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# Quantitative changes in fissure sealant six months after placement

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## Abstract

*Earlier studies have reported extensive volumetric loss of fissure sealant shortly after placement. To determine the volume of fissure sealant lost at six months, we used a servohydraulic profilometric apparatus in combination with computer graphics. Twenty-two premolar teeth were selected, and baseline silicone impressions were made of each tooth. The teeth were sealed and the occlusion adjusted where necessary. Impressions were made immediately of sealed teeth and again at six months. Epoxy replicas were made from all impressions, and their surfaces digitized by sequential profilometry. Using a three-dimensional root mean square (RMS) goodness-of-fit computer program,* before sealant, after sealant, *and* six months after sealant *computer-graphic images were superimposed. The volume of sealant lost after six months for all premolar teeth was* $X = 0.23$ *mm³ (maxillary second premolar:* $N = 9$, $X = 0.29$ *mm³; maxillary first premolar:* $N = 5$, $X = 0.27$ *mm³; mandibular second premolar:* $N = 4$, $X = 0.20$ *mm³; mandibular first premolar:* $N = 4$, $X = 0.08$ *mm³). The volume differences between tooth groups were not significant as measured by analysis of variance (ANOVA). These volumes represented a 13.99% loss of applied sealant for all premolars (maxillary second premolar: 19.72%; maxillary first premolar: 15.37%; mandibular second premolar: 8.46%; mandibular first premolar: 6.37%). The area of wear and the depth of wear also were measured.*

## Introduction

Regional and national surveys continue to report that fissure sealants have yet to be accepted fully by the dental community (Faine and Dennen 1986; Gonzalez et al. 1988). Recently, in a study of oral health of U.S. schoolchildren (Brunelle 1989) only 7.6% had sealants. While the reasons cited for underuse are multifactorial, poor retention and excessive wear are mentioned frequently. The single most important reason for premature loss of fissure sealant is poor application technique. Early loss of fissure sealant is more likely to result from moisture contamination, inadequate curing, or faulty material manipulation.

The problem of sealant wear is more obscure. It is difficult to distinguish between true sealant wear and loss of material due to one of the above-noted factors, and earlier studies have not offered helpful discussion in this regard. However, one study has reported a 50% loss of applied sealant volume within one month of placement, increasing to 75% at the end of two years (Jensen et al. 1985). These amounts seem excessive when compared to other clinical reports (Simonson 1987). Comprehensive qualitative and quantitative measurement of fissure sealant has not been possible with existing methods. In particular, it has not been possible to demonstrate accurately small quantities of sealant on the tooth or measure changes to it over time.

The methods currently used to evaluate clinical performance of fissure sealants fall into two broad categories: qualitative methods and quantitative methods. Each approach presents advantages and shortcomings. The most widely accepted evaluation technique is that adopted by the United States Public Health Services (Cvar and Ryge 1971); this method utilizes a series of operationally defined rating scales for selected characteristics of dental restorations. Using a visual-tactile examination, the restoration is rated intact, partially lost, or completely lost. To measure wear, anatomic form and marginal integrity are evaluated over time by comparing casts to calibrated standards. This is not entirely satisfactory because the method is not quantitative and has a potential for subjective error. The USPH criteria are best suited to large-scale public health studies.

A quantitative system has been reported (Vrijhoef et al. 1985) which calculates the quantity of material wear by establishing the weight of impression material retained between consecutive die replicas and a stone index constructed to the baseline replica. The method involves multiple laboratory steps and affords no information on location or extent of the wear.

Electron microscopy represents yet another measurement approach (Metter et al. 1978). Although useful, it provides largely qualitative information which is limited to small areas of the sealant.

