Comparison of shear strength, fracture patterns, and microleakage among unfilled, filled, and fluoride-releasing sealants

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Introduction

Numerous studies have indicated that pit and fissure sealants effectively prevent or arrest the effects of caries.[1-5] These positive features are determined, in part, by their physical properties, and in many ways are proportional to their retention rate in the oral cavity.[6,7]

The resins used in sealants are Bis-GMA and urethane dimethacrylate diluted with appropriate dimethacrylate resins.[8,9] Recently, inorganic fillers have been added to sealants to allow the materials to be both esthetically pleasing and more visible clinically.[10,11] As a result, the issue of proper polymer tag formation that is essential for sealant retention becomes important.[8,11-13] Although fluoride-releasing sealants are believed to enhance clinical effectiveness,[14,15] evaluations should be conducted to determine whether their bonding characteristics are similar to those of conventional pit and fissure sealants.

The purpose of this study was to compare unfilled, filled, and fluoride-releasing filled sealants to each other through shear bond, scanning electron microscope, and microleakage evaluations.

Methods and materials

The following materials were evaluated in each test:

1. Delton® Pit and Fissure Sealant (Johnson and Johnson, New Brunswick, NJ).
2. Prismashield® (L.D. Caulk, Milford, DE)
3. Fluoroshield® (L.D. Caulk, Milford, DE)

Shear bond strength test

Twenty-four freshly extracted non-carious human molar teeth that had been stored in physiologic saline were used for this part of the study. The 24 specimens were divided randomly into three groups of eight. Each specimen was mounted in an acrylic jig, and one enamel surface (facial, lingual, or proximal) of each specimen was ground flat to 600 grit. All flat surfaces were cleansed with an aqueous slurry of pumice, washed, and air-dried. The ground surfaces were etched with 50% phosphoric acid for 60 sec, washed, and air dried. Clear plastic cylindrical tubes, 3.0 mm inside diameter by 7.0 mm long, were placed in a vertical position on the flat ground enamel surface and filled in an incremental fashion with sealant. Each increment was cured for 60 sec with a visible light-curing unit (Demetron 400,™ Demetron Research Corporation, Danbury, CT).

Prior to shear testing, the plastic tubes were carefully removed, and all the bonded specimens were stored in distilled water at 37°C for 24 hr. Then the sealant posts were sheared in an Instron Universal Testing Machine (Instron® Corporation, Canton, MA) with a shear force to the post and a cross head speed of 0.5 mm/min. The fractured surfaces of each group were evaluated by SEM and the location of fracture identified.

Scanning electron microscopy (SEM)

Three representative samples from each group underwent SEM analysis to evaluate resin penetration into enamel surfaces. Enamel occlusal surfaces were treated in a similar fashion to the shear bond portion of the study and then the teeth were dissolved in 1N HCL and the sealant remnants washed in deionized water, dried, and mounted on SEM specimen stubs. These samples were desiccated and coated with a thin (50nm) film of gold-palladium alloy within a vacuum coating unit (PS-2 Coating Unit®, International Scientific Instrument, Santa Clara, CA). The specimens then were examined in an SEM (ISI Super IIIA, International Scientific Instrument, Santa Clara, CA).

Microleakage

A total of 45 freshly extracted noncarious human molar teeth that had been stored in physiologic saline were divided into three groups of 15 each. The occlusal surfaces were prepared in the same manner as the SEM study. After etching, the sealants were applied with an explorer, and spread into the pits and fissures and then light-activated for 60 sec. Each specimen was coated with two applications of clear nail polish, except for an area 2.0 mm from sealed occlusal surface. Each apex additionally was sealed with polyurethane varnish. The specimens were thermocycled in 0.5% basic fuchsin dye for 500 cycles at 5°C and 55°C with a dwell time of 30 sec at each temperature. After thermocycling, each specimen was mounted with an acrylic block and sectioned buccolingually with a high concentration diamond wafering blade (Buehler Ltd., Lake Bluff, IL). All specimens were inspected for microleakage with an optical microscope (100x). Microleakage, of the basic fuchsin dye was scored according to the following scale:

Score 0: No dye penetration

Score 1: Dye penetration restricted to the outer half of the sealant

Score 2: Dye penetration extending to the inner half of the sealant

Score 3: Dye penetration extending to the underlying fissure.

Results

Shear bond strength test

The overall shear bond strength values of the three different types of sealants and the mean shear bond types of sealants are found in the Table. An analysis of variance (ANOVA) revealed that there were significant differences among the different groups at a 95% confidence level ($P < 0.0005$). Significant differences were noted between the unfilled sealant group (Delton Pit and Fissure Sealant) and the other materials (Student's t-test, $P < 0.001$). No significant differences were found between the Prismashield and Fluoroshield groups (Student's t-test, $0.20 < P < 0.50$).

