Occlusal caries formation in vitro: comparison of resin-modified glass ionomer with fluoride-releasing sealant

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The purpose of this laboratory study was to evaluate caries-like lesion formation in occlusal enamel adjacent to a light-cured resin-modified glass ionomer utilized as a pit and fissure sealant and a conventional light-cured, fluoride-releasing sealant. Fluoride-free prophylaxis was done on occlusal surfaces of 12 caries-free mandibular molar teeth that had not been exposed to the oral cavity. Occlusal surface morphology was examined by SEM on the uncoated specimens. Each tooth was then sectioned into 2 portions buccolingually, producing mesial and distal tooth halve. Occlusal surfaces of mesial tooth halves were prepared for an experimental light-cured resin-modified glass ionomer (RMG) sealant (PH-SE II, ESPE), and for comparison, a light-cured fluoride-releasing pit and fissure (PFS) sealant (Helioseal F, Ivoclar) was placed on occlusal surfaces of the corresponding distal tooth halves. The sealed occlusal surfaces were examined uncoated by SEM to compare RMG and PFS adaptation. After thermocycling in artificial saliva, caries-like lesions were formed in the occlusal surfaces adjacent to RMG and PFS. Longitudinal sections were taken for comparison of lesion formation adjacent to RMG and PFS. Mean lesion depths in occlusal surfaces were 64±17mm for RMG, and 116±27mm for PFS (p<0.05, paired t-test). Occlusal lesions terminated at the point where bonding occurred between the occlusal enamel and RMG or PFS. SEM surface topography demonstrated adequate adaptation of the materials with obliteration of the typical pit and fissure surface morphology by both RMG and PFS. While both the resin-modified glass ionomer and fluoride-releasing sealant materials protected the pit and fissure enamel from caries development, the resin-modified glass ionomer reduced the extent of caries involvement in the adjacent unsealed occlusal incline enamel, when compared with the resin sealant.

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INTRODUCTION

Pits and fissures in occlusal and smooth surfaces are responsible for the majority of caries in the pediatric and adolescent population in the United States.[1-5] Occlusal surface caries accounts for 56% of the total caries experience in children from ages 5 to 17 years. Almost one-third of the total caries experience occurs in buccal and lingual surfaces that contain pits and fissures. The remaining 12% of caries in the pediatric and adolescent age group occurred in proximal surfaces. Occlusal caries prevalence is similar in areas with optimal water fluoridation (1.7 DMFS) compared with non-fluoridated regions (1.9 DMFS). In addition, the annual caries attack rate for occlusal surfaces in 8 to 15 year-olds is considerably higher than that for interproximal surfaces, with 6% of occlusal surfaces developing caries each year versus only 1.3% of interproximal surfaces. This discrepancy in annual caries development results in 47% of occlusal surfaces becoming carious compared with only 10% of interproximal surfaces from age 8 to 15 years. Pit and fissure caries is not only a disease of children.[6-8] Prevalence of newly diagnosed occlusal caries has been shown to be

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12% in United States Coast Guard cadets ranging in age from 17 to 23 years of age. Even a higher occlusal caries prevalence (25%) has been noted in United States military recruits (mean age 21 years).

Over two decades ago, pit and fissure sealants based upon Bis-GMA resin formulation and mechanical retention afforded by the acid-etch technique were introduced and allowed for an effective and reliable method to prevent pit and fissure caries. Clinical sealant studies using a single application protocol have shown a relatively high retention rate over a 7 year period (66%) with a caries reduction effectiveness of 55% and a caries prevalence of only 22%.[9-11] These results are remarkable when one considers that only a single application of sealant to the occlusal surfaces occurred in these clinical studies. With reapplication of sealant material at recall examinations[12,13] when sealant material has been lost, it was found that approximately 8% of tooth surfaces per year require reapplication, and that no children developed caries in sealed surfaces over clinical study periods of up to 7 years. The development of resin-modified glass ionomer, as a potential pit and fissure sealant, may provide an additional method to eradicate pit and fissure caries due to fluoride release from the glass ionomer component and the bonding capability of both the resin and glass ionomer components.

