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The use of pit and fissure sealants in dentistry, present status and future developments

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With information from more clinical studies becoming available, as well as results from long-term clinical trials, a great deal of evidence has accumulated to support the clinical efficacy of pit and fissure sealants. Since smooth surfaces benefit most, and occlusal surfaces the least from the use of fluorides, an alternative technique which prevents occlusal caries can make a major impact on overall caries reduction when used in conjunction with fluoride regimens. The purpose of this report is to examine the current status of fissure sealants. For an account of the development of fissure sealants, their role in caries prevention and the mechanism of bonding, the reader is referred to previous reviews.[1-6]

Clinical Studies

In a well-controlled study, Horowitz and coworkers[7] reported on the effectiveness of Nuva-Seal[a] in a five-year trial in Kalispell, Montana. Participants in the trial were of two age groups, five- to eight-year-old children and ten- to fourteen-year-old children. Portable equipment was used in a school environment to apply the sealant. After the first year, observations of 900 pairs of homologous teeth showed an 81% reduction in caries and an 88% total retention of sealant. After the second year of the trial, the sealed teeth had 67% fewer caries than the controls. Seventy-three percent of test teeth showed full retention of the sealant. Failure of the sealant was recorded if a treated tooth was either carious, restored, or extracted. When a two-surface (Class II) restoration was found in the tooth, although it may have been inserted as a result of approximal caries, it was nevertheless counted as a sealant failure in this trial.

In reporting their four-year results, Horowitz and coworkers demonstrated that 50% of all teeth retained the sealant completely, with 16% showing partial retention. For all sites remaining fully sealed there was a 99% reduction in caries. In addition, a 90% reduction in caries occurred in sites showing partial retention. Furthermore, caries was reduced 6% in sites where the sealant was assessed as being completely lost. The final report, five years after placement of the sealant, showed that 56% of treated sites retained sealant. Nevertheless, a 92% prevention of dental caries resulted in sites with retention of material. Thus, when the sealant is partly or totally retained, it is effective in preventing caries.

Doyle and Brose[8] reported a five-year study of Nuva-Seal on 428 private pedodontic patients. The sealant was more effective in the permanent dentition compared with the primary dentition. Of 148 primary teeth sealed, 63 (43%) retained sealant whereas 85 (57%) required restoration. In the permanent dentition, 1496 teeth (73%) of 2052 originally sealed, retained the sealant. The remaining 556 teeth (27%) required restoration.

Nuva-Seal has recently been modified to form a second generation occlusal sealant, named Nuva-Cote, which is available in addition to Nuva-Seal. Nuva-Cote sealant is preactivated, meaning that it is supplied ready mixed, and it has a one-year shelf life. The filler used in Nuva-Cote produces a material with better resistance to abrasion than unfilled sealants. In addition, a new bulb assembly for the Nuva-lite has a shorter warm-up period and burns cooler so that the apparatus does not cut out as readily as the previous generation of Nuva-lites.

Two chemically polymerized Bis-GMA sealants are currently available and have produced good results *in vitro* and *in vivo*. Concise Enamel Bond System[b] and Delton[c] are fairly similar resins. The former is supplied with 37% phosphoric acid as the etching agent, while the latter employs a 35% solution of phosphoric acid. The clinical effectiveness of Delton fissure sealant after one year was reported by Houpt and Sheykholeslam.[9] Two-hundred and five subjects, aged between six and ten years, having a pair of caries-free contralateral first permanent molars were selected. After 11 months, 185 children were re-examined and only five of the treated teeth showed

[a]L. D. Caulk Co., Milford, DW.

[b]3M Dental Products, St. Paul, MN.

[c]Johnson and Johnson, NJ.

evidence of caries, whereas 53 of the control molars were carious. After 33 months,[10] 22 treated teeth and 101 control teeth became carious or were restored, giving a 78% reduction in caries. These workers also estimated that, after 33 months, the number of teeth per 100 saved by sealant application was 48. Delton was also used in a one-year study in Medellin, Colombia, in which the sealant was applied by dental hygienists.[11] At the 12-month recall examination, 8 of the 275 initially sealed teeth (2.9%) showed occlusal caries. In contrast, 81 of the control teeth (27.5%) showed occlusal caries. Hence the sealant was 90.1% effective.