Other quantitative techniques which measure changes in vertical height of restorations have been developed (Roulet 1985). Electronic images of *before* and *after* restoration surfaces also have been used. These images are related and compared for differences. Images may be obtained by a variety of means including: profilometry using a measuring microscope (Bangerter et al. 1987), laser fringe pattern analysis (Atkinson et al. 1982), stereophotogrammetry (Eick et al. 1971), and stylus profilometry (DeLong and Douglas 1983; Roulet 1983; DeLong et al. 1985). These methods are predicated upon the ability to accurately align *before* and *after* images. Depending on the method, a variety of approaches are used to achieve this. Some are mechanical (Eick et al. 1971); others involve placement of a reference bracket on the tooth (Roulet 1983), or permanently altering the enamel at several specific sites (Lutz et al. 1979). An alternative approach, which is independent of mechanical manipulation, is to use a computer to align the surfaces (DeLong and Douglas 1983; DeLong et al. 1985). This is the method employed at the University of Minnesota.

Our group recently reported a system which utilized servohydraulic-driven profilometry in combination with advanced computer graphics to measure the volume of sealant applied to premolar teeth (Pintado et al. 1988). The surface area of fissure sealant typically required to occlude the pits and fissures of premolars also has been reported (Conry et al. 1989).

The technology has been developed further to measure wear (i.e., changes to the material over time). The objectives of this study were:

1. To measure quantitatively the volume, surface area, and depth of sealant wear on premolars after six months
2. To provide a three-dimensional graphic representation of sealant wear distribution on the occlusal surface
3. To compare the amount of sealant lost at six months to the original amount of sealant applied to the teeth.

## Materials and Methods

Approval for this study was obtained from the University of Minnesota Committee on the Use of Human Subjects in Research. Twenty-two premolar teeth were selected. All teeth were caries-free, of normal morphology, and in occlusion. There were nine maxillary second premolars, five maxillary first premolars, four mandibular second premolars, and four mandibular first premolars. Each tooth was cleaned with a pumice slurry, washed and dried. Prior to sealing, an alginate scavenger impression was taken, followed by a polyvinylsiloxane (Express®, 3M, St. Paul, Minnesota) impression of each tooth. All sealants were applied by a single operator according to the manufacturer's instructions. Teeth were isolated with cotton rolls, and the occlusal enamel etched for one min with 37% phosphoric acid, followed by rinsing for 45 sec. The tooth surfaces were dried thoroughly with contaminant-free compressed air. None of the teeth became contaminated prior to placement of sealant, thus none required reetching. White sealant (Concise®, 3M, St. Paul, Minnesota) was applied using a minimal technique. The amount used was sufficient to obliterate pits and fissures only. The sealant was cured by placing a visible light source for 20 sec within 1 mm of the tooth surface. Each sealant was examined for adequate coverage and retention with an explorer. The occlusion was examined and adjusted with a multifluted tungsten carbide bur where necessary. The sealed teeth were then impressioned again. Subjects were recalled after six months, and a further set of impressions were made.

All impressions were washed, boxed with polyvinylsiloxane putty, and poured with die epoxy (Cerestore®, Johnson and Johnson Dental Care, Inc, E. Windsor, New Jersey). *Before sealant* replicas, *after sealant* replicas, and *six months after sealant* replicas thus became available for study. The replicas were examined for voids, bubbles, or cracks under a binocular microscope. Any discrepancy noted was recorded. The *after sealant* replica was mounted in a nylon ring using stone (Die Keen®, Columbus Dental, St. Louis, Missouri). A stone index was constructed to this replica allowing the *before sealant* and *six months after sealant* replicas to be located in identical positions in the mounting ring (Fig 1, next page). The surfaces of each replica series were digitized with a computer-guided stylus using a method described by DeLong et al. (1985). A diamond stylus was connected to an extensometer with the tip of the stylus contacting the anatomic surface. The surface was free to move in all directions under the tip of the stylus via two sliding tables mounted on the vertical piston of a servohydraulic machine. Profiles of each tooth were taken at 100 μm intervals, yielding between 75 and 100 profiles, depending on the tooth size. A dedicated microcomputer then guided this assembly in such a way that the X, Y, and Z coordinates of each surface point were recorded by scribing the stylus across the surface. Each scribe produced one profile. A series of profiles as-

