



SEM and Microleakage Evaluation of 3 Flowable Composites as Sealants Without Using Bonding Agents

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Abstract

Purpose: The aim of this study was to determine if flowable composites can be used as pit and fissure sealants without bonding agents.

Methods: Three flowable composites (Filtek Flow, Tetric Flow, Charmfil Flow) and a filled sealant (Ultraseal XT Plus) were used. The patterns of resin tag formation in the 4 sealant materials were compared using scanning electron microscopy. For the microleakage assessment, 54 extracted human premolar teeth were randomly divided into 3 groups. In each group, a conventional filled sealant and 1 of the 3 flowable composites were applied to occlusal fissures. The teeth were thermocycled and immersed in a 1% methylene blue solution for 48 hours. Each tooth was sectioned and examined to determine the extent of dye penetration.

Results: Three flowable composites and a filled sealant showed a similar resin tag formation pattern. The 3 flowable composites showed significantly more microleakage in each group than the filled sealant. The level of microleakage was similar in the 3 flowable composites.

Conclusions: Concerning the microleakage data, use of the filled sealant is more effective in sealing mechanically prepared occlusal fissures in comparison to the flowable composites. (*Pediatr Dent* 2006;28:48-53)

KEYWORDS: SEALANTS, FLOWABLE COMPOSITES, MICROLEAKAGE, ENAMELOPLASTY, SEM

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It has been more than 30 years since pit and fissure sealants were first used clinically. During this time, pit and fissure sealants have been shown to be effective in reducing the risk of occlusal caries,¹ and their success largely depends on the long-term retention and tight micromechanical adhesion to enamel surfaces.²

Resin-based sealants can be classified as either filled or unfilled according to their filler contents. There is a great deal of controversy regarding the most appropriate type for pit and fissure sealants. Droz et al reported that a filled sealant is less likely to completely fill a fissure than an unfilled sealant because a less viscous sealant could penetrate the fissures more deeply.³ Barnes et al, however, reported that the viscosity and flow properties of fissure sealants did not affect their sealing ability.⁴ Several studies have also shown similar penetration capability and retention in the 2 sealant types.^{5,6}

Many studies have reported that the efficacy of the sealants depends on the fissure preparation methods as well as the sealant materials used. Mechanical preparation or enameloplasty, which involves widening the fissures using a rotary instrument, allows for a better diagnosis of the underlying decalcification, the removal of debris, and improvement of sealant retention by allowing deeper sealant penetration and increasing the surface area.^{7,8} Blackwood et al, however, reported that enameloplasty followed by acid etching did not reduce the level of microleakage compared with the traditional pumice prophylaxis and acid etching technique.⁹ Even if there has been some controversy regarding the various fissure preparation methods, there are circumstances where bur preparation is reasonable. Suspected carious fissures should be prepared by enameloplasty prior to applying the sealant to identify any potential caries sites.⁹

Recently, flowable composites have been marketed as pit and fissure sealants with the view that flowable composites have a higher wear resistance. One study reported that 20% of practitioners used flowable composites as sealants and 29% of the practitioners used bonding systems before applying flowable composites or compomers. The same study also reported that no practitioners used bonding

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agents with classical sealants.¹⁰ If flowable composites have a comparable bonding quality with enamel without using a bonding system, they can be recommended for widened occlusal fissures with the benefit of a better abrasion resistance than conventional filled sealants.

The aim of this study was to determine if 3 different flowable composites could be used as pit and fissure sealants when bonding agents were not used by evaluating the bonding quality through scanning electron microscopy (SEM) and assessing the level of microleakage.

Methods

This investigation using human specimens was approved by the Institutional Review Board of Samsung Medical Center, Seoul, Korea. Three different flowable composites and a conventional filled sealant were used in this study (Table 1). All sealant materials were visible light cured.

SEM observations

Two extracted, erupted human permanent third molar teeth, which had been stored in normal saline with a 0.5% thymol solution, were selected for each sealant material. Only the crown portion of each tooth was used for the SEM evaluation. The flattest surface, which was usually the crown's mesial surface, was ground flat and polished using 2,000-grit and 4,000-grit carbide abrasive papers under a water stream. The tooth's crown was sectioned in half mesiodistally through the flat ground surface. From each cut crown, one section was prepared for the etched enamel surface observation and the other was prepared to observe the enamel-sealant material interface. Each enamel surface in both sections was cleaned using a pumice/water slurry in a rubber cup rotating in a slow-speed handpiece. The surfaces were then rinsed for 15 seconds with a water spray and dried thoroughly with oil-free compressed air.

