Bond strength and microleakage of self-adhesive and conventional fissure sealants

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The aim of this study was to compare the shear bond strengths (SBS), failure modes (adhesive, cohesive, or mixed), and marginal microleakage occurrence of conventional resin (CR)-based, glass ionomer (GI)-based, and self-adhesive resin (SAR)-based fissure sealants with or without prior phosphoric acid (PA) etching. Fifty extracted premolars were randomly and equally assigned into five groups — G1: PA+CR, G2: PA+GI, G3: GI, G4: PA+SAR, and G5: SAR. Prior PA etching significantly (p<0.05) increased the SBSs of sealants. Adhesive failure mainly occurred in teeth treated with SAR- or GI-based fissure sealants, and cohesive failure mainly occurred in PA-etched teeth. Microleakage occurrence differed significantly (p<0.05) among the five groups of treated teeth. We concluded that conditioning of a tooth’s enamel surface is crucial to creating strong bonds and leak-free sealing between tooth and fissure sealant.

Keywords: Preventive dentistry, Self-adhesive fissure sealant, Fissure sealant, Glass ionomer-based fissure sealant

INTRODUCTION

Despite a substantial decline in the overall prevalence of dental caries in most industrialized countries since the 1960s1, the prevalence rate of caries in teeth with pitted and fissured surfaces has not fallen. Pits and fissures on the occlusal surfaces of posterior teeth are very susceptible to caries because they provide shelter for the causative microorganisms, are relatively inaccessible to plaque control measures, and decrease the efficacy of other dental hygiene procedures2. Since the first recorded use of dental cement as a fissure sealant by Wilson in 18953, different fissure sealants (such as cyanoacrylate adhesives, polyurethane polymers, resin (R)-based and glass ionomer (GI)-based fissure sealants), composite resins (such as bisphenol A (bis)-diglycidyl ether methacrylate (Bis-GMA), bis-dimethacrylate (Bis-DMA)), and ormocer-based agents have been investigated for their sealing and caries-protective efficacies4-7. High-quality adhesion at the interface between dental hard tissues and restorative materials is crucial for achieving leak-free and durable restorations8. Markovic et al.7 stated that a dental fissure sealant is successful only if it firmly adheres to the enamel surface. The bond between a high-performance adhesive fissure sealant and the tooth surface is stronger and more durable than that of a low-performance adhesive fissure sealant because the former resists contraction and functional stresses8-9. Consequences of using a low-performance adhesive fissure sealant are imperfect sealing, faulty and defective marginal integrity, and diminished ability to prevent marginal microleakage — all of which permit a caries process to progress beneath the fissure sealant6-10.

Currently, the most commonly used fissure sealants are R-based and GI-based fissure sealants. Several reasons account for their widespread use in preventive dentistry. R-based fissure sealants adapt to the walls of fissures and can well resist occlusal forces; thus, they provide good sealing and caries-protective actions10 because of their adhesive properties. Conventional resin (CR)-based fissure sealants are not self-adhesive. The tooth’s enamel surface must be conditioned or etched using acids, such as phosphoric acid (PA), before applying the CR-based fissure sealant to create a strong and durable bond between the fissure sealant and the enamel which surrounds the fissure11. CR-based fissure sealants have other disadvantages. A completely dry field is requisite for the creation of an effective bond, and their application is very technique-sensitive and time-consuming.

To overcome these disadvantages, self-adhesive resin (SAR)-based fissure sealants were developed. The resin in these SAR-based fissure sealants is a self-adhesive flowable resin composite, which is presently used in the restoration of small Class I cavities, Class V cavities, and non-carious lesions, as well as a cavity liner for Class I and Class II restorations6,12. The use of self-adhesive flowable resin composites in restorative dentistry has increased because they are easy to handle and manipulate, their application is simple and easy, and the tooth surface does not require prior acid etching11. The sealing and caries-protective actions of R-based fissure sealants are reportedly the same as those of GI-based fissure sealants. For example, Giomer family products are generally known as composite resins which actively release ions12. GI-based fissure sealants are also self-adhesive. While R-based fissure sealants require a completely dry field to create an effective bond, GI-based fissure sealants can be used when faced with the challenge of isolating a partially erupted tooth and when it is not possible to maintain a clean, dry, and etched enamel surface13. However, the retention rate of GI-based fissure sealants is lower than that of R-based...
fissure sealants.