The purpose of this laboratory study was to evaluate caries-like lesion formation in occlusal enamel adjacent to a light-cured resin-modified glass ionomer utilized as a pit and fissure sealant and a light-cured fluoride-releasing resin sealant, and to compare the surface morphology and the dental material-enamel interface between the resin-modified glass ionomer and resin sealant.

MATERIALS AND METHODS

A total of 12 caries-free mandibular molars were selected for this study and underwent soft tissue debridement and a fluoride-free prophylaxis. The occlusal surfaces were examined with a binocular microscope (16x) to determine that these surfaces were free of caries. The occlusal surfaces were examined uncoated by scanning electron microscopy (SEM) at 5kV to evaluate the surface morphology.

Following SEM examination, the teeth were sectioned into mesial and distal halves. The mesial tooth halves had an experimental light-cured resin-modified glass ionomer (PH-SE II, ESPE, Seefeld, Germany) placed on the occlusal surface without acid-etching, surface conditioning or use of a bonding agent according to the manufacturer's recommendation.

The corresponding distal tooth halves had a light-cured fluoride-releasing resin sealant (Helioseal-F, Ivoclar North America, Amherst, NY 14228) placed following acid-etching with phosphoric acid, air-water rinsing, and air-drying per the International Association for Dental Research sealant symposium recommendations.[14] The sealed occlusal surfaces were examined uncoated by SEM at 5 kV to evaluate the surface morphology and the interface between the dental materials and adjacent enamel.

Following SEM evaluation, an acid-resistant varnish was placed leaving a 1mm rim of exposed enamel surrounding the sealed occlusal surfaces. The tooth halves were then thermocycled (5°C to 55°C for 500 cycles with a dwell time of 30 seconds) in artificial saliva (20mM $NaHCO_3$, 3mM NaH_2PO_4, 1mM $CaCl_2$, pH 7.00). Following thermocycling, the tooth halves were evaluated for intact acid-resistant varnish, and varnish reapplication was performed when necessary. The specimens were then exposed to an acidified gelatin gel (dialyzed gel, pH 4.25, 1.0mM calcium, 0.6mM phosphate, <0.05mM fluoride) for 6 weeks in order to produce caries-like lesions in the occlusal enamel adjacent to the glass ionomer and fissure sealant materials.

Two longitudinal sections were taken from each tooth half in both groups, imbibed in water, examined by polarized light microscopy, and photomicrographs were taken. Mean lesion depths of the caries-like lesions were determined in a blinded fashion by projecting the photomicrographs onto a computer-interfaced digitized tablet, and measuring 10 points along the advancing front of the lesions.

Lesion depth measurements were compared between the resin-modified glass ionomer and resin sealant group, using a paired-t test with a significance level of $P<0.05$. A total of 48 caries risk sites per group were available for analysis.

RESULTS

While both the resin-modified glass ionomer and fluoride-releasing sealant materials protected the sealed enamel against a caries-like challenge, the resin-modified glass ionomer provided additional caries protection for the adjacent cuspal incline enamel that had not been sealed (Figures 1 and 2). Mean body of the lesion depth was reduced by approximately 45% ($p<0.05$, paired t-test) in the cuspal incline enamel adjacent to the resin-modified glass ionomer, when compared with that for the fluoride-releasing sealant (Table). While both groups possessed intact enamel surfaces overlying the caries-like lesions, certain qualitative differences in lesion appearance (Figures 1 and 2) were noted between the resin-modified glass ionomer and fluoride-releasing sealant groups.

Enamel lesions adjacent to the resin-modified glass ionomer (Figure 1) had negatively birefringent surface zones, indicating a pore volume of <5%; while the fluoride-releasing sealant (Figure 2) possessed lesions with positively birefringent surface zones, indicating a pore volume of >5%. The typical body of the lesion in the resin-modified glass ionomer group (Figure 1) had a decreased degree of positive birefringence qualitatively; while the typical body of the lesion for the fluoride-releasing sealant group (Figure 2) had a higher degree of positive birefringence (>5% pore volume) qualitatively.