A 35% phosphoric acid conditioning gel was applied to each surface using a small brush and left undisturbed for 30 seconds. Both surfaces were again rinsed thoroughly and air dried. This etching procedure was done after sectioning the tooth, otherwise the etched surface could be destroyed during sectioning. A sealant material was applied to 1 of the 2 acid-etched surfaces, with a penetration time of 20 seconds, and light cured for 40 seconds (Optilux 501, Demetron, Danbury, Conn). The tooth section with the sealant applied was dissolved in 1 N HCl, and the sealant was detached.

The sealant material was washed in deionized water and dried. The detached sealant provided an impression of the etched enamel surface. For each SEM specimen, both the section with the etched enamel surface and the detached sealant from the other section were mounted together on a SEM specimen stub. Each specimen was desiccated and coated with a thin (50 nm) gold-palladium alloy film. The specimens were examined by SEM (S-2460N, Hitachi, Tokyo, Japan).

Microleakage assessment

Fifty-four extracted human premolars—previously stored in normal saline with 0.5% thymol solution at room temperature, which were free of caries, fluorosis, fissure sealants, and restorations—were selected using a visual inspection. The teeth were divided randomly into 3 groups, each containing 18 teeth. In each group, 1 of the 3 flowable composites and a filled sealant were applied:

1. group 1=Ultraseal XT Plus/Filtek Flow;
2. group 2=Ultraseal XT Plus/Tetric Flow; and
3. group 3=Ultraseal XT Plus/Charmfil Flow.

For the tooth preparation, a ¼ round bur in a high-speed handpiece was used to clean and remove the debris from the occlusal fissures, which represented the minimal enameloplasty method with an unprepared middle portion of 1-mm thickness. The preparations were made with a sweeping motion to make a bur-width-wide and 1-mm deep cavity. All of the teeth were prepared by the same operator. Each tooth was then cleaned with a slurry containing a fine flour of pumice in water using an Intracoronary Bristle Brush (Ultradent Products, Inc, South Jordan, Utah) in a slow-speed handpiece. The occlusal fissures were acid etched for 30 seconds using a 35% phosphoric acid conditioning gel, rinsed with distilled water, and dried with oil-free compressed air.

After each tooth had been rinsed and dried, a flowable composite was applied to half of the prepared occlusal fissures. The composite was applied using a dental explorer without a load on the occlusal surface. A penetration time of 20 seconds was followed by light curing for 40 seconds. The filled sealant was then applied to the other half of the occlusal fissure using the same method and light cured for 40 seconds.

After sealing, each tooth was coated twice with clear nail polish, leaving 2 mm uncovered around the sealant's periphery. All the sealed teeth were stored in normal saline

Table 1. The Sealant Materials Used in This Study

Trade name	Manufacturer	Type	Filler %	Filler size
Ultraseal XT Plus	Ultradent Products Inc, South Jordan, Utah	Filled sealant	60	Avg=1.2 µm
Filtek Flow	3M Dental Products, St. Paul, Minn	Flowable composite	68	Avg=1.5 µm
Tetric Flow	Vivadent, Schaan, Liechtenstein	Flowable composite	68	Avg=0.7 µm
Charmfil Flow	Denkist, Seoul, Korea	Flowable composite	58	0.01-1.5 µm

for 24 hours at 37.5°C prior to thermocycling. The teeth were then thermocycled in water for 1,200 cycles between 5°±2°C and 55°±2°C with a dwell time of 30 seconds. The teeth were then immersed in a 1% methylene blue dye solution for 48 hours at 37.5°C. Next, the teeth were rinsed with tap water and sectioned using a water-cooled diamond disc on a low-speed Isomet (Buehler, Ltd, Lake Bluff, Ill).

Two buccolingual sectioning cuts were made parallel to each tooth's long axis—one through the middle of the filled sealant and the other through the middle of the flowable composite (Figure 1). Only 1 surface in each cutting was evaluated, which allowed 2 surfaces per tooth to be analyzed independently. The individual surfaces were then examined using computer-linked optical microscopy (Micro Hiscope KH-1000, I&G Plus, Seoul, Korea) with a ×50 magnification. The magnified images were captured and examined using image analyzing software (Image-Pro Plus, I&G Plus, Seoul, Korea). One person, who was blinded to the treatment groups, recorded the extent of dye penetration using the following ordinal scale described by Överbö and Raadal.¹¹ This examiner was calibrated on 20 sections prior to evaluation of study sections. The presence of the void was also evaluated:

Marginal leakage

- 0 = no dye penetration;
- 1 = dye penetration restricted to the outer half of the sealant;
- 2 = dye penetration to the inner half of the sealant;
- 3 = dye penetration into underlying fissure.

