

Evaluation of two pit and fissure sealants: an *in vitro* study

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Abstract

The penetration coefficients (PC) and tensile bond strengths of two pit and fissure sealants and a low viscosity bonding resin were evaluated. The penetration coefficients of the resin systems were determined at 22°C. Five determinations were done with each resin. Bonded test specimens were loaded to failure in the tensile mode in an Instron testing machine. Ten specimens were prepared with each resin system. The tensile bond strength of a resin was not dependent on the PC of the resin.

Introduction

The occlusal surfaces of newly erupted permanent teeth are particularly susceptible to decay.¹ More than 40% of all carious or filled surfaces in the permanent dentition occur on occlusal surfaces.^{2,3} The fluoridation of the public water supplies has resulted in a 50% reduction in dental caries,⁴ but the reduction in caries prevalence is less evident on the occlusal surfaces of permanent teeth.^{5,6}

The concept of protecting the caries-susceptible occlusal surfaces of teeth by means of pit and fissure sealants is accepted as an integral part of a comprehensive caries preventive program. A single application of a sealant significantly reduced caries incidence five years after application.^{7,8}

The effectiveness of pit and fissure sealants depends on the ability to penetrate into narrow fissures in tooth surfaces before hardening occurs.⁹ The retention of a sealant, on the other hand, depends on its ability to penetrate into the microspaces produced in enamel surfaces by the etching agent.¹⁰ The resultant resin projections bond the cured resin mechanically to the etched enamel surfaces.¹¹

Several unfilled or filled sealants which are either chemically activated or polymerized by exposure to ultraviolet light are commercially available. An un-

filled selfcuring Bis-GMA resin blended with dimethacrylate monomers^a has recently become commercially available. The results of an *in vitro* study suggested that this sealant had the potential to perform well in clinical application.¹² This has been confirmed in recent clinical investigations.^{13,14}

The retention of sealants is often also determined in clinical studies in which the effectiveness of sealants in reducing dental caries is evaluated. It is extremely difficult to evaluate the extent of sealant loss when clear resin systems are used. A tinted sealant^b has recently been introduced to overcome this problem. This sealant is also a chemically activated Bis-GMA resin diluted with aliphatic diacrylates. Titanium dioxide has been added to one part (Resin A) of a two component low viscosity bonding resin system.^c The retention of this sealant was excellent 24 months after application.¹⁵

The purpose of this study was to determine the penetration coefficients and tensile bond strengths of the two pit and fissure sealants and the low viscosity bonding resin from which the one sealant is derived.

Methods and Materials

Penetration Coefficient The rate of penetration of a liquid under its own capillary force into an open, horizontal capillary tube can be derived from Poiseuille's equation:⁹

$$\frac{dx}{dt} = \frac{\gamma \cos \theta}{2n} \cdot \frac{r}{2x} \quad \text{--- (1)}$$

^aDELTON Pit and Fissure Sealant System, Johnson and Johnson, Dental Products Co., East Windsor, NJ 08520

^bCONCISE White Sealant System, Dental Products 3M Company, St. Paul, MN 55101

^cCONCISE Enamel Bond System, Dental Products 3M Company, St. Paul, MN 55101

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where x = length of the liquid column at time t
 r = the radius of the capillary
 γ = the surface tension of the Liquid
 η = the viscosity of the liquid
 θ = the contact angle of the liquid on the capillary wall

Integration of equation (1) gives:

$$x^2 = \frac{\gamma \cos \theta}{2n} \cdot rt \quad \text{--- (2)}$$

$$\frac{\gamma \cos \theta}{2n} = \frac{x^2}{r \cdot t} = PC \quad \text{--- (3)}$$

The penetration coefficient (PC) of a resin can be calculated from the values of γ , n and θ .¹⁶ The determination of these parameters is not easy and requires sophisticated instrumentation.