Against this background, we undertook an investigation to compare the shear bond strengths (SBS), occurrence of marginal microleakage, and failure modes of a GI-based fissure sealant, an SAR-based fissure sealant, and a CR-based fissure sealant with or without prior PA etching following their application on the tooth surface. The null hypothesis of this study was that differences in the SBS, occurrence of marginal microleakage, and failure mode of the different fissure sealants after their application with or without prior PA etching of the tooth surface would not be statistically significant.

MATERIALS AND METHODS

Tooth selection and preparation

This study used 50 upper premolars which were freshly extracted from human patients because of orthodontic problems. These patients gave informed consent to use their extracted teeth for this study, which was reviewed and approved by the Ethics Review Committee of the School of Dentistry, Ataturk University (27/2013). All selected teeth had no caries on their buccal, palatal, and occlusal surfaces, were free of any developmental defects, had no visible cracks as a result of the extraction, had not previously undergone any dental restoration nor treated with a sealant.

After soft tissue remnants and calculus were manually removed, all teeth were cleaned using a fluoride-free pumice and a rubber polishing cup. After cleaning, residual pumice on the teeth was removed by washing in tap water. Teeth were stored in a 0.9% saline solution at room temperature until use. The root of each tooth was embedded in an acrylic resin block up to 1 mm below the cementoenamel junction.

Table 1  Materials Used

<table>
<thead>
<tr>
<th>Material Class</th>
<th>Brand Name (Batch No)</th>
<th>Manufacturer</th>
<th>Material Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional resin-based fissure sealant</td>
<td>Grandio seal (1243478)</td>
<td>Voco, Cuxhaven, Germany</td>
<td>Bis-GMA/TEGDMA, nano-filled, releases fluoride.</td>
</tr>
<tr>
<td>Glass ionomer-based fissure sealant</td>
<td>Fuji Triage Capsule (1210171)</td>
<td>GC Corporation, Tokyo, Japan</td>
<td>Glass ionomer, aluminofluoro-silicate glass, polyacrylic acid, distilled water, polybase carboxylic acid.</td>
</tr>
<tr>
<td>Self-adhesive resin based fissure sealant</td>
<td>Vertise Flow (3172311)</td>
<td>Kerr, Orange, CA,USA</td>
<td>GPDM, Prepolymerized filler, 1µm barium glass filler, nano-sized Ytterbium fluoride.</td>
</tr>
<tr>
<td>Coating varnish</td>
<td>Final Varnish LC (1241)</td>
<td>Voco, Cuxhaven, Germany</td>
<td>Bis-GMA, diurethanedimethylacrylate, HEDMA, Catalyst</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>Vococid (1306510)</td>
<td>Voco, Cuxhaven, Germany</td>
<td>34.5% phosphoric acid.</td>
</tr>
</tbody>
</table>

Bis-GMA: Bisphenol A glycidyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate; GPDM: Glycerol phosphate dimethacrylate; HEDMA: 1,6-Hexanediol dimethacrylate.

Experimental groups and procedures

Fifty teeth were randomly and equally assigned to five groups which were named according to the type of fissure sealant applied and with or without prior acid etching (Table 1). To ensure standardization of specimen preparation, bonding sites on the buccal and palatal surfaces of each tooth were demarcated by placing a small strip of adhesive tape with a 2.5-mm-diameter hole in the center (Fig. 1a). Teflon O-rings (2 mm diameter, 2 mm thickness) were then placed in these holes (Fig. 1b). A 2-mm-thick build-up was created on each tooth by incrementally adding layers of each fissure sealant, and standard dental practices were used to apply each fissure sealant (Table 1).