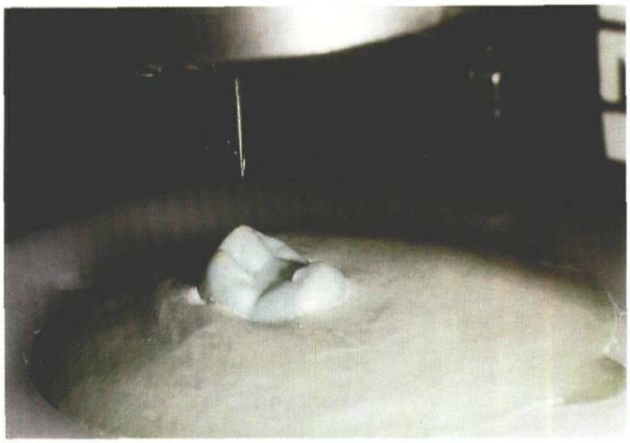

**Fig 1.** Profiling assembly showing epoxy tooth replica mounted in nylon ring with displacement stylus positioned over occlusal surface.

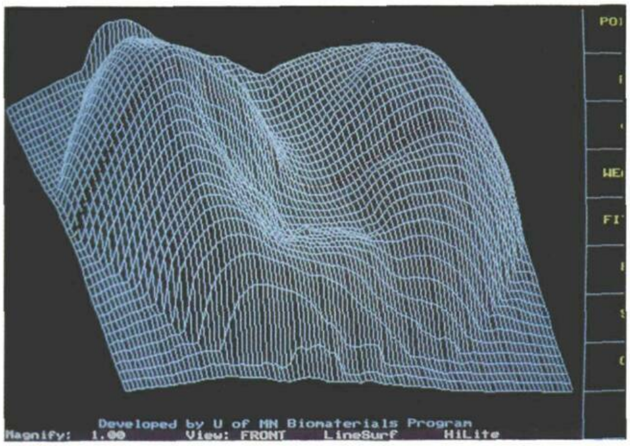


**Fig 2.** Anatomical view of upper first premolar showing graphic representation of profile #40. (Viewing angle 45°)

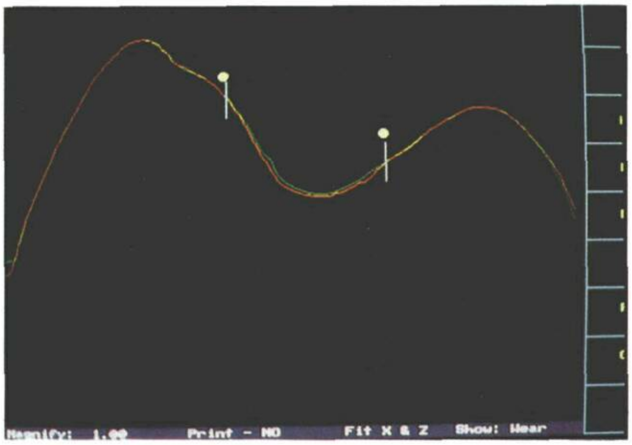


**Fig 3.** Occlusal surfaces "before" and "after" wear, superimposed at profile #40 This "slice" view shows area of fitting outside blue cursor lines. Area inside cursor lines represents the area of sealant wear. Upper green line represents original contour of sealant at time of placement. Red line represents sealant contour at 6 months. The depth of wear can be seen clearly. (Viewing angle 90°)

