An evaluation of sealant restorations after 2 years

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Aim To obtain evidence of the efficacy of sealant restoration used in the management of fissure caries.
Design A controlled study in a UK dental hospital environment.
Methods Suspect fissure lesions were investigated in 164 young adult patients attending for routine dental care. Only one test tooth per subject was included in the study. Patients were recalled after 6, 12 and 24 months at which time the fissure sealant retention and the performance of the restorative materials were noted.
Results Successful recall was achieved with 91.5% of patients. Most teeth treated (92%) involved the preparation of an investigative cavity. The mean age of patients treated was 23.9 years and second permanent molar teeth were the most commonly affected teeth requiring treatment in this age group. The presence of small composite restorations did not adversely affect fissure sealant retention but after 2 years, significantly more sealant was lost from the surface of light cured glass-ionomer cement and larger composite restorations.
Conclusions Sealant restorations provide an effective method of management of fissure caries in young adult patients.

The prevalence of caries in children has fallen throughout the developed countries of Europe[1] and in the USA.[2] The data on caries shows that the relative proportion of pit and fissure lesions has increased to 84% of the total new caries experience.[3] In the late 1980s new recruits to the Australian Armed Forces showed a high incidence of occlusal caries despite being in their late teens and early twenties.[4] Untreated caries accounts for almost a third of the treatment need of young people in this age group — with the majority of these lesion in pits and fissures.[4]

A number of letters from dental practitioners to professional journals report concern over the difficulty of making an accurate diagnosis of active fissure caries.[5–9] Older practitioners may remember being taught to use a probe as a diagnostic aid to determine whether a pit or fissure was 'sticky'. It has been shown, however, that such a procedure not only damages the surface enamel of the fissure walls and prevents remineralisation occurring[10] but also results in a greater rate of caries progression.[11]

A number of papers and recent editions of standard texts have discussed the problem of accurate diagnosis of fissure caries. Most advocate the use of careful inspection of the cleaned and dried fissures using magnification, in combination with the examination of bitewing radiographs.[12] Future developments may include the routine use of electronic instruments designed to measure changes in the electrical conductivity or resistance of enamel produced by the early lesion.[13] The term 'occult caries' has been suggested to describe the phenomenon of a clinically undetectable enamel lesion overlying extensive caries in dentine. These lesions may be demonstrated by a bitewing radiograph only when at a very advanced stage.[12]

Until the introduction of the Preventive Resin Restoration (first described by Simonsen and Stallard in 1977),[14] the options for the management of a suspect pit or fissure lesion were limited to the application of fluoride containing varnishes or a fissure sealant. Alternatively, an amalgam restoration could be placed. When placing a fissure sealant over a suspect fissure many dentists are concerned that an inadequate seal may be obtained and fear that any underlying active lesions may progress undetected. For an occlusal amalgam to be placed, a cavity is normally prepared into dentine and extended to eliminate a considerable part of the fissure pattern. This is a destructive procedure usually necessitating the removal of considerable amounts of sound enamel. There are now ample data to show that once placed amalgam restorations require periodic maintenance or replacement every 5 to 10 years.[15]

In the preventive resin technique, the suspect lesion is investigated with a very small bur (ISO 008) and cavity preparation is limited to caries removal. The cavity is restored with composite resin (or composite diluted with unfilled Bowen's resin) and the remaining fissure pattern sealed in the usual way using a pit and fissure sealant. Sometimes this is referred to as 'the enamel biopsy technique'.[12] This concept has been expanded by the rapid progress that has taken place in the development of composite resins, bonding agents and glass-ionomer cements. These have resulted in a series of restorative techniques suitable for the management and minimal restoration of fissure caries — these have been termed 'sealant restorations'.

These restorations are available throughout the UK under the NHS General Dental Regulations under item 14 E. Cavity preparation is limited to the removal of caries and its subsequent restoration with glass-ionomer cement, composite resin or a combination of the two materials. In place of the traditional extension for prevention, fissure sealants are applied to retain as much sound tooth structure as possible thus preventing unnecessary weakening of the tooth. The advantage of this technique lies in the fact that it is more conservative of tooth structure and less patient discomfort is experienced. In addition, sealant restorations provide an aesthetic alternative to an amalgam filling.

A number of authors have described different combinations of materials for the varying sizes of carious lesion that may be found at the time of enamel biopsy. Paterson *et al.* have summarised these recommendations.[12] This summary is found in Table 1.