In Group 1 (G1:PA+CR), the buccal and palatal surfaces of 10 teeth were first etched with 34.5% PA (Vococid®) before applying a CR-based fissure sealant (Grandio Seal®). In Group 2 (G2:PA+GI), the buccal and palatal surfaces of 10 teeth were first etched with 34.5%...
PA before applying a GI-based fissure sealant (Fuji Triage®). In Group 3 (G3:GI), the buccal and palatal surfaces of 10 teeth were applied with GI-based fissure sealant (Fuji Triage®) only. In Group 4 (G4:PA+SAR), the buccal and palatal surfaces of 10 teeth were first etched with 34.5% PA before applying an SAR-based fissure sealant (Vertise Flow®). In Group 5 (G5:SAR), the buccal and palatal surfaces of 10 teeth were applied with SAR-based fissure sealant (Vertise Flow®) only.

Following their application, CR-based and SAR-based fissure sealants were light-cured for 20 s using a dental light curing unit (LED.G, Woodpecker Medical Instrument Co., Ltd., National High-Tech Zone, Guilin, Guangxi, China).

For G2:PA+GI and G3:GI teeth, capsules that contained the GI-based fissure sealant were first inserted into an activator device whose lever was pressed for 2 s to activate the capsule. Activated capsule was then inserted into a mixing unit for 10 s, before fissure sealant was applied to the inner surface of the Teflon O-ring and the buccal and palatal surfaces of each tooth. Fuji Triage® could easily absorb light energy because of its pink shade. Its setting reaction was accelerated by irradiation with a halogen or plasma arc light source16, reducing its photocuring time from 2–3 min to 20 s to simulate its use in the clinical environment and to obtain durable adhesion. GI-based fissure sealants degrade in aqueous, moist, and dry environments. Therefore, a varnish coating (Final Varnish LC®), which was a light-cured methacrylate-based resin, was applied to the tooth surfaces to protect the applied sealant from water contamination and prevent hygroscopic expansion, as recommended by its manufacturer.

After applying the fissure sealants, the adhesive tape and Teflon O-ring were removed from each tooth. Treated teeth were thermocycled 500 times in water at 5°C and 55°C. To prepare the teeth for SBS testing and determination of microleakage occurrence, they were first immersed in a 0.5% basic fuchsin dye solution for 24 h and then stored in distilled water at 37°C for 24 h until time of testing.

**Shear bond strength test**

The SBSs of different fissure sealants were measured using a knife-edge shear test in a universal test machine (AGS-5kNG, Shimadzu Co., Kyoto, Japan). Each tooth was mounted in a holder such that the metal knife blade was parallel to the treated buccal and palatal surfaces of the tooth (Fig. 2a). The metal knife blade of 0.2 mm thickness was then moved vertically across the treated

![Fig. 2](image)

(a) Schematic representation of shear bond strength test procedure.
(b, c) Images of adhesive failure of conventional resin-based fissure sealant, where enamel surface is exposed after debonding.
(d, e) Images of mixed failure of self-adhesive resin-based fissure sealant with prior phosphoric acid (PA) etching of the tooth surface, where enamel surface is covered with sealant.
(f, g) Images of mixed failure of self-adhesive resin-based fissure sealant without prior phosphoric acid (PA) etching of the tooth surface, where enamel surface is also covered with sealant (†: Enamel, *: Fissure sealant).
(h, i) Images of cohesive failure of glass ionomer-based fissure sealant with prior PA etching of the tooth surface. Enamel surface cannot be seen because it is covered by fractured fissure sealant.
surfaces at a crosshead speed of 0.5 mm/min until debonding occurred (Fig. 2a).

SBS values were first recorded as a force (in Newtons) when debonding (failure) occurred, and subsequently converted into Pascals (MPa=Newtons/mm²) by dividing the force by the bonding area (mm²). For each fissure sealant, two SBS values were obtained from the buccal and palatal surfaces. These SBS values were averaged, and the average was used in statistical analysis.

Failure mode analysis
Micrographs (×20 magnification) of the debonded specimens were taken by a camera attached to a stereomicroscope (SMZ-V multipoint-sensor system, Nikon, Japan). These micrographs were independently examined by two of the authors (BC and PC), who were blind to the treatments, to determine the failure modes. In the case of disagreement between these two examiners, final failure mode classification was arrived at by consensus.