The differences in microleakage between Ultraseal XT Plus and each flowable composite in the 3 groups were examined using a chi-square test. A Fisher exact test was used to determine if there were any significant differences in microleakage among the 3 flowable composites. A $P < .05$ was considered significant.

Results

Scanning electron microscopic observations

The results are shown in Figure 2. Figures 2a and 2b show an etched enamel surface and the resin replica of etched enamel created by resin penetration of Filtek Flow, respectively. A type II etching pattern (enamel rod boundary preferentially dissolved) was displayed in all specimens. All

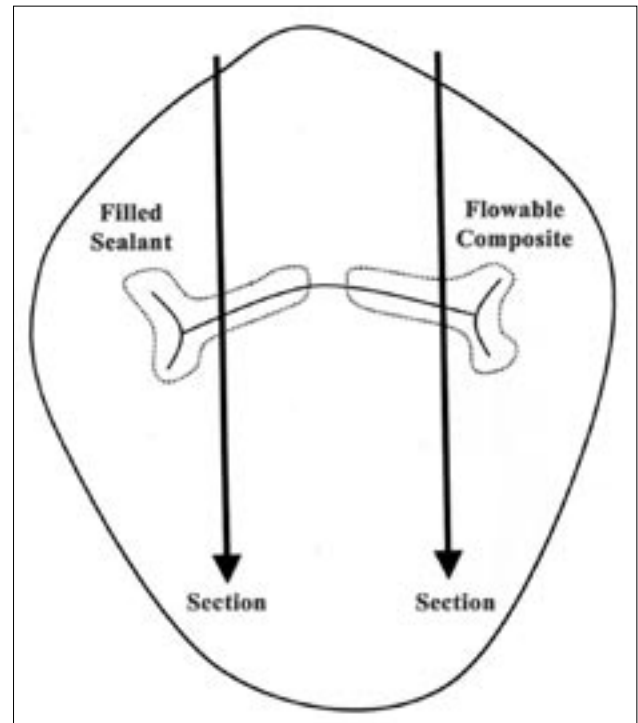


Figure 1. Two buccolingual sectioning cuts are illustrated, one through the middle of a filled sealant and the other through the middle of the flowable composite.

4 sealant materials showed a very similar pattern of resin replicas, even with some morphological differences.

Microleakage assessment

Table 2 shows the microleakage scores at the interface between each sealant material and enamel. The Ultraseal XT Plus showed significantly less microleakage than the 3 flowable composites in all 3 groups ($P < .05$). There was no statistically significant difference in microleakage scores among the 3 flowable composites ($P > .05$). None of the sealant materials had a score of 3.

No void was observed in any of the Ultraseal XT Plus specimens in all 3 groups. A void was found, however, in 3 of the Filtek Flow specimens and in 6 of the Tetric Flow and Charmfil Flow specimens (Table 3). In void evaluation, statistical comparison could not be performed because none of the Ultraseal XT Plus specimens had voids. Figure 3 shows one of the flowable composite specimens with a void.

Table 2. Microleakage Scores for Each Sealant Group

	Sealant materials	Microleakage score				Chi-square test P value
		0	1	2	3	
Group 1	Ultraseal XT	17	1	0	0	<.05
	Filtek Flow	11	7	0	0	
Group 2	Ultraseal XT	17	1	0	0	<.01
	Tetric Flow	7	10	1	0	
Group 3	Ultraseal XT	16	2	0	0	<.01
	Charmfil Flow	8	9	1	0	

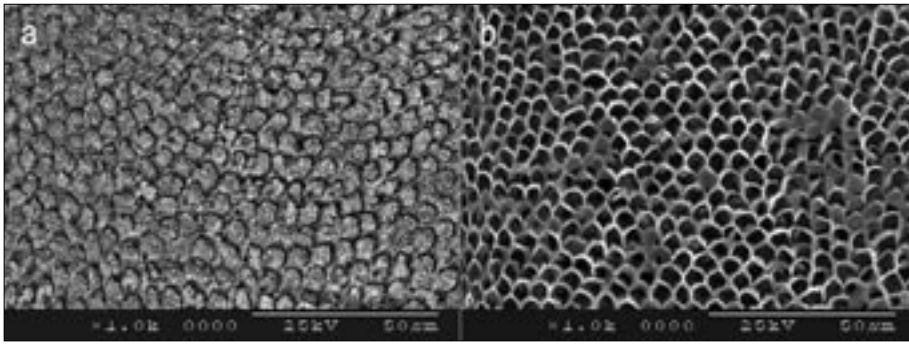


Figure 2a. Scanning electron photomicrograph ($\times 1,000$): pattern of acid-etched enamel surface. Filtek Flow was applied to the adjacent surface.