The testing of new techniques and materials for clinical use usually comprises three stages:

1 Laboratory investigations of the physical characteristics of new materials
2 Carefully controlled clinical trials with rigidly defined protocols
3 Field trials where the techniques and materials are tested under normal practice conditions.

While there is extensive literature on the laboratory testing of fissure sealants, glass ionomer cements and composite resins, there is

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Table 1 Summary of the indications for use of each of the four types of sealant restoration

Type of sealant restoration	Indications
Type 1 Fissure sealant alone	Stained and decalcified fissure. No radiographic sign of dentine involvement. Less than two other carious lesions in mouth.
Type 2 Composite plus sealant	Stained and decalcified fissure. More than two other carious lesions in mouth. Enamel biopsy shows lesion confined to enamel.
Type 3 Glass-ionomer cement plus sealant	Enamel biopsy indicated. Cavity in dentine with minimal lateral spread. Margins not in occlusal contact.
Type 4 Laminate restoration	Enamel biopsy indicated. Lesion in dentine with lateral spread along EDJ. Cavity margins in occlusal contact.
Amalgam restoration	Enamel biopsy indicated. Large radiolucency in dentine. Significant lateral spread along EDJ. Few fissures remaining surrounding cavity.

little evidence of any clinical evaluation of the sealant restoration technique beyond Simonsen's original reports on the use of composite resin combined with fissure sealant.[14]

The current report describes a hospital-based clinical trial designed to test the ultimate performance of sealant restorations placed under ideal conditions. This trial sought to validate the following hypotheses:

- That fissure sealant will be adequately retained when placed over early non-cavitated fissure lesions and prevent further progress of those lesions.
- That small composite restorations are retained adequately through acid etching of the enamel alone in the non undercut occlusal cavities prepared during the enamel biopsy technique.
- That unlined glass ionomer cement restorations are clinically satisfactory materials for the restorations of small occlusal cavities in adults, providing their margins are out of occlusion.
- That the 'laminate' or 'sandwich' restoration, consisting of a structural base of glass ionomer cement and a posterior composite filling, is as durable as silver amalgam for the restoration of larger fissure cavities.
- That fissure sealant will adhere to restorations of glass ionomer cement and composite resin placed in occlusal cavities.

Materials and methods

Patients attending for routine care at Glasgow Dental Hospital and School were assessed for inclusion in the clinical trial. They were selected for treatment on the basis of a clinically diagnosed or suspected fissure caries lesion without obvious or extensive cavitation of enamel. The selection process specifically excluded patients with existing occlusal restorations or radiographically diagnosed interproximal caries lesions. Diagnoses were made on cleaned and dried teeth viewed, without magnification, under good illumination and using a visual technique only: a probe was not used. Bitewing radiographs were taken where clinically necessary and were obtained using a long cone apparatus with Rinn film holders. The radiographs were dried, mounted and viewed at the chairside using diffuse background illumination. Approval for this trial was obtained from Greater Glasgow Health Board. The advantages and disadvantages of the sealant restoration technique over an amalgam restoration were discussed with each patient before treatment commenced and their informed consent sought. Any patient expressing disquiet with the proposed treatment was excluded from participating in the trial.

Use of investigative cavity or enamel biopsy technique

At the time of diagnosis it was decided if an investigative cavity or enamel biopsy was warranted. An assessment of the caries risk was also reached by charting the number of other active caries lesions and the number of filled surfaces in the dentition. The result of this determined the type of restoration to be placed.

Type 1 Sealant restorations (fissure sealant only)

Where there was staining and decalcification in the fissure pattern but no clinical evidence of cavitation of enamel or of dentine caries on the bitewing radiograph, an investigative cavity was not prepared. Before this treatment option was selected, a careful inspection of the remaining dentition was necessary to assess the patient's caries risk. Where fewer than two other caries lesions was recorded, the patient was catagorised as low risk and suitable for the application of fissure sealant alone.

Types 2, 3 and 4 sealant restorations (combinations of glass-ionomer cement and composite resin with fissure sealant)

In any situation where there was suspicion of early cavitation in addition to staining and decalcification or where there was caries visible in dentine on the radiograph, an investigative cavity or enamel biopsy was performed. In addition, any stained and decalcified fissure was investigated where the patient was deemed to be in a higher caries risk group by having more than two other caries lesions in their remaining dentition. The type of restoration used depended on the size of the cavity:

Type 2 restoration: where the lesion did not extend into dentine, the enamel cavity was restored with composite and fissure sealant applied over the restoration and to the remaining fissure pattern.