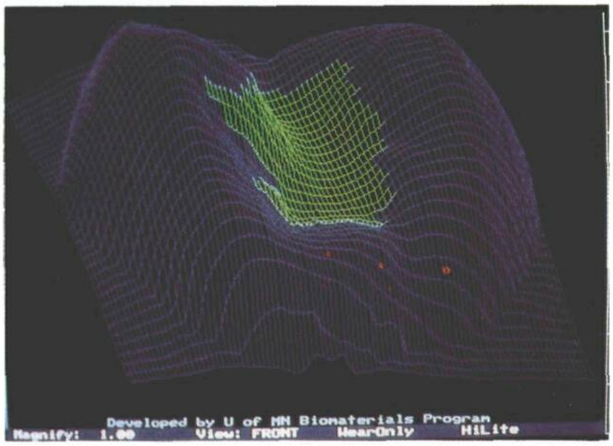


**Fig 4.** Computer-generated graphic image of occlusal surface, upper first premolar, showing graphic representation of sealant area in green on occlusal surface. (Viewing angle 45°)

sembled on the computer screen gave a three-dimensional image (Fig 2).

*Before sealant*, *after sealant*, and *six months after sealant* computer-generated graphic images of occlusal surfaces were superimposed using a *goodness of fit* mathematical routine based on a least squares fit. Computer fitting was confined to areas of anatomic stability. Areas of wear were tagged electronically, profile by profile (Fig 3). The computer program calculated volume, area, and depth of applied sealant. The volume, area and depth of sealant wear at six months also was computed and could be identified graphically (Figs 4 and 5).

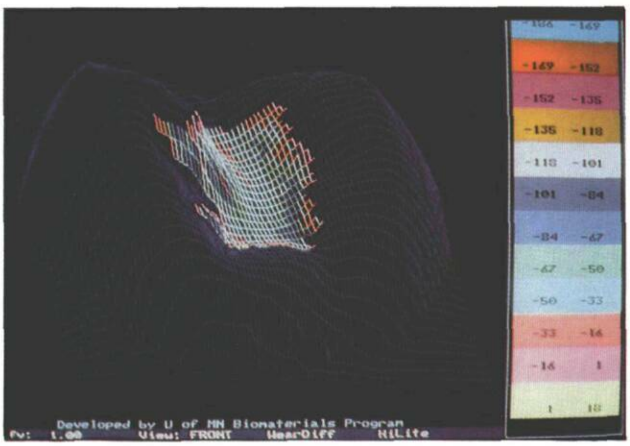


**Fig 5.** A computer-generated graphic image of sealant wear on upper first premolar. Different colors represent changes in depth of sealant wear over different areas of the occlusal surface. The color scale on the right is graduated in microns. (Viewing angle 45°)

**Table 1.** Volume, Area, and Depth of Sealants Applied to Premolars

| *Tooth group* | *Volume mm³* | *Area mm²* | *Depth μ* |
|---|---|---|---|
| Maxillary 2nd premolar (N=9) | 1.69±0.48* | 7.6±1.84 | 800±170 |
| Maxillary 1st premolar (N=5) | 1.98 0.51 | 8.94 1.26 | 840 230 |
| Mandibular 2nd premolar (N=4) | 2.18 0.40 | 8.94 1.88 | 890 110 |
| Mandibular 1st premolar (N=4) | 1.30 0.26 | 6.92 0.64 | 760 100 |
| All premolars | 1.77±0.53 | 8.06±1.67 | 820±170 |

*standard deviation

**Table 2.** Mean Volume Area and Depth of Fissure Sealant Wear After 6 Months

| *Tooth group* | *Volume mm²* | *Area mm²* | *Depth μ* |
|---|---|---|---|
| Maxillary 2nd premolar (N=9) | 0.29±0.07* | 0.63±0.27 | 190±99 |
| Maxillary 1st premolar (N=5) | 0.27 0.12 | 0.65 0.18 | 134 52 |
| Mandibular 2nd premolar (N=4) | 0.20 0.12 | 0.56 0.29 | 128 77 |
| Mandibular 1st premolar (N=4) | 0.08 0.05 | 0.34 0.18 | 99 35 |
| All premolars | 0.23±0.15 | 0.57 0.25 | 148 80 |