In a seven-year trial by Mertz-Fairhurst and colleagues,[12] Delton was used on first permanent molars in a comparison study with Nuva-Seal. Children aged six to eight years received a single application of either Delton or Nuva-Seal on first permanent molars on one side, while the first permanent molars on the opposite side served as untreated controls. Of the 385 children participating in the study initially, 167 were reexamined seven years after the single application of material. Delton was used on 80 of these children, whereas the remaining 87 had been treated with Nuva-Seal. Results showed that 64% of the Delton treated teeth had complete retention, whereas with Nuva-Seal, 33% of the teeth showed complete retention. The net gain, which estimates the number of teeth saved from caries by sealant, was 45 teeth for Delton and 10 teeth for Nuva-Seal. This is an important clinical study because of the duration of the trial as well as the use of both autopolymerized and ultraviolet light activated materials.

Two years after application of Concise Enamel Bond Sealant in a Danish trial, 60% of the sealed sites remained intact.[13] The effectiveness of the treatment was highly significant, the caries reduction being 50% overall, irrespective of sealant status. Where the material was fully retained, caries reduction was 98%.

Colored Sealants

A new version of the 3M product has been introduced in recent years named "Concise White Sealant System." Essentially the same as its forerunner, a titanium salt has been added to give the resin a brilliant white color. Simonsen[14] has published findings on Concise White Sealant System 24 months after application. A total of 583 permanent and 436 deciduous teeth were sealed initially. At 12 months, 96.1% of the permanent teeth and 98.9% of deciduous teeth retained sealant. Two-year results showed little change, with complete retention being 94.1% for permanent teeth and 98.8% for deciduous teeth. At 36 months,[14] the results were an impressive 93.5% complete retention for permanent teeth and 94.9% for deciduous teeth. The colored sealant was extremely well accepted by both parents and children. Simonsen stated that an additional benefit to the white color in the sealant was the markedly decreased examination time at recall, relative to subjects who had clear sealants placed for comparison purposes. The white color also allowed a more accurate assessment of sealant presence than was possible with the clear resin sealants.

Richardson, Gibson, and Waldman[15] used a pink-colored autopolymerized sealant on occlusal surfaces of 425 newly erupted first permanent molars. A 90 second etch with 37% phosphoric acid was employed, no rubber dam being used during sealant placement on both sound and "sticky" occlusal surfaces. The significant features of this study were the location, a school clinic, and the operator, a third-year dental student. After four years, 330 pairs of molars were available for reexamination. The number of sealants remaining intact was 226 (68.5%) with 34 partially lost and 70 completely lost. Of the control teeth, 179 (54.2%) became carious or were restored, and 68 (20.6%) of the sealed teeth became carious or were restored. Thus, a 62% reduction in caries was demonstrated. These authors also found that the colored sealant enhanced detection, with no complaints received concerning the color of the resin.

Comparison of Sealants with Amalgam Restorations

Dennison, Straffon, Corpron, and Charbeneau[16] carried out a clinical study on two alternative methods for the treatment of occlusal pits and fissures in the early posteruptive period. Contralateral pairs of permanent first and second molars were selected such that one was sealed while the paired surface was restored with amalgam. Both treatments were evaluated independently by two examiners at periods of zero, six, twelve, and eighteen months after placement. The retreatment rate for sealants was highest after six months (17.3%) and declined to 7.8% after eighteen months. There was evidence of a generalized margin deterioration in more than 50% of amalgam restorations whereas 55% of the sealant margins remained undetectable clinically.

These workers further showed that the cumulative mean time required to place and maintain the amalgams was 13 minutes, 58 seconds, whereas the cumulative time invested in the sealant treatment was 8 minutes, 45 seconds.[17]

Sealants in a Public Health Program

Recently Kentucky initiated a school-based program of sealant placement.[18] The program was planned as an adjunct to the state's existing caries preventive program which includes systemic or

topical fluoride procedures. Sealants are placed by a traveling team of dental hygienists and trained dental assistants under the supervision of a dentist. Since the fall of 1978, a team of ten people have sealed approximately 100,000 teeth of 15,000 children in 20 counties in the state. At the six-month period, 87% of the sealants were fully retained; this figure dropped slightly, to approximately 74%, at reexaminations taken at 12 and 18 months. Total cost per sealed tooth was estimated to be $1.75.

A further public health sealant program has been carried out under the auspices of the National Preventive Dentistry Demonstration Program of the American Fund for Dental Health, supported by a grant from The Robert Wood Johnson Foundation. In this program Delton sealant was placed on approximately 100,000 teeth in 10,000 children by auxiliaries in ten different geographic regions. Assessment at the six-month period showed the sealant to be intact in more than 90% of the teeth.[19]

Public health programs such as the two just mentioned are extremely important in demonstrating the tremendous potential sealants have in an overall caries preventive program. Currently, 29 states permit dental hygienists to apply sealants, with 11 of these states extending this rule to dental assistants.