Type 3 restoration: where the cavity had reached dentine but the lateral spread was limited and the cavity margins were not in occlusal contact, glass-ionomer cement was placed in the cavity and fissure sealant applied over the restoration and into the adjacent fissure pattern.

Type 4 restorations: where the lesion had reached dentine and spread laterally bringing the cavity margins into occlusion, a glass-ionomer cement base was placed before restoring the cavity with composite resin and applying fissure sealant. This is sometimes known as the 'laminate' or 'sandwich' restoration.

Following the preparation of the enamel biopsy, any extensive cavity with few or no remaining fissures was deemed unsuitable for restoration using the sealant restoration technique. Such patients were excluded from the trial.

The individual brands of material used were randomly selected for each restoration. Between January 1990 and April 1993, 164 sealant restorations were placed by the author ensuring that only one restoration was provided for each patient.

The following protocol was used:

Preparation of the tooth for examination

The tooth was cleaned using a slurry of pumice and water on a small bristle brush operating at slow speed (less than 500 rpm). The tooth surface was then washed for 30 seconds with an atomised water-spray and dried for 30 seconds with warm dry air. The fissures were then carefully inspected under good conditions of illumination. Magnification was not used during the examination process.

Investigative cavity (enamel biopsy) technique

Where the operator was suspicious of the presence of active caries in dentine an investigative cavity was prepared. An 008 diamond coated tapered fissure bur was used operating at speeds up to 120,000 rpm with a light stroking action limited to the suspect area of the pit or fissure. This allowed the elimination of decalcified enamel. Where larger lesions were present, it provided access for the removal of carious dentine. This was achieved using a steel latchgrip round bur (size 012 to 016) operating at conventional speed. No extension beyond that required for caries removal was performed. Local analgesia was administered only where required. After cavity preparation, the type of sealant restoration and the restorative materials were selected according to the size of the cavity and the position of the occlusal stops relative to the cavity margins.

Isolation of cavities
All restorations were then placed under rubber dam isolation with a waxed floss ligature around the tooth to be restored. This inverted the punched edge of the rubber dam and improved the seal around the tooth.

Selection and use of materials
The material combinations used in each type of sealant restoration are shown in Table 2. Three different fissure sealants, three different glass-ionomer cements and four hybrid composite resins were used. Immediately before each restoration was placed, the materials were chosen by selecting at random from a range of printed cards.

The materials were prepared and used according to the manufacturers' instruction sheets. The main variables under the operator's control were:

Etching technique before the fissure sealant application: a 37% buffered phosphoric acid gel was applied for 20 seconds followed by 30 second washing and a 30 second drying regime before the application of sealant.

Fissure sealant application technique: a drop of the sealant was passively dispensed into a Dappen's dish to eliminate air inclusions. Sealant was transferred to the fissures on the tip of a smooth Ward's amalgam carver (Ash Instruments, Dentsply UK Ltd). This instrument was then dragged along the fissures to apply the resin into the fissures and onto the adjacent cusp slopes without inclusion of air voids. The buccal and palatal fissures of mandibular and maxillary molar teeth were included in the fissure sealing process. Each tooth surface with fissure sealant was separately polymerised by exposing it, for 60 seconds, to a visible blue light source with a wavelength of 470 nm.

Treatment of glass-ionomer cement surfaces: Before applying sealant to the cement surface of Type 3 restorations and before the insertion of composite resin over a base of glass-ionomer cement, an enamel and dentine bonding agent (Scotchbond Dual Cure, 3M, St. Paul, USA) was applied to the surface of the recently set cement using an endodontic paper point. In this way, etching of the cement surfaces was avoided as this has been shown to be destructive.[16]

Use of bonding agents: the etched enamel walls of Types 2 and 4 cavities were coated in the appropriate bonding resin depending on the composite resin to be used for the restoration of the cavity. This was applied carefully using an endodontic paper point and then polymerised by exposure to visible blue light for 20 seconds.

Follow-up examinations
The restorations were examined separately by two assessors (the author and one external assessor — Professor R C Paterson) who conferred after seeing each patient. In the rare event of a disagreement, the patient was re-examined before agreeing the final ratings. A record was kept of the small number of changes in each examiner's decisions.