Delton Pit and Fissure Sealant specimens exhibited a mixed pattern of cohesive and adhesive sealant fractures. No Delton Pit and Fissure Sealant specimens exhibited fractures in enamel. Three Prismashield specimens exhibited enamel fractures. The remaining specimens exhibited adhesive fractures or a mixed pattern of adhesive and cohesive fractures. The Fluoroshield specimens almost exclusively exhibited enamel fractures.

Table. Sheer bond, fracture location, and microleakage scores

Parameter	*Sealant*		
	Delton	*Prisma*	*Fluoro*
*Shear Bond Strength**	*12.18 ± 2.70*	*22.32 ± 4.52*	*24.20 ± 2.67*
Location of Fracture†			
AF	2	1	—
CF	—	—	—
EF	—	2	2
AF + CF	6	4	1
AF, CF, EF	—	1	1
AF + EF	—	—	3
EF + CF	—	—	1
Microleakage‡			
0	15	15	14
1	—	—	1
2	—	—	—
3	—	—	—

* In mPA. (N = 8)

† AF = Adhesive Fracture; CF = Cohesive Fracture; EF = Enamel Fracture.(N = 8)

‡ 0 = no dye penetration; 1 = dye penetration restricted to outer half of sealant; 2 = dye penetration restricted to inner half of sealant; 3 = dye penetration extending to underlying tissues. (N = 15)

SEM evaluations

The results obtained from the sealant replicas after the demineralization of enamel are depicted in Figs 1–4. The micrographs of the Prismashield and Fluoroshield materials revealed a detailed pattern of resin penetration compared to the Delton Pit and Fissure Sealant. Enamel etched with 50% phosphoric acid for 1 min may be observed in Fig 4.

Microleakage study

The microleakage scores at the interfaces between the three different types of sealants and enamel are listed in the Table. A Student's t-test at a 95% confidence level revealed that no significant differences were noted in microleakage results between Delton Pit and Fissure Sealant and Fluoroshield. In addition, no significant differences were noted between Prismashield and Fluoroshield (Student's t-test, $0.20 < P < 0.50$).

Discussion

The results of the microleakage study revealed that all three sealants bond to etched enamel as evidenced by the polymer tag formations.[16, 17] In order to standardize the bonding mechanism in the study, the 50% etchant and 60-sec recommended time for Prismashield were used even though this concentration and time vary from established practice. In addition, all the sealants exhibit polymer tag formations, which promote areas of micromechanical adhesion between the sealants and enamel surfaces.[18, 19] Microleakage is therefore kept to a minimum, and the separating forces caused by the different thermal expansion rates of the sealants may be substantially reduced.[18, 20]

SEM analyses revealed that both Prismashield and Fluoroshield adapted to the etched enamel surface in a more complete fashion than did Delton. Prismashield and Fluoroshield exhibited continuous and uniform sieve-like tag formations throughout the entire surfaces, while Delton exhibited diffuse resin tags.

No significant difference in microleakage occurred between materials, but a significant difference was noted in shear bond strength between Delton and the two filled sealants. Filled sealants also had higher shear bond values. The differences in bond strengths between the filled groups and the unfilled group may be related to the ability of the sealants to adapt or intimately contact the etched enamel surface[20-23] or to the chemical compositions of the filled groups and the unfilled group. Delton is composed of a Bis-GMA formulation; Prismashield and Fluoroshield sealants are modified urethane Bis-GMA formulations. Thus, this difference in the chemical composition of the monomeric matrix causes a difference in the flow properties of the final polymers. Urethane monomer may confer more elasticity and adhesiveness to the resin than does the Bis-GMA monomer.

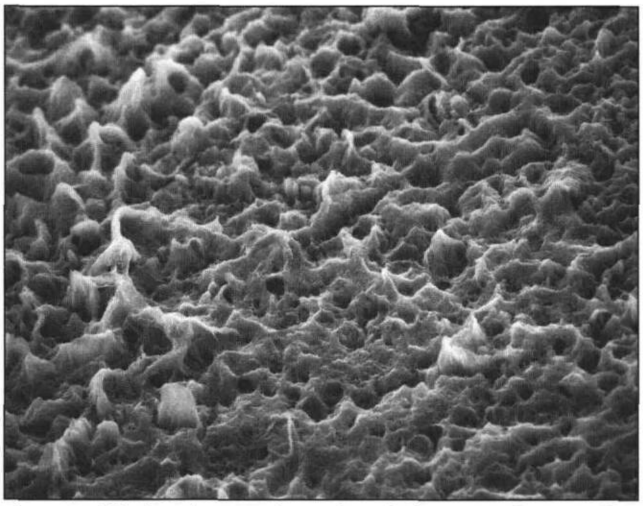

Fig 1. Unfilled sealant (Delton Pit and Fissure Sealant) replica 1000x). A continuous polymeric film with irregular penetration patterns are noted around enamel rods.