Failure modes of the fissure sealants were classified as follows17). Adhesive failure: debonding occurred at the interface between the treated buccal and palatal surfaces and fissure sealant; cohesive failure: failure in sealant/enamel; mixed failure: occurrence of both adhesive and cohesive failures. In each group, failure modes of fissure sealant on the buccal and palatal surfaces were separately determined for each tooth. The two failure mode classifications were pooled, and these pooled classifications were used in statistical analysis.

In each group, scanning electron micrographs of the failure modes of two randomly selected debonded specimens were also examined to improve failure mode characterization. For this purpose, each specimen was first sputter-coated with a gold-palladium alloy using an ion coater (SEM Coating Unit E 500, Polaron Equipment Limited, Barcelona, Spain) before being imaged under a scanning electron microscope (JSM-6400, Jeol, Tokyo, Japan).

Determination of marginal microleakage occurrence
After each treated tooth was secured by clamps placed on its mesial and distal surfaces, it was longitudinally sectioned into two fragments using a water-cooled diamond saw (Fig. 3a). Each tooth section was kept in a humid environment until it was time to be examined for microleakage occurrence at the enamel-fissure sealant interface.

Scoring for the presence and location of 0.5% basic fuchsin dye was done under a stereomicroscope at ×20 magnification, where 0: no fuchsin dye was present at enamel-fissure sealant interface; 1: fuchsin dye was present in middle-third of enamel-fissure sealant interface; 2: fuchsin dye was present at the base of enamel-fissure sealant interface. Scoring was independently done by two of the authors (BC and PC) who were blind to the treatments. In the case of disagreement between these two examiners, the final score was arrived at by consensus. Final score of
microleakage occurrence was the average of the scores of the two examiners.

Statistical analysis
Data were statistically analyzed using a computerized statistical software program (SPSS Statistics for Windows, Version 20.0, SPSS Inc., Chicago, IL, USA). SBSs of the different sealants were compared by a one-way analysis of variance (ANOVA) and a post hoc Duncan’s multiple range test. The chi-square test was used to analyze the failure modes and microleakage occurrence. Data were displayed as mean±standard deviation, and statistical significance was set at 5%.

RESULTS
Table 2 displays the mean SBSs of the five experimental groups of this study, ranging from 4.2 MPa (G5:SAR) to 49.8 MPa (G4:PA+SAR). There were statistically significant differences \((p<0.05)\) in the SBS among the five groups. SBSs of G1:PA+CR and G4:PA+SAR teeth were the highest, and they were not significantly different from each other (Table 2). However, they were significantly higher \((p<0.05)\) than those of G2:PA+GI and G3:GI teeth (Tables 2 and 3).

Table 2 also summarizes the failure modes of the five experimental groups, and statistically significant differences \((p<0.05)\) were found (Table 3). Adhesive failure was the most common failure mode of fissure sealants applied to the buccal and palatal surfaces of G3:GI and G5:SAR teeth. This failure mode differed from those found in the other three groups. Cohesive failure was the most common failure mode of fissure sealants applied to the buccal and palatal surfaces of G1:PA+CR and G4:PA+SAR teeth. For the fissure sealant applied to the buccal and palatal surfaces of G2:PA+GI teeth, mixed failure was the most common failure mode.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Shear Bond Strengths of the Different Pit-and-Fissure Sealants (MPa)</th>
<th>Failure Modes of the Different Pit-and-Fissure Sealants on the Buccal and Palatal Surfaces</th>
<th>Microleakage Scores of the Different Pit-and-Fissure Sealants on the Occlusal Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Adhesive</td>
<td>Cohesive</td>
</tr>
<tr>
<td>G-1: PA+CR</td>
<td>42.6±3.2</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>G-2: PA+GI</td>
<td>10.8±2.1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>G-3: GI</td>
<td>5.9±1.1</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>G-4: PA+SAR</td>
<td>49.8±5.3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>G-5: SAR</td>
<td>4.2±0.9</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

The shear bond strengths are displayed as mean megapascals±standard deviation. Means followed by the same letter are not significantly different at \(p=0.05\). The sample size of each group=10, and the number of replications for each study parameter was either two (shear bond strength and failure modes) or four (occurrence of microleakage).