As the PC is equal to the square of the distance penetrated into a horizontal capillary tube of unit radius in unit time under capillary pressure [equation 3], the PC of a sealant can be obtained from the slope of the straight line of an "x²" vs. "t" plot.⁹

$$PC = \frac{\text{slope}}{r} \quad \text{--- (4)}$$

The penetration coefficients were determined according to a method developed by Fan, et al.⁹ Five random sections were cut from a length of thick-walled capillary tube and the inside diameters of the sections measured with a traveling microscope.^d The capillary tube was cut into 6-inch sections and cleaned in concentrated nitric acid overnight, washed well and dried. An aluminum^e reservoir was attached to the end of a capillary tube. The tube was taped to graph paper and placed in a horizontal position on a level table top. A resin system was mixed according to the manufacturer's instructions and introduced in the aluminum reservoir. The distance "x" penetrated at time "t" was continually measured on the graph paper. The values of "x²" at different time intervals were plotted against "t". The points were distributed about a straight line (Figure 1). A regression analysis was performed to determine the slope of this line. Five calculations were made for each sealant. The room temperature was 22°C.

Tensile Bond Strength Sixty noncarious maxillary central incisor teeth were used in this part of the study. The crowns of the teeth were cut off and

wedge-shaped grooves prepared on the lingual aspects of the crowns with a diamond disk. This procedure provided for the mechanical retention of the teeth in the embedding medium during the tensile testing procedure.

The tensile bond strengths were determined by means of a test method developed by Kemper and Kilian.¹⁷ The crowns of the teeth were embedded in epoxy resin in the tooth specimen cups with the polished facial surfaces projecting above the lip of the cup. The surfaces of 30 of the embedded teeth were machined in a lathe to produce circular pegs, 3.0 mm in diameter, projecting from the tooth surfaces. Final wet polishing of an embedded tooth surface and a tooth peg was done just prior to the preparation of a test specimen on 320, 400, and 600 silicon carbide disks respectively. During the polishing procedure the tooth cup was placed in a polishing block to ensure a planar enamel surface perpendicular to the direction in which the forces would be applied during testing.

The enamel surfaces were etched for 60 seconds with the etching solutions supplied with the two sealants and bonding resin respectively. The etched surfaces were washed in water and dried with oil-free compressed air. Two tooth cups were assembled in the bonding alignment block, a resin system mixed according to the manufacturer's instructions and applied to the enamel surface of the peg in the lower tooth cup. The upper tooth cup containing the embedded tooth was lowered until the two enamel surfaces made contact. The resin was allowed to cure at room temperature for 15 min. under a load of one pound. The bond-

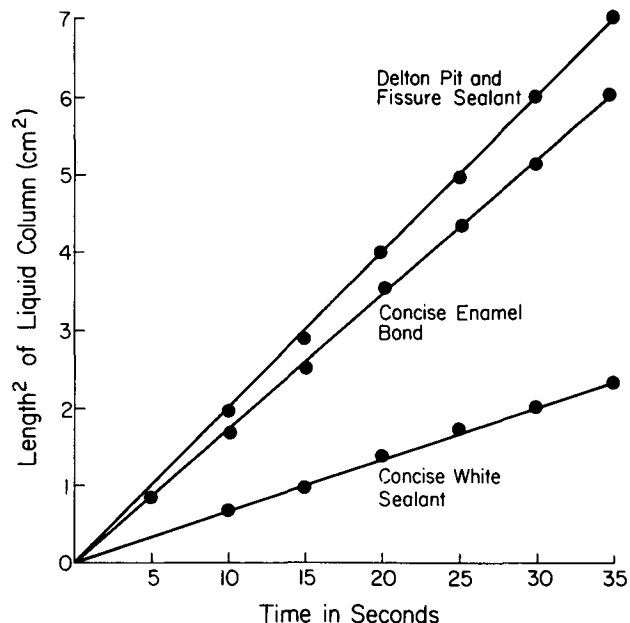


Figure 1. Plots of "t" vs "x²" for the three resin systems at 22°C (r = 0.0279 cm).