*standard deviation

**Table 3.** Percentage Change in Volume Area and Depth of Fissure Sealants After 6 Months

| *Tooth group* | *% change volume* | *% change area* | *% change depth* |
|---|---|---|---|
| Maxillary 2nd premolar (N=9) | 19.72 | 7.91 | 27.93 |
| Maxillary 1st premolar (N=5) | 15.37 | 7.11 | 17.16 |
| Mandibular 2nd premolar (N=4) | 8.46 | 6.13 | 14.19 |
| Mandibular 1st premolar (N=4) | 6.37 | 4.76 | 13.55 |
| All premolars | 13.99 | 6.48 | 18.21 |

## Results

Results are summarized in Tables 1, 2, and 3. Data were analyzed using analysis of variance (ANOVA) and the Multiple Range Test. Table 1 shows the mean volume, surface area and depth of fissure sealant applied to premolars.

The mean volume loss of sealant from all premolar teeth was 0.23 ± 0.15 mm³; the mean area loss was 0.57 ± 0.25 mm²; and the mean maximum depth loss of material was 148 ± 80 µm. While there were no statistical differences between tooth groups with respect to the absolute volume, area, and depth of wear after six months, individual differences between some tooth groups were seen. Maxillary second premolars showed three times the sealant volume loss, twice the sealant area loss, and twice the depth loss of mandibular first premolars. Maxillary first premolars and maxillary second premolars showed comparable amounts of both volume and area loss.

When the wear values were compared to the original quantities of sealant at time of application (volume: $\bar{X}$ =1.77 ± 0.53 mm³; surface area: $\bar{X}$ = 8.06 ± 1.67 mm²; maximum depth: $\bar{X}$ = 820 ± 170 µm), they represented, on average, a 14% loss of volume, a 6% loss of surface area, and an 18% reduction in maximum sealant depth. The percent volume loss of fissure sealant after six months differed significantly between tooth groups ($F = 3.63$, $P < .05$). Mandibular first premolars showed a 6.37% change in volume compared to 19.72% for maxillary premolars. Although similar differences occurred between tooth groups for both area and depth, they were not statistically significant (Table 3).

## Discussion

Maxillary teeth demonstrated greater amounts of sealant loss than mandibular teeth. This was true for all three parameters (volume, area, and depth). In particular, mandibular first premolars exhibited least wear, both in absolute amounts and in the percentage of applied material lost after six months. This would suggest that the differences measured were real and not exclusively related to tooth size. Maxillary second premolars showed the greatest absolute amount of sealant loss, and the greatest percentage loss, as measured by all three parameters. The differences in amount of sealant wear between tooth groups may have been related to relative tooth position and, consequently, masticatory function. Both maxillary and mandibular first premolars exhibited less wear than maxillary and mandibular second premolars. The mandibular first premolar, which has least function, showed the least wear. Since a minimal technique was used when applying the material, and the occlusion was checked carefully before dismissing the subjects, we do not believe the sealants were in hyperocclusion.

All quantitative measurements were demonstrated graphically and related to tooth structure. This important feature provided information on the distribution and character of wear. Localized areas of extreme wear could be identified together with generalized wear patterns. It was possible, for example, to view the depth of wear at any given point on the occlusal surface. Qualitative differences were seen. The pattern of sealant wear differed between maxillary and mandibular premolar teeth. Mandibular premolars exhibited a saucer-shaped wear distribution with the maximum depth located toward the center of the sealant mass. Maxillary premolars, however, exhibited a different wear pattern; wear was more evenly distributed over all aspects of the sealant. Again, we believe that these differences may be related to the functional characteristics of individual teeth.