*: For each group, the mode of failure of the FS on the buccal and palatine surfaces of each tooth was determined separately. †: For each group, the occurrence of microleakage score was scored according to the presence and location of fuschin dye on the interfacial surfaces of the two tooth sections. See text of Experimental Groups and Procedures subsection in the Materials and Methods section for an explanation of each of the five experimental groups (G-1:PA+CR, G-2:PA+GI, G-3:GI, G-4:PA+SAR, and G-5:SAR) of teeth and text of Study Parameters and Data Collection subsection in the Materials and Methods section for explanations of the classification of the failure modes and the scoring for the occurrence of microleakage.

Table 3 Results of statistical analysis

<table>
<thead>
<tr>
<th>Groups</th>
<th>Shear Bond Strength</th>
<th>Failure Mode</th>
<th>Microleakage Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1: PA+CR</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>G-2: PA+GI</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>G-3: GI</td>
<td>b</td>
<td>c</td>
<td>c, e</td>
</tr>
<tr>
<td>G-4: PA+SAR</td>
<td>a</td>
<td>a</td>
<td>d, a</td>
</tr>
<tr>
<td>G-5: SAR</td>
<td>b</td>
<td>c</td>
<td>e, a</td>
</tr>
</tbody>
</table>

The difference between the groups marked by the same letter or letters is statistically insignificant \((p>0.05)\).
Representative stereomicroscopic images and scanning electron micrographs of debonded tooth surfaces are displayed in Figs. 2b–2i. Figures 2b and 2c show the adhesive failure images of CR-based fissure sealant, where the enamel surface was exposed after debonding. Mixed failure images of SAR-based fissure sealant with and without prior PA etching are displayed in Figs. 2d and 2e and Figs. 2f and 2g respectively. In both instances, the enamel surface was visible but partially covered with the sealant. Cohesive failure images of GI-based fissure sealant with prior PA etching are displayed in Figs. 2h and 2i, where the enamel surface was covered with fractured fissure sealant.

Table 2 also summarizes the findings of microleakage occurrence at the enamel-fissure sealant interface in the five groups of treated teeth, and statistically significant differences (p<0.05) were found (Table 3; Figs. 3b–3f). Microleakage occurrence was least (score 0) at the enamel-fissure sealant interface of G1:PA+CR and G4:PA+SAR teeth, but highest (scores 1+2) at the enamel-fissure sealant interface of G3:GI teeth. No statistically significant differences in microleakage occurrence were found at the enamel-fissure sealant interface between: (a) G3:GI and G5:SAR teeth; (b) G1:PA+CR and G4:PA+SAR teeth; and (c) G1:PA+CR and G5:SAR teeth.

**DISCUSSION**

Clinicians are interested in acquiring deeper knowledge about the properties of adhesive systems that they use to improve the quality of dental treatments they deliver to their patients. In the case of fissure sealants, the traditional method of assessing their clinical performance is to determine their retention. But now, dentists seek information on their SBSs and sealing ability.

The SBS of sealants is considered to be a very reliable parameter in the quantification of their adhesive ability on enamel substrate. SBS testing of biomaterials is based on the premise that the stronger the tooth-biomaterial adhesion or bond, the better the biomaterial will resist contraction and functional stresses.

Microleakage is defined as the passage of bacteria, fluids, molecules, and ions between tooth and the sealing material. Results of in vitro microleakage studies make it possible to predict the marginal sealing capacity of different dental materials. Bravis et al. asserted that useful information on the durability of adhesive interfaces can be obtained by combining microleakage measurements with another in vitro test, such as bond strength testing on the same tooth. For this reason, we used the same teeth to investigate whether self-adhesion would increase the bond strength and reduce the occurrence of marginal microleakage of fissure sealants.