^dGaertner Scientific Corp., Chicago

^ePure Aluminum Heavy Duty Foil, S.S., Kresge Co., Troy, MI 48084

ed unit was removed from the mounting block and immersed in distilled water at 37°C for 24 hours. Ten specimens were prepared with each of the sealants and bonding resin respectively.

The test specimens were mounted in the measurement alignment block which was suspended in the jaws of an Instron^f testing machine. A tensile load was applied at a speed of 0.02 inch/min. and the force required to break an experimental bond recorded. The tensile bond strength was calculated and expressed in MN/m².

Results

The means (\pm SE) of the penetration coefficients of the two sealants and the bonding resin are given in Table 1. Students t-test was used to analyze the data. The PC of the Concise White Sealant System was significantly lower ($P < 0.001$) than those of the other two resin systems while the PC of Delton Pit and Fissure Sealant was significantly greater ($P < 0.01$) than the PC of Concise Enamel Bond.

The means (\pm SE) of the tensile bond strengths of the three resins are given in Table 2. There were no significant differences among the tensile bond strengths of the resin systems ($0.200 < P < 0.400$).

Discussion

Examination of fractured test specimens by scanning electron microscopy revealed that the majority of the test specimens failed partly within the resin and at the interface (Figure 2). A higher magnification showed that air bubbles were distributed along the fracture line within the resin (Figure 3). Stress concentrations could arise at these sites and be propagated along these voids during the application of the tensile stress. Test specimens will fail as a result of the well-known zipper effect.¹⁸

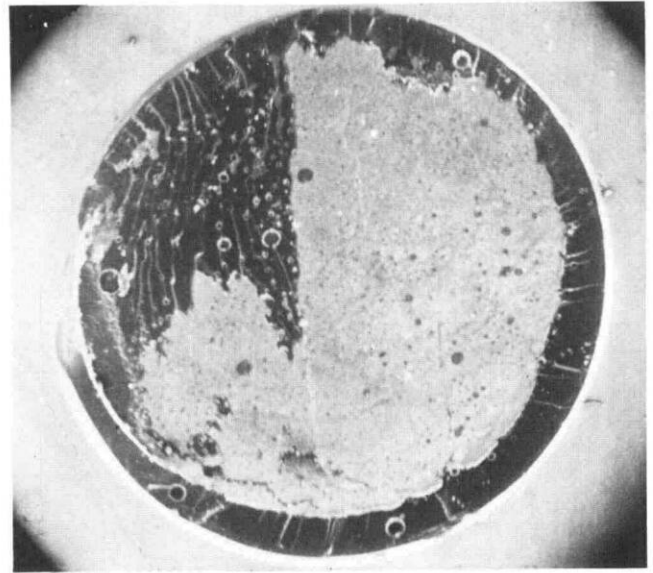


Figure 2. Photomicrograph of a fractured specimen showing failure partly within the resin and at the interface (SEM x25).

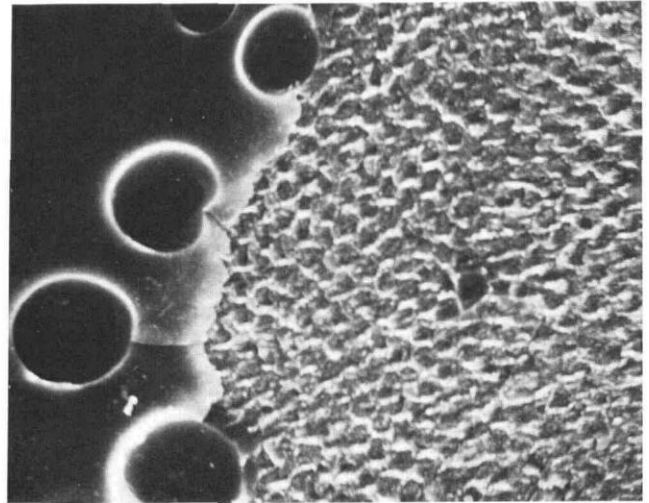


Figure 3. Distribution of air bubbles in resin along line of fracture (SEM x500).