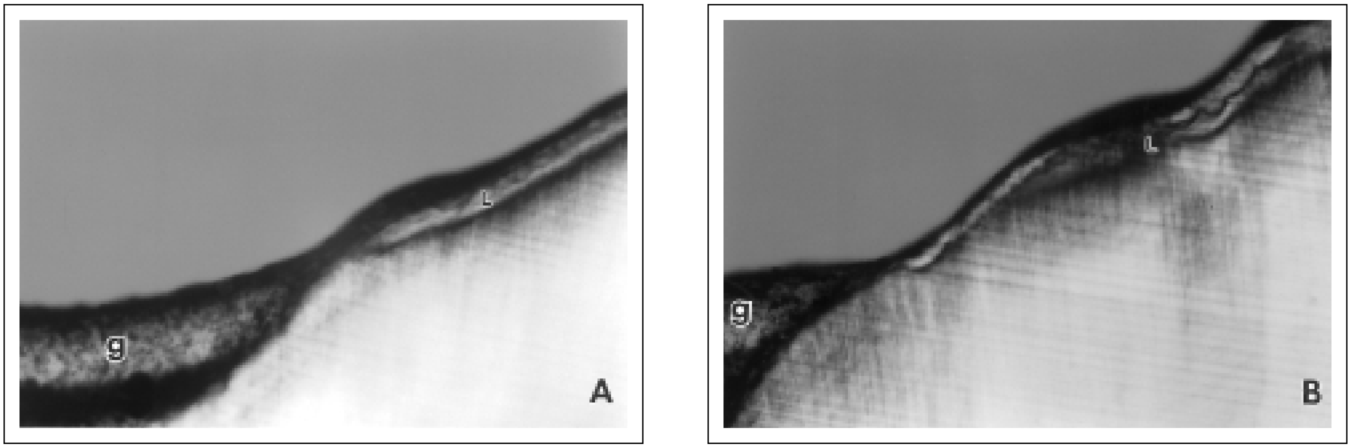

Figure 1. Caries-like lesion formation (L) in occlusal cuspal incline enamel adjacent to resin-modified glass ionomer (G) placed on occlusal surface. (Polarized Light, Water Imbibition, Original Magnification 200X).

These qualitative polarized light differences in lesion appearance imply a decrease in pore volume, and retention of more mineral within both the surface zone and body of the lesion for the resin-modified glass ionomer group when compared with the fluoride-releasing sealant group. The resin-modified glass ionomers and fluoride-releasing sealants were adapted well to the enamel forming the cuspal inclines and provided protection against a caries-like attack in the underlying sealed enamel. Even with thermocycling and examination of at least 48 enamel-dental material interfaces, caries was not identified in the sealed enamel along the enamel-dental material interface with either treatment group.

Caries-like lesions occurred only in the adjacent cuspal incline enamel, which had not been protected by either resin-modified glass ionomer or fluoride-releasing sealant. The caries-like enamel lesions terminated at the point where bonding between the glass ionomer or sealant material occurred with the cuspal incline enamel.

Prior to sealant placement, the occlusal surfaces possessed numerous primary and secondary fissures, as well as deep pits (Figure 3). The pits and fissures of the occlusal surfaces of tooth halves sealed with either resin-modified glass ionomer (Figure 4) or fluoride-releasing sealant (Figure 5) were effectively obliterated. There was a relatively smooth transition between the material and the adjacent cuspal incline enamel that had not been covered by either the resin-modified glass ionomer or fluoride-releasing sealant. Microspaces between the dental material and the cuspal enamel were not apparent. The cuspal inclines with the fluoride-releasing sealant possessed occasional exposed enamel prisms.

Table. Resin-Modified Glass Ionomer and Fluoride-Releasing Pit and Fissure Sealant: Effect on Caries-Like Lesion Formation.