Figure 2b. Scanning electron photomicrograph ($\times 1,000$): resin replica (Filtek Flow) of acid-etched enamel surface.

Discussion

The use of the most adaptable sealant in a clinical situation is very important for protecting occlusal fissures because the sealant needs to be both durable and long lasting. There are no standardized preparation methods or sealant types, and clinicians usually select the sealant material or preparation method according to their personal preference. Currently, flowable composites are marketed as pit and fissure sealants, and this material is recommended for fissures prepared mechanically because thin applications of flowable composites will not be durable under function.¹²

The resin sealant creates a mechanical bond with the underlying etched enamel rods by flowing into the microspaces and forming “resin tags”, but the pattern of the etched enamel may be different in each tooth as well as on the different surfaces of the same tooth. The sample preparation method used in this study has eliminated each tooth’s variation. All sealant materials used in this study showed that resin tags had formed according to the etched enamel’s pattern and made an accurate impression of the adjacent etched enamel surface, even though Ultraseal XT Plus showed enhanced flowing properties compared with the 3 flowable composites that had a higher viscosity. Therefore, the SEM evaluation suggests that flowable composites can be bonded to etched enamel with a quality comparable to filled sealants, even though the bonding procedure was omitted, if they are applied to a flat surface.

Microleakage at the tooth/sealant interface can indicate the sealing ability because microleakage is dependent on the intimacy of the contact between the sealant and the tooth. In this study, significantly higher microleakage scores were measured in the 3 flowable composites than in the filled sealant, even though SEM showed that all sealant materials had a similar resin tag formation pattern. The level of microleakage in the 3 flowable composites was similar. This result compares to those reported by Duangthip and Lussi, who showed that classical sealants produced significantly less microleakage than flowable composites.¹⁰

A different study design was used in the present study than in previous microleakage studies, in which only 1 sealant

material was applied to each tooth and the leakage scores were compared. In this study, a filled sealant and one of the flowable composites were applied to the occlusal fissures of the same tooth. Each tooth can have a different etching pattern, which might influence the sealant’s bonding quality, even with the same acid concentration and etching time. The design adopted in this study eliminated this possibility and made the microleakage assessment more valid.

One study showed a low correlation between the formation of the resin tags and microleakage, even though the formation of the resin tags is one of the indicators for predicting the sealing ability.¹⁰ In this study, the microleakage observations did not correlate with the SEM observations. Hannig et al reported that, to obtain reliable data on the sealant materials’ sealing ability, both a dye penetration test and an SEM evaluation should be combined.¹³ The results of this study corroborate their suggestions.

The resin tags evaluated using SEM were prepared on a flat surface, while the specimens used to evaluate the level of microleakage were prepared in the fissures. This difference can explain why the microleakage scores were higher in the flowable composites. Ultraseal XT Plus has enhanced flowing properties compared with the 3 flowable composites used in this study. This property allowed the Ultraseal XT Plus to be applied more easily to the prepared fissures than the flowable composites, even though the fissures were enlarged by the bur preparation.

The flowable composites’ viscosity is significantly lower than the paste type of conventional composites. This study’s

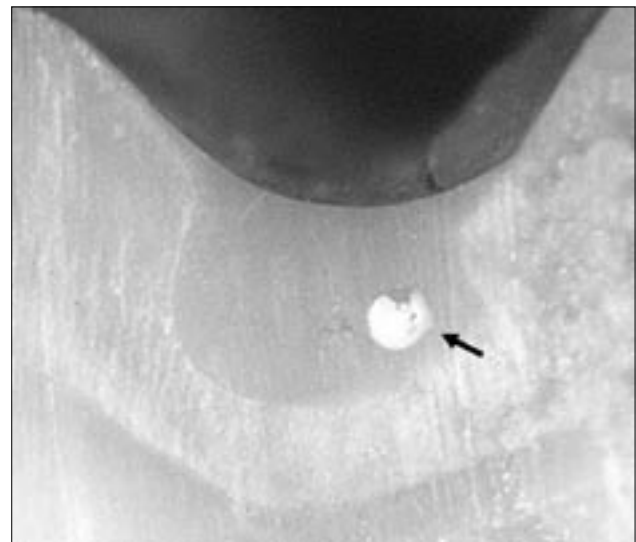


Figure 3. A representative specimen of flowable composite used as a sealant demonstrating a void (arrow).

