention at one year, to 67 percent at five years, to 66 percent at seven years (**Figure**). Ripa,⁹ in a 1993 summary, reported similar figures for second-generation materials, ranging from 83 percent at one year to 66 percent at seven years. He reported the average percentage of

complete sealant retention for second-generation and third-generation materials to be 77.4 percent and 76.3 percent, respectively. The longest clinical evaluation of a third-generation sealant at the time of Ripa's review was five years. A comparison of the percent effectiveness data with those from retention studies reveals that percent effectiveness parallels percent retention over time but is slightly lower at each time point.

Weintraub⁷ reviewed 19 studies that evaluated the percent of sealed permanent first molars that became carious and/or restored. The grand medians ranged from 4 percent at one year to 26 percent at five years (**Figure**). Rates were slightly higher in fluoride-deficient communities than in optimally fluoridated communities. As the percentages of complete retention and effectiveness declined over time, there was a concomitant rise in sealed teeth that became carious or restored.

Finally, Weintraub⁷ reported on four studies that assessed sealant reapplication rates. These studies revealed that reapplication rates were relatively high after initial sealant placement, possibly reflecting sealant loss from partially or newly erupted teeth. Following those initial replacements, the reapplication rates showed a pattern similar to the rates of caries development or restoration placement in studies where sealants were not reapplied.

One study deserving of mention simply because of the longevity of followup was reported by Wendt and colleagues in 2001.¹⁰ That study evaluated 151 permanent first molars and 161 second molars that had been sealed 15 to 20 years earlier. Sealants on first molars had been reapplied if they were missing at the time the second molars were sealed. For first molars, sealants were completely retained on 65 percent and partially retained on 22 percent. Complete and partial retention rates on second molars were 65 percent and 30 percent, respectively. Caries and/or restorations were found in 13 percent of first molars and 5 percent of second molars. Those data included sealants and caries in the buccal pits of lower molars, areas notorious for poor sealant retention and high caries rates. The rate of complete retention was higher than predicted by Weintraub's review, while the caries/restoration rate was lower. While the merits of this study could be debated, it certainly indicated a long-lasting caries protective effect. It is clear from the literature that sealant integrity must be evaluated over time, and sealants must be reapplied as necessary to maintain their benefit.

Implications of Changes in Caries Epidemiology

Changes in dental caries epidemiology in the latter decades of the 20th century have, in a real sense, enhanced the rationale for sealant usage. Large-scale national surveys^{11,12} have shown a reduction in the caries experience of children in the United States during the latter part of the 20th century. Of particular interest is the relative increase in the percentage of the DMFS constituted by the occlusal surface -- from 49 percent in 1971 to '74 to 58 percent in 1986 to '87.¹² This change was accompanied by concomitant reductions in proximal caries, while buccolingual lesions (also based in pits and fissures) increased slightly. Clearly, smooth surfaces became increasingly less caries-susceptible as a result of increased fluoride exposure, while caries in pits and fissures became relatively more prominent. This pattern was also borne out in a study by Li and colleagues¹³ comparing surface-specific caries attack rates in U.S. schoolchildren in the 1979 to '80 and 1986 to '87 national surveys. **Table 1** shows the permanent tooth surfaces most commonly attacked by caries in each of the two surveys, as well as the percent reduction in the attack rate seen in the second survey. **Table 2**, from the same study, demonstrates that the reduction in caries attack rates has been disproportionately lower for pit and fissure surfaces compared to other surfaces in permanent teeth. Thus, while the absolute reductions in attack rates were greatest for pit and fissure surfaces, those surfaces had the lowest

relative reduction. The caries attack pattern in primary teeth was shown to be more evenly distributed, with the highest proportion on smooth surfaces.

A second epidemiologic change in dental caries is the general slowing of the rate of lesion progression, a finding that is consistent with the increase in exposure to fluoride.^{14,15} This slowing of lesion development has extended the period of caries progression into the teenage years. Data from several studies indicate that pit and fissure caries can no longer be dismissed as a possibility within a few years after a tooth has erupted.^{16,17} Thus we should ignore former recommendations that sealants need not be placed after an apparently caries-free tooth has been in the mouth for four or more years. Teeth deemed to be caries-susceptible because of pronounced pits and fissures should be sealed, regardless of patient age.