	Lesion Depth* (mean+ sd)	Reduction In Lesion Depth
Glass Ionomer Cement (PH-SE II, ESPE) (caries risk sites = 48)	64 ± mm	44.8%*
Pit and Fissure Sealant (Helioseal-F, Ivoclar) (caries-risk sites = 48)	116 ± mm	

* Significantly different ($p<0.05$, paired t-test)

DISCUSSION

Surfaces with pits and fissures continue to provide a challenge to caries prevention and account for the majority of the caries experience in children and adolescents. Longitudinal school-based studies evaluating the effects of combining sealant and fluoride rinsing programs have demonstrated the synergistic effect of sealants and fluoride on reduction of pit and fissure caries.[15-17] In fact, occlusal caries has been reduced by 35 to 78% in schoolchildren in the United States and Guam by combining the benefits of conventional sealants and fluoride rinses.

With the introduction of glass ionomers, the ability to release fluoride to adjacent tooth structure and into the oral environment became possible. However, retention rates for glass ionomer sealants were quite low with complete loss occurring in about 50% during a 2 year period.[18-26] Even with the loss of the glass ionomer material from the occlusal surfaces, caries development was only 5% over a 2 year period. Despite the lack of clinical detection of glass ionomer material, replica studies have shown that the material was maintained within the depths of the pits and fissures in 93% of cases, thereby affording caries protection. During the last several years, it has been possible to combine the fluoride releasing ability of glass ionomer with the retentive capabilities of resin.

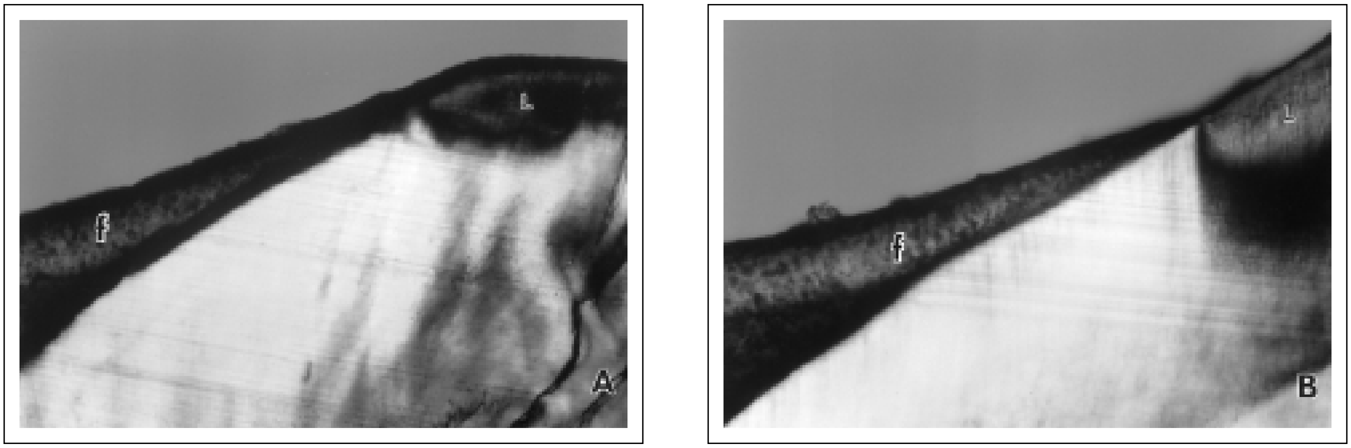

Figure 2. Caries-like lesion formation (L) in occlusal cuspal incline enamel adjacent to fluoride-releasing pit and fissure sealant (F) placed on occlusal surface. (Polarized Light, Water Imbibition, Original Magnification 200X).