In the examination of the Types 2, 3 and 4 restorations (that is where a cavity had been restored in addition to the placement of fissure sealant) the condition and presence of the restoration was recorded separately from that of the fissure sealant using criteria and codes modified from those used by the United States Public Health Services (USPHS).[17] The re-application of the appropriate fissure sealant was only performed where the patient was placed in an 'at risk' group by the number of caries lesions present or where signs of decalcification of the exposed fissure were noted.

The fissure sealant and restorations were examined and the following data were recorded after the initial examination at 6 months and also after 1 and 2 years:

Table 2 Material combinations used in the restoration of the 150 teeth restored using the sealant restoration technique

	Concise#	Estiseal‡	Fluoroshield•
Type 1 (n = 12) No investigative cavity — fissure sealant alone	2	3	7
Type 2 (n = 15) (Comp + FS)			
Fulfill*		5	
P 50#	4		
Prisma APH*			5
Degufill H+		1	
Type 3 (n = 26) (GI + FS)			
Baseline VLC*		4	
Ketacbond capsules†	9	5	5
Baseline capsules*		3	
Type 4 (n = 97) (Laminate restoration with Ketacbond base)			
Fulfill*		39	
P 50#	15		
Prisma APH*			31
Degufill H+		12	
	n = 30	*n* = 72	*n* = 48

List of manufacturers: all composite resins used were hybrid materials
*De Trey/Dentsply — Dentsply GmbH, Germany
#3M Company — St Pauls, USA
+Degussa, Germany
†Espe — Fabrik Pharazeutischer Preparate GmbH, Seefeld, Germany
‡Kulzer, Heraeus Kulzer GmbH, Wehrheim, Germany
•Caulk — Dentsply International Inc, York, USA

Sealant
1. Retention.
   - Fissure sealant completely retained
   - Fissure sealant entirely missing
   - Fissure sealant partially retained
2. Missing zone
   - Over restoration
   - Occlusal fissure pattern
   - Buccal fissure
   - Palatal fissure

Restoration
1. Presence/absence
   - Present and covered with sealant
   - Present but with no sealant covering
   - Restoration absent
2. Marginal integrity (assessed if sealant missing)
   - Probe catches but no visible crevice
   - Visible crevice but no dentine visible at base
   - Dentine exposed but restoration not mobile/fractured/missing
   - Dentine exposed at base: restoration missing/fractured/mobile.

The presence of caries was noted and the need for additions of fissure sealant or further enamel biopsy was considered where exposed fissures showed signs of decalcification. Additions of fissure sealant were considered necessary where the exposed fissure was demineralised or there were more than two other caries lesions elsewhere in the dentition: the latter was considered to imply a high caries risk.

The anticipated presence of small numbers of teeth with partially or completely missing fissure sealant meant that statistical analysis was best undertaken using the Poisson Probability Distribution. Significance was assessed when $P < 0.05$ or $P > 0.95$ of the cumulative Poisson probability.

Results

In total, 164 sealant restorations were placed with only one test tooth per subject. Fourteen patients were lost to recall before the first review at 6 months. All of these patients informed the departmental secretary at the Dental Hospital that they had moved away from the Glasgow area. A successful recall rate of 91.5% was achieved at the end of the 2-year clinical trial period.

The mean age of the patients treated was 23.9 years and 64% of the patients were male. Almost half of the restorations (49%) were placed in second permanent molar teeth. The first molar tooth was the next most commonly restored tooth having received 43% of the total restorations placed.

An investigative cavity or enamel biopsy was prepared in 92% of the treated teeth (138 patients). Caries was found to be limited to the enamel in only 15 cavities (10.9%). In the remainder of the teeth a dentine lesion was present.