The decrease in caries rates and the slowing of lesion progression make caries diagnosis more difficult. Our traditional method of using explorers to probe pits and fissures tends to increase the number of false positive diagnoses. Lussi¹⁸ concluded that use of an explorer did not improve the validity of diagnosing occlusal caries compared to a visual inspection alone. Cardoso and colleagues¹⁹ determined that clinical experience did not enhance occlusal caries diagnosis via visual inspection supplemented by explorer use. It should be noted that the teeth used in that study were extracted impacted third molars that were assumed to be caries-free, meaning that any diagnosis of caries was assumed to be a false positive. Other studies have confirmed the inefficiencies of the dental explorer for the diagnosis of occlusal caries.^{20,21} Clearly, dentistry must find ways to improve its diagnostic abilities and thus maximize sealant effectiveness.

Cost-Effectiveness

As caries rates decline, the use of sealants becomes increasingly less cost-effective. Söderholm²² has suggested three approaches to help maintain or improve cost-effectiveness. The first is targeting population risk groups. This option is public-health based and beyond the scope of many dental school programs and private practice. Risk assessment of individuals, however, can be done in these settings, however, and should be an integral part of sealant placement decision-making. A second approach is to encourage dentists to place sealants on incipient lesions and defective restorations. While most dental schools and practitioners would hesitate to adopt this approach, it should be investigated as a means of conserving tooth structure in a program of nonsurgical caries management. The third approach is to increase the prophylactic placement of sealants by dental hygienists and dental assistants. This approach is commonly employed in practices where the auxiliaries are under the supervision of the dentist.

Sealant effectiveness and cost-effectiveness are dependent upon disease levels and the selection of patients and tooth surfaces to be sealed. Thus, another critical way in which sealant usefulness can be increased is by developing and applying evidence-based caries risk assessments to individual patients. The reduction of caries rates in U.S. schoolchildren is not uniform, resulting in a skewed distribution of disease.²³ Today, approximately 80 percent of the dental caries burden is found in 20 percent of the population. In general, socioeconomic status is inversely related to caries experience and caries risk. The use of sociodemographic data can be useful in a gross estimation of caries risk, but a myriad of other factors can be applied to refine risk assessment.

Sealant Concerns

The major concern with sealants has been the inadvertent sealing of dental caries.²⁴ This misapprehension has been put to rest by a number of studies showing that dental caries becomes arrested under intact sealants.²⁵⁻²⁷ These findings have largely served to comfort those clinicians who were concerned about sealing unrecognized caries. It is likely that few clinicians employ, and even fewer schools teach, intentional therapeutic use of sealants. However, as noted earlier, the sealant technique is becoming more invasive, so clinicians are more likely to ensure that sealants are not being placed over carious lesions. A second concern has arisen in recent years regarding the estrogenicity of sealant components.²⁸ More recent work²⁹ suggests that these components may not be absorbed, or that they may be present in nondetectable levels in the blood. Dentists can take steps to minimize the patient's exposure to uncured resin components after sealant placement.³⁰

Sealant Guidelines

The Workshop on Guidelines for Sealant Use, convened in 1994, published its recommendations in 1995.³¹ The guidelines for sealant use in individual care programs promulgated by that group should form the basis for what is taught in dental schools and residency programs, and for sealant use in practice. The guidelines call first for risk assessment of the individual based on caries experience, dental care utilization pattern, use of preventive services, and pertinent medical history. This is followed by risk assessment of individual teeth based on pit and fissure morphology, level of caries activity, and caries pattern. These assessments are followed by an evaluation of pit and fissure surfaces, with determinations of "caries-free," "questionable," "enamel caries," and "dentin caries." Sealant is recommended for teeth classified as "questionable" or "enamel caries," and for those caries-free teeth deemed to be at risk for caries. At this time, sealants are not recommended for teeth with dentinal caries. Sealants are also not recommended if the tooth cannot be isolated; if a proximal restoration involves a pit and fissure surface; or, in the case of a primary tooth, if the life expectancy of the tooth is short. In addition, the guidelines call for evaluation of previously sealed teeth for sealant integrity, retention, and caries progression.

The Role of Sealants

Sealants should continue to play a strong role in prevention programs for children, adolescents, and adults. The relative increase in pit and fissure caries enhances that role, even in the face of recent declines in caries prevalence. Schools must teach, and clinicians should apply, caries risk assessment at the levels of the individual and the tooth. Pit and fissure caries diagnosis must be improved by reducing reliance on dental explorers, and through the evaluation and, where appropriate, adoption of new technologies. Schools should teach a meticulous technique, incorporating minimally invasive procedures as warranted. Emphasis should be given to continuous re-evaluation of previously placed sealants, with reapplications when required. Manufacturers should be encouraged to continue to improve their products, and research should continue in the areas of sealant technique, effectiveness, and use of sealants as a therapeutic modality. Sealant use should be promoted as one of the cornerstones of caries prevention programs in community- and practice-based settings.