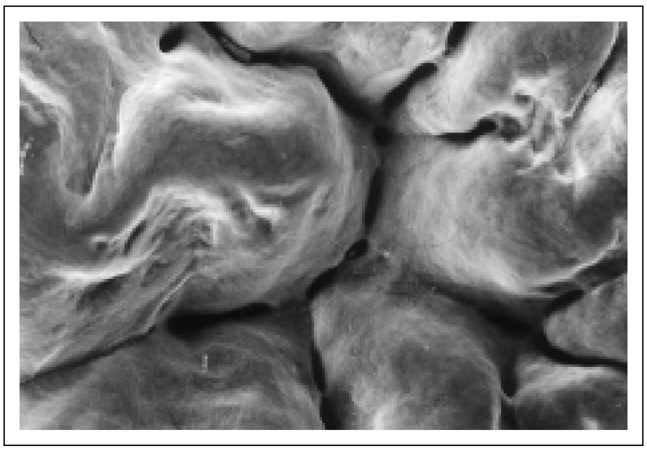

Figure 3. Pits and fissures in occlusal surface of molar tooth prior to sealant placement. (SEM, original magnification x 30).

Resin-modified glass ionomers have been introduced and several have been employed as pit and fissure sealants. Retention rates have increased considerably over conventional glass ionomers, with 100% complete or partial retention occurring over a 12 month period and a caries incidence of only 5%. With a clinical study using a reapplication protocol when material is lost, caries reduction compared with age matched controls is 67% over a 3 year period, with only 10% of glass ionomer sealants at 36 months requiring reapplication of material.[20] This reapplication rate at 36 months is similar to that reported for resin sealants (8%).

The adaptability of glass ionomer material in less than ideal conditions is exemplified by its employment in third world nations as a caries preventive agent, along with placement of glass ionomer atraumatic restorations.[27,28] In much less than optimal situations and placement by non-dental personnel, glass ionomer sealants have been shown to be retained in 73% of primary teeth and 78% of permanent teeth at 12 months, and in 58% of permanent teeth at 24 months. Although retention was lower than hoped, only 4% of teeth with glass ionomer sealants developed caries over a 2 year period.

As illustrated in the current *in vitro* caries study, resin-modified glass ionomer affects the caries susceptibility of the adjacent cuspal inclines by providing an intimate interface with the cuspal incline enamel, similar to that seen with the resin sealant, and acting as a reservoir for fluoride. There was a significant difference ($p<0.05$) between the fluoride-releasing sealant and the resin-modified glass ionomer material, with respect to lesion depth in the cuspal incline enamel. Fluoride release from both materials purportedly occurs over an extended time period; however, it is well recognized that the increased fluoride content of glass ionomer allows for a greater fluoride release.[29-35]

It is also possible to "recharge" fluoride releasing materials by exposure to fluoride agents, including fluoridated toothpastes, over the counter fluoride rinses, and topical fluoride agents.[29-35] This ability of resin-modified glass ionomers to absorb fluoride from an exogenous source (fluoridated toothpaste, fluoride rinse) allows for extended fluoride release following salivary clearance of the fluoride from the exogenous source. Not only could one expect an improved resistance of sound enamel adjacent to the resin-modified glass ionomer sealant, but white spot lesions and enamel hypoplasia in close proximity to this material may be afforded a certain degree of protection against lesion progression and could possibly undergo remineralization.

CONCLUSIONS

1. glass ionomer and fluoride-releasing resin sealant materials:
   A) Provided protection of sealed occlusal enamel from caries development using a caries-like lesion formation system;
   B) Demonstrated intimate adaptation to the occlusal surfaces and obliteration of the pit and fissure morphology as examined by SEM.