Treatment Costs

In a recent report, Simonsen[20] has estimated the cost of maintaining a group of children on sealants relative to carrying out necessary restorative work on a matched group. The sealed group had the fissures of first permanent molars sealed with Concise white sealant for a five-year period and complete retention was assessed as being 82%. Ninety-four percent of the pit and fissure surfaces were sound after five years with only 6% carious or restored. In contrast, a matched control group showed that only 41% of pit and fissure surfaces remained sound over the same time period, whereas 59% of the surfaces were carious or restored. Thus, the control group showed ten times as many carious or restored surfaces relative to the sealed group. The cost for the sealed group was calculated at $10.23 per child per year and this included the placing of sealants and restorations where necessary. In contrast, the cost for the control group was $21.15 per child per year. All costs were calculated on the basis of a dentist carrying out all of the procedures. Simonsen stated that if a first permanent molar was not sealed, it was 23 times more likely to become carious or be restored.

Thus, many trials in various parts of the world have shown that fissure sealants can prevent a highly significant amount of occlusal caries (Figure 1). Recent work with the chemically polymerized sealants has demonstrated that they can be at least as effective as the materials polymerized with ultraviolet light. The majority of studies indicate that if the sealant is still *in situ* at the six-month recall examination, then it will remain in place for a number of years. If failure is to occur, this usually takes place soon after the sealant has been applied. The most common reason for failure is contamination of the etched surface by saliva prior to sealant placement. When the sealant is partially or totally retained, it is highly effective in preventing caries. A clinician should remember that in a clinical trial, the material is applied only at its commencement. Thus, the material is tested under rigid conditions. In a general or private practice, it is possible to reapply the material if there is evidence of wear. Reapplication of material can therefore significantly increase the final degree of caries prevention achieved. The most critical stage in applying a sealant is acid-etching of the enamel surface. Once the surface has been etched, washed and dried, it is essential that it remain uncontaminated by saliva.

The Effect of Sealing Microorganisms Under a Sealant

Handelman and coworkers[21] made a two-year study in which carious occlusal cavities were coated with a sealant polymerized with ultraviolet light. Teeth of children and young adolescents, in which there were frank carious cavities, were sealed with Nuva-Seal. Samples of carious dentin were taken from both unsealed and sealed teeth during periods of up to two years after the sealant had been placed. The major reduction in viable microorganisms occurred during the first two weeks after sealing. At the end of two years, the decrease was 2,000-fold (99.9%) in the numbers of cultivable microorganisms in the sealed teeth. Preliminary clinical and radiographic findings

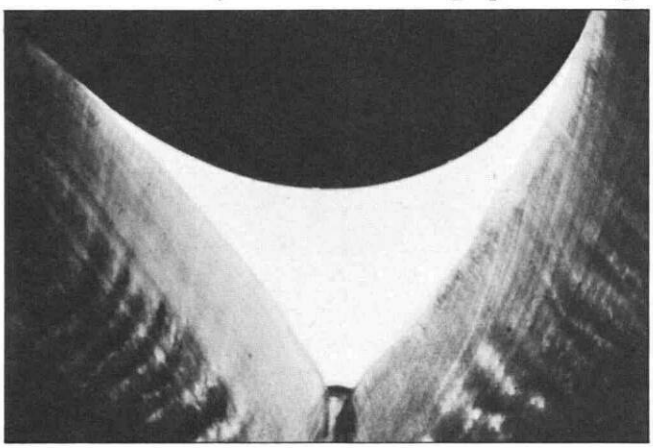

Figure 1. Longitudinal ground section through a human fissure containing a fissure sealant and examined by ultraviolet light fluorescence microscopy. The resin is seen to occlude the fissure and is well bonded to the enamel surface.

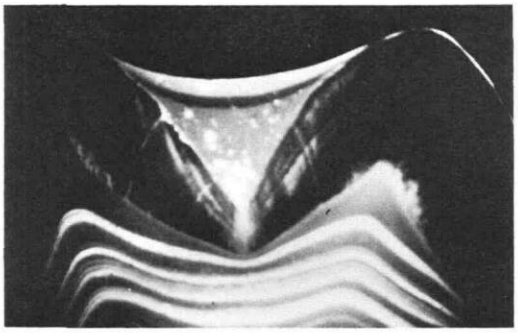

Figure 2. (left photo) Human tooth containing a fissure sealant examined with U/V fluorescence microscopy. Two different sealant materials were added to the original sealant, and they can be distinguished from each other by different degrees of fluorescence. All of the materials have bonded with each other. Note the tetracycline lines in the dentin.