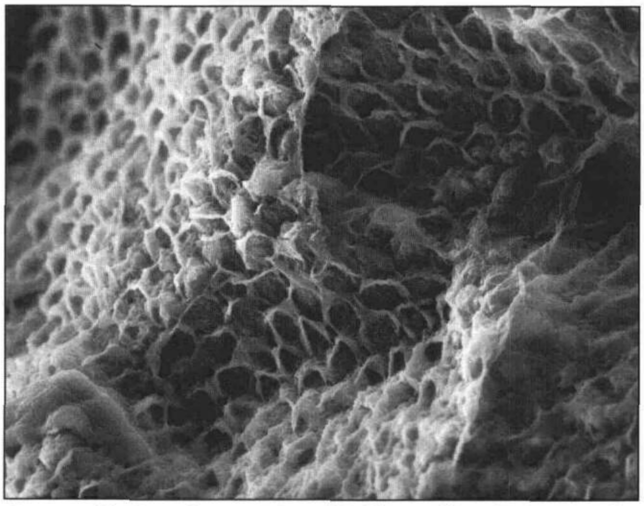

Fig 2. Filled sealant (Primashield) replica (1000x). The penetration of the sealant follows the pattern of etched enamel.

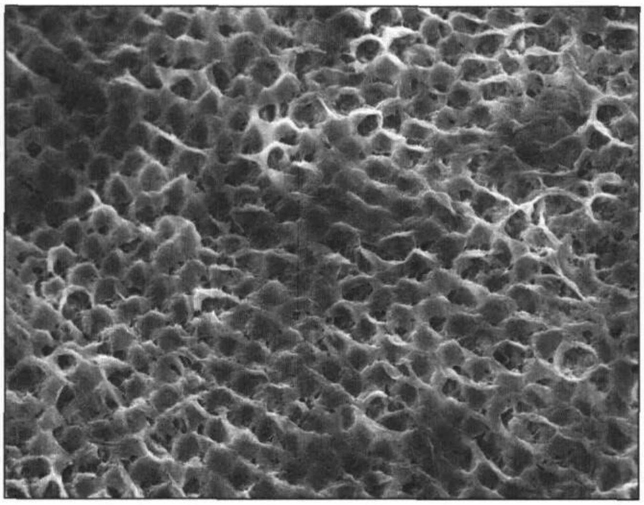

Fig 3. Filled sealant (Fluoroshield) replica (1000x). The penetration of the sealant follows the pattern of etched enamel.

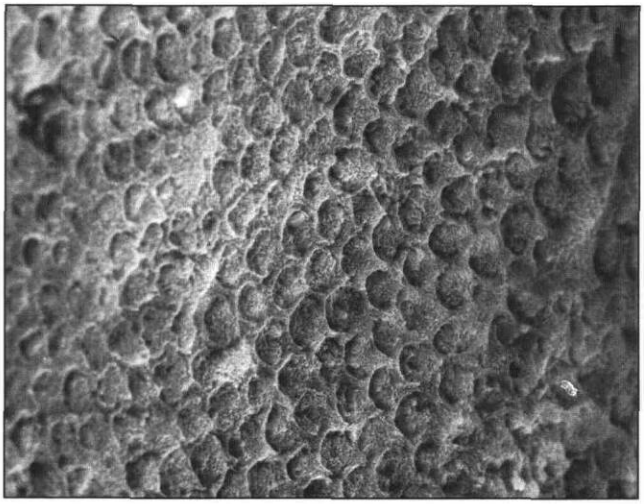

Fig 4. Etched enamel pattern after 1 min of etching with 50% phosphoric acid (1000x).

All specimens were examined by SEM to evaluate the fractured interfaces. The SEM micrographs of Prismashield and Fluoroshield revealed that these sealants appeared to be in intimate contact with enamel rods. The micromechanical bonds obtained by these two sealants may, in part, be due to the flow characteristics conferred by the urethane groups. This pattern of bonding yielded shear bond values that can exceed the strength of enamel (20–24 MPa).[24] In this study, enamel fractures occurred if the bond values reached 20 MPa. No enamel fractures were observed in the Delton specimens. Since the shear bond values associated with Fluoroshield were in the range of 21–28 MPa, most fractures occurred in the enamel. Prismashield exhibited a combination of enamel fractures, adhesive fractures, and a combination of adhesive and cohesive fractures.

Conclusions

1. No significant differences in microleakage were noted among the three sealants.
2. Prismashield and Fluoroshield exhibited significantly higher mean shear bond strength values than the Delton Pit and Fissure Sealant.

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