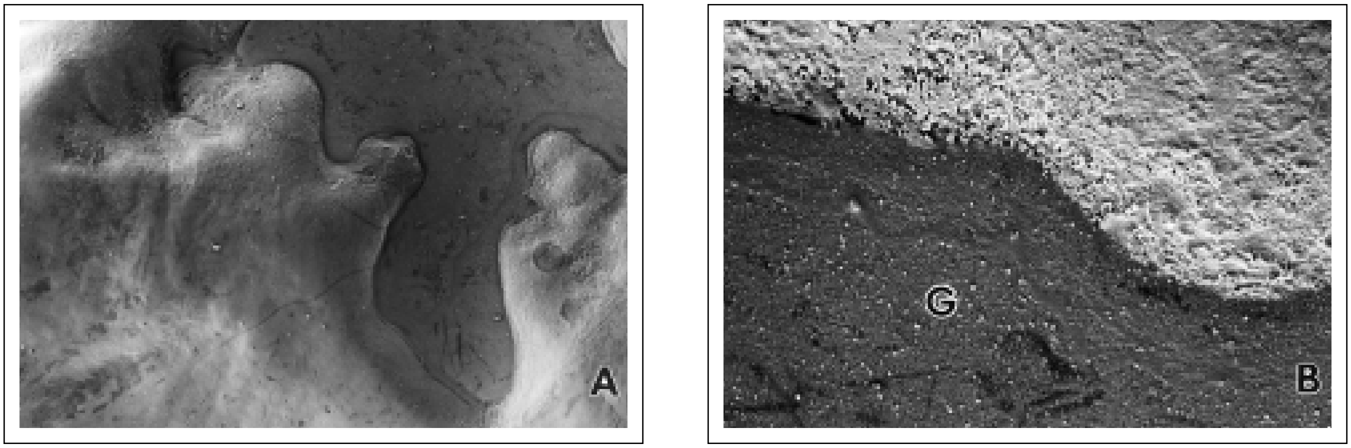

Figure 4. Surface morphology of occlusal surface following resin-modified glass ionomer (G) placement. (A, original magnification x 50; B, original magnification x 500; arrow=glass ionomer-enamel interface).

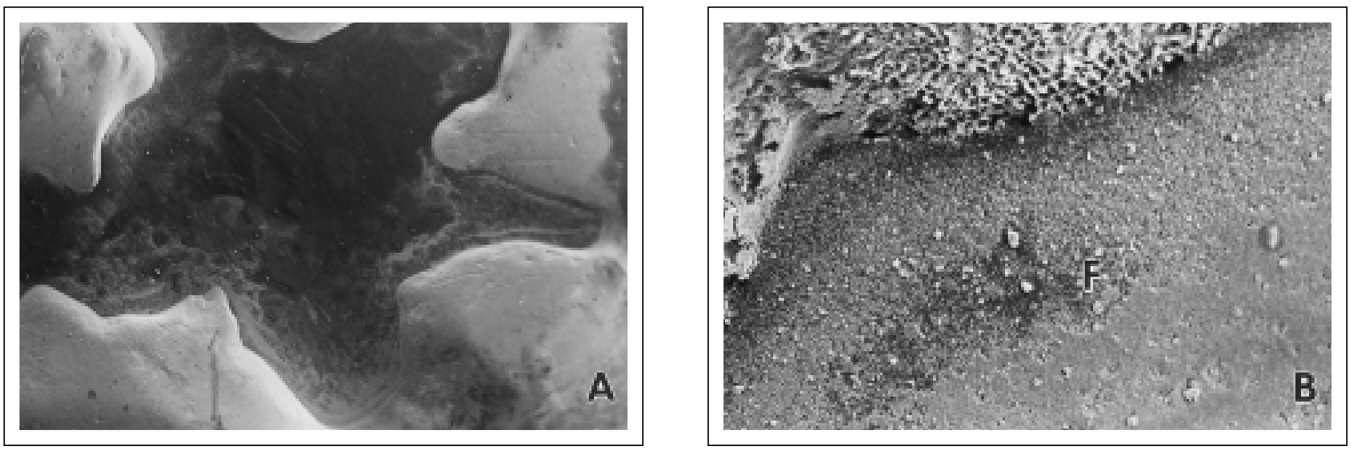

Figure 5. Surface morphology of occlusal surface following fluoride-releasing pit and fissure sealant (F) placement. (A, original magnification x 50; B, original magnification x 500; arrow=resin-enamel interface).

2. Resin-modified glass ionomer reduced the extent of caries involvement in adjacent unsealed occlusal incline enamel when compared with fluoride-releasing sealant ($P<0.05$, paired t-test).

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