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Micromorphology of the fitting surface of failed sealants

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Abstract

Examination of sealants recovered at their moment of failure offers clues to factors which played a role in failure. The fitting surfaces of 10 failed sealants recovered immediately after placement, and 14 which had failed after several months in the mouth were examined by scanning electron microscopy. Large areas of the fitting surfaces were smooth, with only localized regions showing evidence of contact with etched enamel. Those fitting surfaces exposed to the oral environment showed structures resembling microorganisms. The observations strongly suggest contamination of the etched enamel at the time of sealant placement, therefore emphasizing the importance of proper isolation methods and careful technique.

The adjunctive value of pit and fissure sealants in caries prevention is now becoming well established. The results of numerous clinical studies have been compiled and most recently reported by Ripa.[1] The protective benefit of sealants is only gained and maintained so long as the resin sealant remains completely intact and bonded in place.

Sealants fail and when they do, failure is generally attributed to the conditions under which the sealants were placed, the skill of the operator, and the cooperation of the patient. Specific factors related to bonding at the enamel/sealant interface are also believed to influence the long-term performance of sealants. These include: (1) the type of micromorphological change in the enamel following acid conditioning, (2) contamination of the etched surface with reaction products left through inadequate washing or salivary contact, (3) the rheological properties and handling characteristics of the resin, and (4) the low abrasion or wear resistance of the resin.

The sealant technique involves a prophylaxis followed by acid conditioning which renders approximately 30 microns of the outermost enamel more porous. The resin, in monomer form at the time of application, penetrates the porosities as much as 50 microns.[2,3] The resin polymerizes and its entrapment in the enamel micropores serves to retain mechanically the bulk of resin located at the enamel surface. The sophisticated physical relationship between the resin and enamel can be demonstrated microscopically.[4,5]

When a sealant is dislodged under laboratory conditions it commonly fails at the resin/enamel interface, which is the fitting surface of the resin with the enamel. On microscopic examination, this surface frequently shows morphological characteristics comparable with the topographical features of enamel seen after etching. The fitting surface of the resin may therefore be used as a guide to (1) the extent to which the resin wetted or gained contact with the enamel, and (2) the topographical characteristics of the enamel itself.

In order to identify factors which affect the successful bonding and retention of sealants under clinical conditions, an examination of sealants recovered at their moment of failure was done to offer clues as to their failure.

Sealants were examined microscopically in this preliminary study. They fell into two groups; those sealants which failed on gentle explorer pressure immediately following placement, and those which failed on a similar examination at recall visits three months or longer after insertion.

Methods and Materials

Twenty-four sealants were recovered for examination. These consisted of 10 that were obtained from patients attending the Children's Dental Care Center at Stony Brook and were recovered immediately following their placement. The remaining 14 were obtained from patients being treated under the auspices of the American Fund for Dental Health's National Preventive Dentistry Demonstration Program. These sealants were recovered at recall visits and had

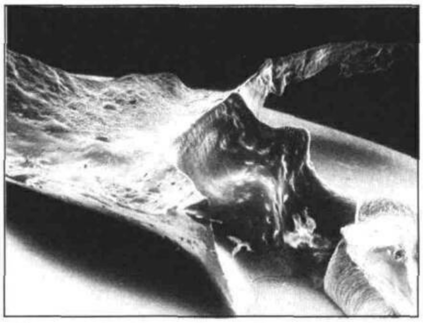

Figure 1. Scanning electron micrograph showing the contour and characteristics of a sealant fitting surface. Original magnification, 20x.

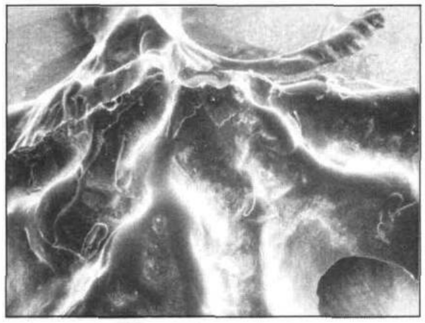

Figure 2. Scanning electron micrograph illustrating the smoothness of the fitting surface of a failed sealant. Original magnification, 16x.

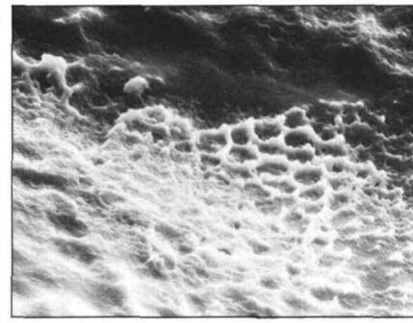

Figure 3. Scanning electron micrograph showing localized areas in which surface projections resemble contact with etched enamel. Original magnification, 1, 200x.

been in place for several months. The sealants in both groups were readily detached with explorer pressure.

The sealants were mounted on aluminum studs using a colloidal carbon adhesive. Figure 1 shows the orientation of the sealants which were mounted with their fitting surface uppermost. Since the resin sealants were nonconductors, the specimens were coated with a thin layer of gold/palladium in a sputtering device equipped with a water-cooled anode. The latter helps to reduce any heating effect on the resin. The samples were examined in an AMR 1000 scanning electron microscope operated in the range of 10-20 KV and observations were recorded on Polaroid type 52 film. A preliminary study of the surface of a few sealants was made using energy dispersive x-ray analysis.

Results

Sealants With Immediate Failure

The majority of sealants recovered at failure immediately following their placement were completely intact. At low magnification (Figure 1) one can follow the contours of the fitting surface from the free cuspal edge of the sealant, down the inclined plane of the cusp toward the wedge-shaped termination in the region of the fissural constriction.