The findings of this study differ markedly from those of Jensen et al. (1985). Using quantitative methods, they reported a 50% volumetric loss of fissure sealant from premolars one month after application. Furthermore, sealant loss continued up to and beyond six months. There are several possible explanations for the conflicting results. The initial amount of sealant applied in that study was three times greater (5.3–9.0 $mm^3$) than the amount used in the present study (1.77 $mm^3$). In contrast to our minimal technique, the method used by Jensen et al. (1985) represented the volumetric upper end of sealant used on premolars. In addition, the vertical dimension of occlusion was increased with their sealant technique, and the sealant was not adjusted after application. Also, the materials used were different. We used a visible light-cured sealant in contrast to both the autopolymerized and ultraviolet light polymerized materials used by Jensen et al. (1985).

Our findings do, however, more closely resemble those of Muhlbauer et al. (1981). Using a quantitative photometric technique, which recorded surface area, they reported a 23% loss of fissure sealant from maxillary and mandibular molar teeth at six months. Since molar teeth typically exhibit the greatest amount of sealant loss, we expected the loss from premolars to be less.

The least squares method for a three-dimensional surface comparison is an important feature of this measurement technique. It estimates the scaling, translation, and rotation required to bring one surface into a position of maximum congruence with a second surface. This is achieved by minimizing the linear distances between pairs of homologous points on the two surfaces. The root mean square (RMS) of the residual distance then is taken as an expression of the degree of congruence, or fit. When using this method to demonstrate changes in anatomic contour, the computer fitting is confined to areas of anatomic stability. Without a *goodness of fit* routine, the method would be dependent on physically mounting the two surfaces in the same location in space before the stylus began generating profiles. Currently, the system is capable of measuring changes of 0.0006 $mm^3$ in anatomic contour (DeLong and Douglas 1983).

Since both qualitative and quantitative information is stored on magnetic disk, it provides a permanent record of wear at a given time and serves as a reference for sequential measurements over time. The method could be applied readily to other preventive or restorative materials.

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## AIDS-related discrimination: past, present, and future *continued from page 156*

AIDS also has revitalized the debate over whether the terminally ill have a right to experimental or innovative treatments. Gostin wrote that there is "no established legal right to experimental therapy." Nevertheless, patients continue to argue for unimpeded access to experimental drugs. Such access though, could hurt research by cutting the number of subjects willing to participate in controlled clinical trials.

In the early days of the disease, there were many complaints of workplace discrimination. These employment disputes were clustered largely among health care workers, food handlers, and human services providers, such as teachers and foster parents.

Complaints dealt with dismissal, demotion, harassment, salary reduction, and the denial of insurance benefits. "Virtually all courts have held that a positive HIV test result or a diagnosis of an HIV-related disease does not provide a sufficient basis for unfair treatment by employers," the author wrote.

There remains, however, a conflict between insurance underwriting and nondiscrimination principles. By its nature, the insurance industry discriminates against high risk individuals. Gostin feels that the industry regards HIV-infected people as uninsurable.

"The consequence of systematic refusal to insure people infected with HIV is that the financial burden shifts to public hospitals, which must care for patients without compensation," he wrote. Gostin calls for the costs of AIDS care to be split equally among the government, employers, and private insurers.

In the area of education, the courts consistently have overturned decisions to exclude HIV-infected children from ordinary schools, although they have required the school, parents and child "to comply with rigorous safeguards." Future cases in education are expected to deal with admission of HIV-infected students into medical and dental schools.

Antidiscrimination protection for HIV-infected people has come under the federal Rehabilitation Act of 1973, which prohibits discrimination against an otherwise qualified handicapped person from participating in, or receiving benefits from any program that receives federal funding. The courts consistently have found that all stages of HIV infection qualify as a handicap.

Congress, though, is close to passing the Americans with Disabilities Act, Gostin noted. That act would "comprehensively extend antidiscrimination protection for people with disabilities, including HIV infection, to the private sector in employment, public accommodations, transportation, and public services."