PA etching of dental enamel surface superficially changes 10–30 µm of the tooth surface from a low-reactive surface to one which is very amenable to adhesion. Acid etching creates a morphologically porous enamel layer which a fissure sealant, usually a resin, can penetrate to a depth of 25–50 µm. After sealant application and polymerization, the resultant resin tags create a resistant, durable, and effective bond between the enamel and sealant. However, PA etching presents problems because of its bad taste, time-consuming procedure, and increase in patient’s anxiety during dental treatment. To overcome these problems, SAR-based and GI-based compounds were developed for use as fissure sealants. One prominent advantage of self-adhesive light-cured flowable composite resins is that their use reduces the 3-step system of bonding (etching, priming, and bonding) to a 1-step system.

Horiuch et al. compared the changes in enamel surface and debonding forces of two adhesives that required prior PA etching of the enamel surface against two self-etching adhesives. Changes in enamel surface after applying the self-etching adhesives were less than those that required prior PA etching, and debonding forces of the self-etching adhesives were significantly lower than those that required prior PA etching. A milder etching effect and a lower depth of resin penetration of the self-etching adhesives into the enamel substrate accounted for these results. In another investigation, Iijima et al. compared the effects of a conventional etching system and a self-etching system on the nanohardness and elastic modulus of enamel. The self-etching system exhibited minimal effects because of the low strength of its chemical attack on enamel.

In the present study, SAR-based and GI-based fissure sealants exhibited low enamel bond strengths. In light of the findings of Horiuch et al. and Iijima et al., we surmised that the low bond strength of Vertise Flow, the SAR-based fissure sealant used in this study, was due to its minimal effects on tooth enamel. Another possible explanation for the low SBS of Vertise Flow could be found in its pH value, and hence its ability to etch uncut enamel surface. According to the manufacturer, the pH of Vertise Flow was about 1.9, which was higher than that of PA. Hence, its acidity upon deionization in the presence of water and after incorporation of phosphoric acid ester monomers into a resin-based material was generally milder than that of PA. Consequently, the amount of resin which penetrated the enamel surface was not high because PA esters caused only small changes to tooth enamel. Besides, all-in-one self-etching dental adhesives are susceptible to hydrolytic degradation, which in turn reduces their bond strength. It was probable that such degradation played a role in the low SBS of Vertise Flow. In a study by Goracci et al., thermocycling test revealed that Vertise Flow application with prior PA treatment created a stronger bond than that created by sole application of Vertise Flow.

Bond strength of G4:PA+SAR teeth was higher than that of G1:PA+CR teeth, although the difference was not statistically significant. This increase in bond...
strength could be due to the presence of the well-proven glycerol dimethacrylate dihydrogen phosphate (GPDM) adhesive monomer in Vertise Flow®. This self-etching, acidic, adhesive monomer is also a constituent of OptiBond Solo Plus, a single-component dental etching, acidic, adhesive monomer is also a constituent that is used with conventional flowable resin composites. Boratto et al. also reported that when an intermediary adhesive layer was applied between etched enamel and a CR-based fissure sealant, it improved fissure sealant adhesion.

GIs bind to the tooth surface by two mechanisms: micromechanical interlocking and chemical bonding. Although GIs can bond to enamel even in the presence of a smear layer, bond strength can be increased by pretreatment with a surface conditioner (such as PA, citric acid, maleic acid, or polyacrylic acid) to remove the smear layer. PA etching of the tooth surface provides good wetting of the surface and enables GIs to chemically interact with the mineral phase of enamel by ionic interaction. Polyalkenoic acids have been shown to be irreversibly adsorbed onto hydroxyapatite surfaces. Chemical bonding occurs through the formation of ionic bonds between the carboxyl groups of polyalkenoic acid and calcium ions in hydroxyapatite. However, it must be cautioned that various minerals or salts, which are products of the chemical interaction between polyalkenoic acid and enamel hydroxyapatite, can prevent intimate contact between cements and the enamel substrate because they are deposited onto the enamel surface. In this study, we used PA to condition the enamel surface prior to fissure sealant application, and our results were similar to those obtained when polyacrylic acid was used to condition the tooth surface.