The most striking feature at low magnification (Figure 2) was that a large portion of the fitting surface area of all the sealants was relatively smooth. At higher magnification (Figure 3) only localized areas showed surface projections. These appeared either rounded and relatively smooth or as irregular, cone-shaped projections whose size and configuration resembled the structural patterns of etched enamel. Preliminary energy dispersive x-ray analysis (Figure 4) showed the presence of calcium and phosphate associated with the irregular form but this was absent in the rounded form. The presence of calcium and phosphate strongly suggests the possible detachment of some enamel when the sealant was dislodged.

The narrow, wedge-shaped ridge of resin that was localized in the fissural region was always smooth and usually rounded. No indication of penetration deep into the fissures was evident. There was also no evidence of fracture along these ridges. In the event of resin penetration deep into fissural undercuts, resin fracture might be expected during sealant dislodgement. When fracture did occur through the resin it resulted in a characteristic pattern similar to that seen in Figure 5.

Three specimens displayed unusual phenomena. The first took the form of a dendritic crystal growth pattern and was localized to one area of one of the sealants. Energy dispersive x-ray analysis showed the presence of calcium, phosphorus, potassium and chloride. The second observation made on the remaining two specimens was one in which the surface exhibited numerous folds suggesting that resin shrinkage had occurred. These phenomena require further investigation.

Sealants With Delayed Failure

An examination of sealants recovered after being in place for several months showed all the features just described. These included large relatively smooth areas and scattered regions which showed projections, suggesting sites of contact with etched enamel rods. X-ray analysis again suggested that some enamel was attached to the resin. The most significant difference between this group of sealants and those recovered immediately after placement was the presence of numerous rod-shaped and spheroidal bodies covering much of the fitting surface (Figure 6). Their size and shape was consistent with that of microorganisms. The shape of the bodies was not always distinct since fixation methods were not used to preserve any cellular elements associated with the specimens.

Discussion

In order to draw conclusions from these results it

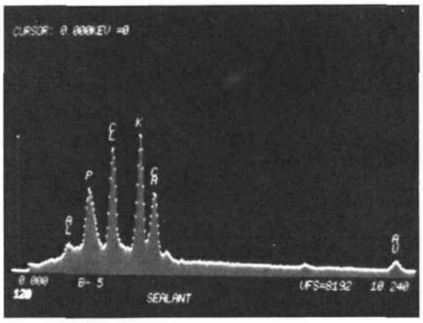

Figure 4. Elemental display from energy dispersive analysis of the fitting surface of a failed sealant. Note the calcium peak.

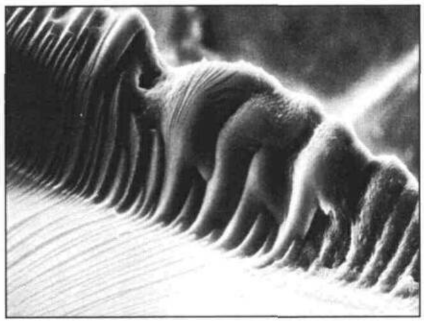

Figure 5. Scanning electron micrograph showing a typical resin sealant fracture pattern. Original magnification, 700x.

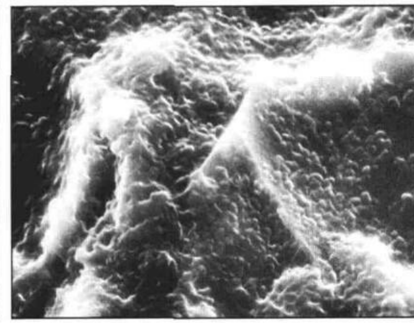

Figure 6. Scanning electron micrograph showing folds in the fitting surface of a failed sealant. Original magnification, 150x.

is logical to examine the sealant protocol to determine the event or events most likely to have caused the observations. Much of the fitting surface of all 24 sealants was predominantly smooth. This strongly suggests lack of resin adaptation to or penetration into enamel. One plausible explanation is inadequate or faulty prophylaxis.

Miura and his coworkers[6] demonstrated that a dental prophylaxis is important to achieve maximum bond strength between resin and enamel. Acid conditioning without a prophylaxis can result in only isolated areas of enamel etching.[7] Relatively smooth enamel integument with occasional microorganisms, appears unaffected by acid action and subsequent application of resin to these surfaces may result in areas of smoothness on the fitting surface and only localized resin penetration. A dental prophylaxis was purportedly done prior to placement of the sealants used in this study, but thoroughness was not evaluated. The lack of resin penetration into the deeper confines of the pits and fissures may well reflect a failure to remove organic and cellular material from these sites during prophylaxis.[8,9]

Another possibility relates to the acid etching and contamination of the etched surface. Several surface patterns may result from acid etching human enamel.[2,3] Variations may exist from site to site on the same tooth, from tooth to tooth, as well as from subject to subject. Biological variation and differences in enamel micromorphology and solubility account for these variations in etching patterns. All patterns provide a significant increase in surface energy and surface area changing enamel from a smooth to a more roughened and porous condition. If the surface is dry and not contaminated at the time of resin application, the resin fitting surface will reflect many of the topographical features of the etched enamel. If the etched surface becomes contaminated with saliva, much of the etched enamel surface becomes occluded with a biofilm. The source of the potassium and chloride in the elemental analysis of a sealant in this study may have been saliva. The wetting characteristics of enamel with respect to the resin are changed drastically by saliva. The surface energy is lowered and as Hormati[10] and his colleagues demonstrated recently, bond strength between enamel and resin is reduced. The appearance of the fitting surface of the resin after saliva contamination is predominantly smooth.

Summary

A majority of failed resin sealants examined via electron microscopy showed smooth sealant-enamel interface of fitting surfaces suggesting (1) contamination of etched enamel surfaces after etching but prior to sealant application, or (2) inadequate dental prophylaxis prior to etching the enamel surface.

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