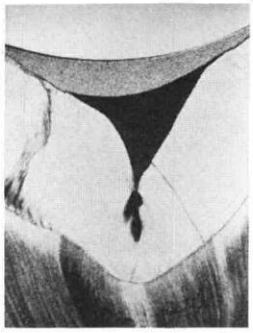

Figure 3. (right photo) Longitudinal ground section through a tooth which was sealed with a resin containing a blue dye. After this, the resin was abraded *in vitro* so that the bulk of the material was removed. The specimen was then exposed to whole saliva *in vitro.* A second sealant material was then added to the original surface and can be seen as a relatively clear material due to the exclusion of the blue dye. It was found that provided the surface was acid etched in the normal manner, a new layer of sealant could be chemically bonded to the original material.

suggest that the lesions did not progress.

In a similar study, Going, Loesche, Grainger, and Syed[22] investigated carious lesions that were covered with Nuva-Seal containing a red dye for a five-year period. Bacterial cultures were predominantly negative; 16 of 18 test sites judged to have had active caries in 1972 were found inactive in 1977. Ten of twelve sites suspected to have had caries in 1972 were found to have inactive caries in 1977. Sealant treatment resulted in an apparent 89% reversal from a caries-active to a caries-inactive state. These data confirm and extend previous observations that a limited number of cultivable organisms persist in some lesions but their numbers are few, and they do not appear capable of producing tissue damage.

Application of Sealant Over a Previously Sealed Region

If it is necessary to reapply sealant to a surface which was sealed previously, the technique is identical to that used when sealing a virgin enamel surface. The previously sealed surface is acid-etched for 60 seconds in the normal way to remove organic coatings from any remaining sealant as well as to etch enamel not previously coated with resin. If the resin has worn down completely to the original enamel surface, the acid solution will remove pellicle from the surface and also expose and clean the superficial aspect of tags of sealant present in the surface enamel. Resin can then be applied in the usual manner and, when polymerized, it will bond chemically with any resin still present on the enamel surface (Figures 2 and 3). Because all sealant materials belong to the same chemical family, any brand of sealant can be added to the original material. Provided that the original resin surface is free from pellicle and other organic debris, chemical union will occur betweeen the old and the new material. In this manner, tags originally present from a first coating of sealant will also anchor subsequent coatings.

Does Acid Etching Increase the Susceptibility of the Enamel to Caries?

Since the enamel surface is etched with an acid solution prior to the application of a fissure sealant, may eventual loss of material expose a surface more susceptible to caries? This is a question that the dental profession has been asking ever since sealants have appeared as a viable clinical technique. Microsolubility studies[23] have shown that acid-etched enamel surfaces have higher solubility rates relative to adjacent sound enamel. However, after a 24-hour exposure of etched enamel surfaces to whole saliva *in vitro,* remineralization brought about a significant reduction in solubility rate, approaching the level for sound enamel. In addition, after removal of sealant from the enamel surface *in vitro,* the remaining surface was still less soluable than adjacent sound enamel. This was related to the retention of tags of sealants which penetrated deep into the enamel surface, remaining after grinding off the resin.

A more recent study[24] confirmed these findings for the clinical situation. Teeth that were to be extracted for orthodontic reasons were used. Prior to extraction, one-half of the buccal surface was etched, and the tooth extracted one hour later. Examination of specimens with the scanning electron microscope after extraction failed to identify the previously etched region. However, a test area on the control surface which had been etched *in vitro* in an identical manner to that employed in the clinical technique showed a typical etched appearance. Thus, exposure of the etched enamel surface to the normal oral environment, even for a one-hour period, resulted in rapid surface remineralization.

A further study,[25] in which blocks of etched human enamel were exposed to whole saliva *in vitro* for periods ranging from 1-60 seconds, showed a significant contamination produced as a result of salivary coating (Figure 4). Current work has shown that if salivary contamination occurs, the clinical procedure

must be stopped and the etching phase repeated in its entirety prior to any attempt at bonding a resin material.

The Limited Use of Sealants

The limited use of fissure sealants by members of the dental profession is generally stated as being due to the following five points: (1) they are not convinced that research data justify their use; (2) they believe that sealants are lost too often; (3) they are afraid of sealing in caries; (4) they have difficulty in motivating patients and parents in accepting the technique and justifying a fair fee; and (5) they believe that they can place amalgam restorations in the same amount of time, for the same fee, with better and lasting results.