Attin et al. compared the tensile bond strengths to enamel of restorative materials which contained a GI and a composite resin with and without pre-conditioning of the tooth. They found no statistically significant differences in bond strength between a conventional GI and unconditioned enamel and a conventional GI and enamel that was conditioned using 25% polyacrylic acid. In another investigation, Bishara et al. found that the conditioning of the tooth surface with 34.5% PA did not increase the SBS of a GI-based fissure sealant. In the present study, pre-conditioning of the tooth surface with PA doubled the bond strength obtained with GI-based fissure sealant application only — but this increase was not statistically significant. This increase in bond strength was due to the use of PA as a conditioner and the good ability of GIs to wet the enamel surface.

In this study, the SBS of GI-based fissure sealant was lower than those of CR-based and SAR-based fissure sealants. When resins become attached to enamel after acid etching, micromechanical bonds are created and this type of bond is stronger than the chemical or molecular (ionic) bonds of GI-based fissure sealants. Mechanical retention of CR-based sealants is achieved through resin penetration into etched enamel followed by resin tag formation. Monomers in CR-based fissure sealant polymerize in situ, and the CR-based fissure sealant becomes interlocked with the enamel surface. Moreover, GIs are very brittle compared with composite resins, and they have lower plastic deformation ability when loaded.

Occurrence of marginal microleakage following the application of CR-based fissure sealant was similar to that obtained with SAR-based fissure sealant — with or without prior PA etching. This similarity was due to the presence of functional monomers in the SAR-based fissure sealant used in this investigation, which improved its flowability and penetrability into the capillary-like spaces of etched enamel surface, thereby resulting in improved adhesion and good sealing.

Ganesh and Shobha reported that the sealing ability of CR-based fissure sealants is better than that of GI-based fissure sealants, as indicated by a lower occurrence of marginal microleakage. In contrast, Ashwin and Arathi reported that marginal microleakage occurrence following the application of a GI-based fissure sealant was not different from that of a CR-based fissure sealant. In the present study, marginal microleakage occurrence following the application of Grandio Seal®, the CR-based fissure sealant used in this investigation, was significantly lower than that with Fuji Triage®, the GI-based fissure sealant used in this investigation. The thermocycling regime could be the reason for this difference. It was reported that following thermocycling, marginal microleakage occurrence was higher in teeth sealed with a GI-based fissure sealant than those sealed with a CR-based fissure sealant.

Reduced marginal microleakage was observed for G2:PA+GI teeth when compared with G3:GI teeth, a finding in agreement with that reported by Birkenfeld and Schulman. They reported that PA etching significantly reduced microleakage in teeth that were sealed with a GI-based fissure sealant. According to the manufacturer, the pH of Fuji Triage® is significantly lower than that with Fuji Triage®, the GI-based fissure sealant used in this investigation, was 1.9. We surmised that this pH value was responsible for the high microleakage occurrence following its sole application to the enamel surface. Additionally, the buffering effect of the minerals in the dental hard tissues and a time-dependent increase in the pH of GI further contributed to the high microleakage occurrence.

Pereira and his colleagues proposed that adhesive failures occur when bond strength is low and that cohesive failures occur when bond strength is high. Glasspoole et al. and Erhardt et al. proposed increasing bond strength by pre-conditioning tooth surfaces with acids. This surface treatment would create microporosity within the etched enamel surface, thereby increasing the available surface area for either chemical or micromechanical bonding. In this study, adhesive failure was the predominant failure mode in teeth which were not conditioned prior to fissure sealant application. On the other hand, cohesive failure was the predominant failure mode in teeth which were pre-conditioned. These failure mode results were attributed to the different bond strengths of different fissure sealants and the resultant changes in enamel surface.
achieved with prior PA conditioning.

Based on the findings of this investigation, we have rejected the null hypothesis that the SBs, marginal microleakage occurrence, and failure modes of SAR-based fissure sealant and CR-based fissure sealant with or without prior PA etching would not be significantly different. Specifically, we found that self-adhesive GI-based and CR-based fissure sealants were not as effective as conventional GI-based and CR-based fissure sealants which required acid pre-conditioning of the tooth to create strong bonds, which then effectively sealed the tooth defect. We also concluded that further technological advancements are required to improve the bond strength and sealing ability of SAR-based fissure sealants.

REFERENCES