Conclusions

* Dental sealants are safe and effective in preventing pit and fissure dental caries on at-risk surfaces when they are properly applied and maintained.

- * Decisions regarding sealant placement must be based on caries risk assessments of individual patients and individual teeth.
- * Diagnosis of pit and fissure caries must be improved so that clinicians can more reliably distinguish between categories of pit and fissure status: caries-free, questionable, enamel caries, and dentinal caries.
- * Guidelines should be developed for the placement by dentists of sealants over incipient caries, over newly placed restorations, and for use in repairing minimally defective restorations.
- * Dental auxiliaries should be trained to place prophylactic sealants after diagnosis by a dentist.
- * Meticulous sealant placement techniques must be taught in dental schools and auxiliary programs, including the need for periodic re-evaluation and replacement as necessary.
- * Manufacturers should be encouraged to continue to develop improved and innovative products.

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Legend

Figure 1. Grand medians for percent effectiveness, complete retention, and caries/restoration rates by time since applications.⁷

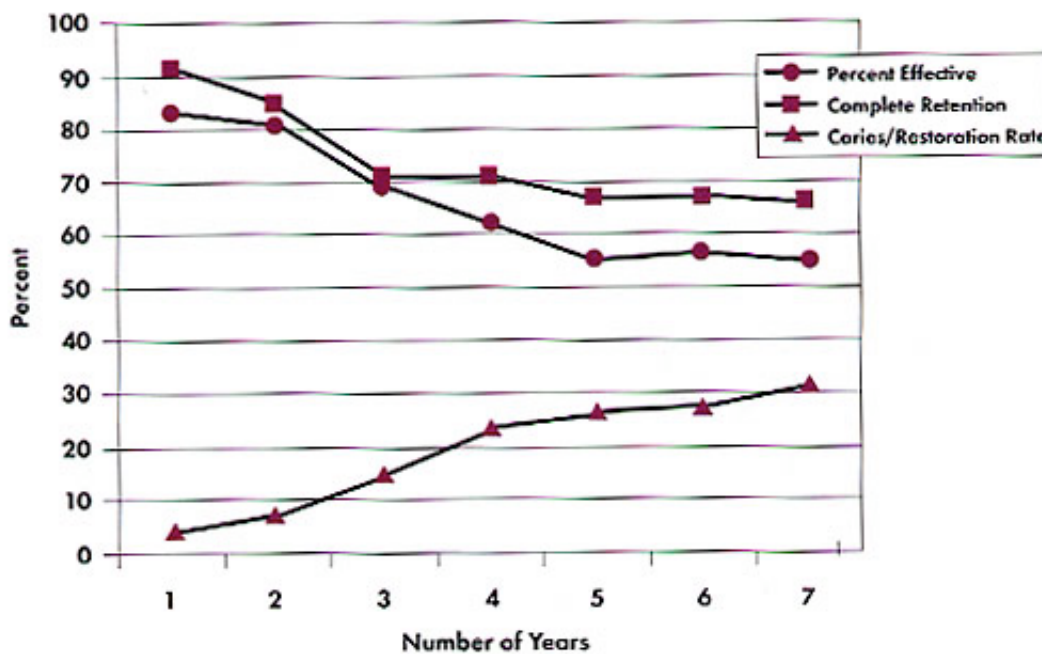


Figure 1. Grand medians for percent effectiveness, complete retention, and caries/restoration rates by time since applications.⁷

Table 1

Pit-and-Fissure Surfaces Attacked per Thousand Surfaces at Risk in Permanent Teeth.
Data from Li et al.¹³ for U.S. schoolchildren.

Tooth	Surface	1980	1987	Percent reduction
Maxillary first molar	Occlusal	445.12	324.40	27.12%
Mandibular first molar	Occlusal	432.03	312.61	27.64%
Mandibular second molar	Occlusal	309.65	209.79	32.25%
Mandibular first molar	Facial	247.72	190.69	23.02%
Maxillary second molar	Occlusal	259.65	174.09	32.95%
Maxillary first molar	Lingual	202.50	155.51	23.21%

Table 2

Tooth Surfaces Attacked per Thousand Surfaces at Risk in Permanent Teeth by Type of Surface.
Data from Li et al.¹³ for U.S. schoolchildren.

Type of surface	1980	1987	Difference	Percent reduction
Pit and fissure surfaces	191.46	135.93	55.53	31.03%
Proximal surfaces of posterior teeth	27.31	13.40	13.90	51.86%
All other surfaces	8.21	3.71	4.50	50.10%