These so-called shortcoming were raised when the technique was first introduced some ten years ago. Why then, are they still cited widely today since many, if not all, of these points have been dealt with in a comprehensive manner in the literature? Clearly, if members of the dental profession are not aware of the current literature, they will go on quoting these points *ad infinitum.*

Thus, the profession must be educated with respect to the current status of fissure sealants. This is far easier said than done. A step in the right direction is to hold conferences designed to present the state of the art and science of the technique. Two such meetings have recently been organized by the National Caries Program of the NIDR. The spectrum of the meetings was wider than sealants alone, since they covered, in addition, fluorides, diet, and education. In the first of these conferences, state dental directors and their supervising hygienists were invited. In the second, the invitations went to faculty members from departments of pedodontics, community dentistry, hygiene, and operative dentistry. Both meetings were well attended, and achieved their aims. A monograph is now available[26] from the first meeting containing the formal papers and general discussion sessions.

Since meetings of this type have limited attendance, and since conferences are expensive to hold, this mechanism cannot be applied to the profession as a whole. Therefore, other mechanisms must be employed, such as in continuing education courses, and the issuing of recommendations and carefully designed handouts containing clear and unequivocal statements. Dental students and hygiene students should become well informed with respect to sealants and must gain experience in their use. Due to cost-effective considerations, dental auxillaries should play a vital role in sealant programs. Demonstration programs such as those mentioned earlier in this report are vital in showing how effective sealants can be in the hands of auxillaries.

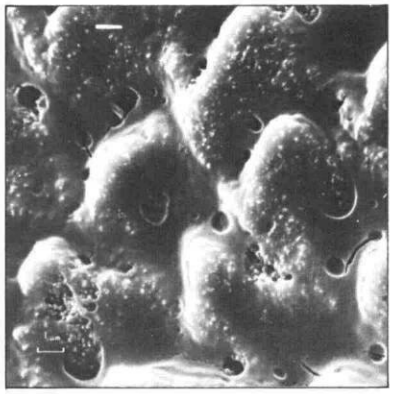

Figure 4. Scanning electron micrograph showing several prisms which had been etched with phosphoric acid *in vitro* (X6,000). The specimen was then exposed to whole saliva for one second, after which it was thoroughly washed with an air/water spray for 60 seconds, and air dried. In spite of this, a surface film of organic material is seen as a contaminant on the etched prisms. This would affect adversely the bonding of a resin to this surface.

Future Advances

What advances in the field can the profession hope for in the future? Because of excellent data now available from long-term clinical studies, there are those who believe that sealants require no further development. In addition, because of their limited use, funding organizations and manufacturers have little incentive to spend vital funds on improving sealants. However, what advances could possibly be made? Contamination of the etched surface by saliva prior to resin application appears to be the most common reason for failure. Thus, if a resin was able to bond chemically to clean enamel surfaces, acid etching might not be necessary. This would save time in application and overcome the problem of salivary contamination, whereby the micropores become filled-in before sealant application. Even if it were necessary to continue with the etching phase, contamination would not be so critical a problem if the resin had good chemical bonding properties. In addition, if resins could be more hydrophilic, they could wet the enamel surface better. This would also overcome the problem of having to obtain a surface that was completely dry. Improving the abrasion resistance of the sealant would also be of advantage, and the use of filled resins might solve this problem. The use of fluoride-releasing resins would also be desirable provided that the integrity of the sealant was not compromised, as was the case with earlier materials of this type.

Further studies on the effect of sealing-in microorganisms are necessary in order to give support to the limited number of studies which have been carried out in this area. In addition, more studies are certainly required on the cost effectiveness of sealants and their cost-benefit ratio. Therefore, further research activity in the field is certainly justified, but this must go hand-in-hand with real attempts to

educate the dental profession and the general public of the safety and efficacy of this technique.

In a developed community, dependent upon an average diet, the high prevalence of dental caries cannot be controlled by reparative techniques alone. Caries prevention programs are necessary in addition to restorative procedures if the disease is to be controlled. From all available evidence, fissure sealants play an important role in caries prevention by augmenting fluoride use and other techniques, because they can protect the caries-susceptible surfaces that are least benefited by fluoride. Caries of the occlusal surface account for at least half the caries in children during their time at school.[27] According to Jackson,[28] pit and fissure caries contribute about 80% of total attacks by fifteen years of age. Jackson also calculated that if sealants could achieve a 50% prevention of fissure caries in a fluoridated community, the need for restorations in permanent teeth by age fifteen could be reduced by 74%.[29]

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