^fInstron Corporation, Canton, MA 02021

Table 1. Penetration coefficients (PC) of the resin systems

| Resin System | Number of Specimens | PC cm/sec | \pm SE cm/sec | Coefficient of Variation % |
|--------------------------------|---------------------|-----------|-----------------|----------------------------|
| Delton Pit and Fissure Sealant | 5 | 7.22 | 0.10 | 3.2 |
| Concise Enamel Bond | 5 | 6.40 | 0.22 | 7.8 |
| Concise White Sealant | 5 | 2.43 | 0.10 | 8.9 |

The test method used in this investigation reduces the introduction of forces other than tensile during the testing procedure. It is, however, impossible to eliminate these forces altogether. Air bubbles may be incorporated into the resin during the mixing of the two components of the resin systems. Stress concentrations may arise at these sites during polymerization of the resins and may be propagated along the defects during the application of the tensile load resulting in premature fracture of a test specimen. A slight malalignment of the test specimens in the bonding or measurement alignment blocks may introduce a shear component at the resin/enamel interface during the testing procedure. This may explain the relatively high coefficients of variation obtained in this study.

In this study the penetration coefficients were determined in horizontal glass capillary tubes which were open at one end. This situation does not pertain in the clinical situation where air may be entrapped in the narrow fissures on the occlusal surfaces. This will undoubtedly occur in the minute microspaces produced in the enamel surface by the etching procedure. It was shown that trapped air in the fissures prevented further penetration of a sealant after equilibrium was reached.¹⁰ This resulted in incomplete penetration even for sealants with high coefficients of penetration. Asmussen,¹⁶ however, stated that the entrapped air may dissolve in the resin as a result of the increased pressure created in a fissure by the resin inflow.

Faust and his coworkers¹⁹ evaluated the tag length or extent of penetration into etched enamel surfaces of orthodontic direct bonding cements. They reported that the tag length of a resin with a low penetration coefficient appeared to be less than the tag length of a resin with a high penetration coefficient. A major factor which will determine the extent of resin penetration into etched enamel surfaces is the etching pattern

of the underlying enamel. The etching pattern varies tremendously not only from one tooth to another but also in adjacent areas of the same tooth.^{20,21} It is impossible to determine the etching pattern in the underlying enamel prior to the evaluation of the tag length of a resin.

The penetration coefficient of a resin is inversely related to the viscosity of the resin system [equation 3]. Asmussen²² calculated the depth to which a given monomer will penetrate into the pores of an etched enamel surface. He concluded that for given penetration times, complete penetration was obtained for monomers with viscosities below a certain value and that the depth of penetration decreased only slightly with viscosities above this critical value.

Pit and fissure sealants are not indefinitely retained in the oral environment. It is not likely that decay will be initiated under an intact sealant, but caries susceptible sites from which sealant has been lost may become carious. It is therefore of extreme importance that sealant loss should be readily recognizable during clinical examination. The addition of tinting or coloring agents will greatly facilitate detection of these sites. In the present study the addition of the tinting agent to a low viscosity bonding resin resulted in a significant reduction of the PC of the bonding resin but had no significant adverse effect on the bond strength of the resin to etched enamel surfaces. There is no reason to believe that the clinical performance of sealants will be adversely affected by the addition of tinting agents.

Conclusion

The tensile bond strengths of the three resin systems to etched enamel did not differ significantly despite significant differences among the penetration coefficients of the sealants.

Table 2. Tensile bond strengths of the resin systems

| Resin System | Number of Specimens | Bond Strength MN•m ⁻² | ± SE MN•m ⁻² | Coefficient of Variation % |
|--------------------------------|---------------------|----------------------------------|-------------------------|----------------------------|
| Delton Pit and Fissure Sealant | 10 | 10.18 | 0.44 | 13.4 |
| Concise Enamel Bond | 10 | 11.48 | 0.77 | 21.1 |
| Concise White Sealant | 10 | 11.16 | 0.78 | 22.2 |

The penetration coefficient of a resin as determined in the present and other studies is of little clinical significance in predicting the extent of resin penetration into etched enamel.

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