results, however, showed that the flowable composites' viscosity was still too high to be applied to the pits and fissures. Opdam et al explained that there is a critical consistency for a composite material to allow proper wetting of the cavity.¹⁴ It was also anticipated that larger voids might form with flowable composites. The result showed that voids were only detected with the flowable composites and that no void was detected with the Ultraseal XT Plus. It was assumed that there would be fewer voids if compressed air were applied to the flowable composites to allow for better penetration into the fissures.

Irinoda et al reported that to obtain satisfactory sealant penetration, it is very important to allow sealant to penetrate as long as possible before polymerization. At least 60 seconds of sealant contact has been recommended for adequate bonding.¹⁷ In this study, all the sealant materials were applied to the fissures with a penetration time of 20 seconds. Therefore, if penetration time was increased to 60 seconds, it is possible that the microleakage scores would be improved and the voids would be diminished. In clinical practice, a 60-second application time is difficult to obtain, particularly with young children. Some studies showed that the void formation could also be dependent on the application methods.^{14,16} When the sealant material sticks to the instrument and is pulled away from the preparation wall, air could be entrapped.

In this study, 3 flowable composites adhered more to the explorer during the application and caused stirring motion to be applied to the cavity wall. This fact could have caused more voids in flowable composites than the filled sealant. The void formation at the interface between the sealant material and the tooth could explain the higher microleakage scores in flowable composites.

In this study, bonding agents were not used before the flowable composites had been applied. Bonding agents are used routinely for other types of restorations, and good clinical results have been shown. Feigal et al reported a beneficial effect of bonding systems in combination with sealants.¹⁷ The additional step of applying bonding agents, however, can make the sealing procedure more time consuming and difficult because pit and fissure sealants are usually applied to younger patients. Further investigation of the bonding agents with flowable composites is recommended.

Conclusions

Based on this study's results, the following conclusions can be made:

1. Concerning the microleakage data, use of the filled sealant is more effective in sealing mechanically prepared occlusal fissures compared to the flowable composites.
2. Special care is needed when applying the flowable composites to occlusal fissures because of void formation.

Table 3. The Presence of Voids for Each Sealant Group

	Sealant materials	Void	
		Absent	Present
Group 1	Ultraseal XT	18	0
	Filtek Flow	15	3
Group 2	Ultraseal XT	18	0
	Tetric Flow	12	6
Group 3	Ultraseal XT	18	0
	CharmFil Flow	12	6

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Abstract of the Scientific Literature



Simulation to Identify Errors in Pediatric Procedural Sedation

The practice of sedating patients for diagnostic and therapeutic procedures may be associated with life-threatening respiratory depression. A simulated scenario was developed that was reproducible with realistic pediatric physiology that degraded over time if no interventions occurred and improved when treated appropriately. Management of the scenario was observed and videotaped in an ideal setting—with a pediatric anesthetist (the gold standard), a radiology department, and an emergency department all in the same institution. Sedation experts, using a set of video markers for adverse event detection, diagnosis, and treatment, measured deviations from best practice. Hypoxia and hypotension lasted 4 1/2 and 5 1/2 minutes in the radiology and emergency departments, respectively, compared with 0 minutes in the gold standard setting. Many latent failures were identified during videotape review. This method revealed that use of a “crash test dummy” was a reliable and feasible method to objectively quantify rescue performance in actual sedation care settings. Vulnerabilities in personnel and care systems were identified, even though sedation care regulatory requirements (ie, “the guidelines”) were met.

Comments: This study is an excellent example of the use of simulation to assess the performance of medical personnel during a sedation emergency. It paints a sobering picture of systemic and personal failures that can occur during a simulated pediatric adverse sedation event, even though those involved regularly provide sedation to children in a hospital setting. It clearly shows that meeting the guidelines is not enough and that regular practice during realistic simulated events is necessary to maintain diagnostic and rescue skills. Dentistry has not yet embraced sedation simulation as a teaching tool. The \$120,000 price tag for the simulator used in this study may require interested dental institutions to partner in developing sedation simulation training centers that can be used by many. **ARM**

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