Table 3 Fissure sealant retention at the recall appointments after 6, 12 and 24 months

6 months	*Type 1*	*Type 2*	*Type 3*	*Type 4*
Completely present	12 (100%)	15 (100%)	25 (96%)	92 (97%)
Partly missing	0	0	1 (4%)	3 (3%)
Completely missing	0	0	0	0
Recall rate	100%	100%	100%	98%
12 months	*Type 1*	*Type 2*	*Type 3*	*Type 4*
Completely present	12 (100%)	15 (100%)	20 (77%)	72 (76%)
Partly missing	0	0	6 (23%)	23 (24%)
Completely missing	0	0	0	0
Recall rate	100%	100%	100%	98%
24 months	*Type 1*	*Type 2*	*Type 3*	*Type 4*
Completely present	11 (92%)	15 (100%)	18 (69%)	62 (67%)
Partly missing	1 (8%)	0	8 (31%)	31 (33%)
Completely missing	0	0	0	0
Recall rate	100%	100%	100%	96%

Statistical comparisons
Differences in sealant retention at the three reviews.
Type 4: 6mo v 12mo $P = 0.02$
12mo v 24 mo $P < 0.001$

Sealant retention

Sealant retention after 6, 12 and 24 months is shown in Table 3. Fissure sealant loss over the three time intervals was not significant for the Types 1, 2 and 3 restorations ($P > 0.05$). Type 4 sealant restorations showed a significant loss of sealant with time ($P < 0.02$). After 12 and 24 months, the fissure sealant was well retained over the smaller composite fillings used in the Type 2 restorations. Type 2 restorations showed significantly less missing fissure sealant after 12 and 24 months than the other sealant restoration types with larger fillings ($P < 0.03$).

In Table 4, the areas of fissure sealant loss are shown by restoration type. Significantly greater amounts of fissure sealant loss was observed from the surface of the light cured glass-ionomer cement restorations than for the adjacent occlusal pits and fissures ($P < 0.02$). In the larger Type 4 sealant restorations, loss of sealant from the surface of the composite filling material was significantly greater than the loss observed from the surface of the small composite fillings placed in the Type 2 sealant restorations ($P < 0.001$).

Performance of the glass-ionomer cement and composite restorations underlying the fissure sealant

Where fissure sealant had been lost the performance of the composite or glass-ionomer was assessed. Table 3 indicates that most of the fissure sealant loss occurred between the first review after 6 months and the second performed after 12 months. Loss of the overlying sealant then exposed the restorative materials to the oral environment but it was not thought necessary to replace it at this time. The composite fillings placed as part of Type 2 or Type 4 sealant restorations performed well with no deterioration in the clinical parameters recorded. The glass-ionomer fillings showed signs of deterioration 2 years post-placement. Crevice formation occurred in three restorations (11.5%) and surface wear was noted in a further four restored teeth (15.4%) belonging to the light-cured glass-ionomer cement group.

Overall performance of the restorations

After 12 months it was noted that two of the three laminate restorations, where sealant loss had been observed at the recall 6 months earlier, required the addition of further sealant to exposed fissures. It was considered that one of the patients was at risk because of a higher than average caries incidence, while in the other patient, loss of sealant after 1 year had exposed a fissure that now showed signs of decalcification. No composite or glass-ionomer fillings were lost and, with the exception of the light cured glass-ionomer cement restorations, no significant differences in the marginal discoloration or integrity of the individual restorative materials could be found.

Discussion

Sealant restorations have been available under the National Health Service Regulations since 1987. Within a short time of the introduction of the sealant restoration technique to the General Dental Services, 81% of a sample group of Scottish dentists were actively using the technique.[18] No published data are available on their performance when used under these conditions. The renewed controversy over the use of amalgam restorations has focused media attention on alternative restorative materials.

The present author has conducted a series of laboratory investigations, a large field trial and the present clinical evaluation in order to assess the effectiveness of sealant restorations in the management of fissure caries in children and young adults in dental practice.[19,20]

In this clinical evaluation, the age group of the patients (23.9 years) was higher than that commonly reported in the extensive literature on fissure sealants and the more limited reports on the preventive resin and sealant restoration technique. The majority of restored teeth were second molars with almost twice as many lower teeth being treated. The bulk of the restorations were the larger 'sandwich' glass ionomer/composite type. Very small numbers of premolar teeth had developed pit or fissure caries.

Design of the study

The combination of the 'enamel biopsy' or investigative cavity and the use of various combinations of composite resin, glass ionomer cements and fissure sealants provide a wide range of options suitable for the management of pit and fissure lesions. Fissure lesions may range from very early enamel cavities through to more advanced dentinal caries. The current study was designed to evaluate the results of these techniques when applied under the optimal conditions of a hospital practice, where time and materials costs were not a factor in deciding a management option.

A classically designed clinical trial usually involves the use of patients with paired contra-lateral teeth with identically sized lesions. An experimental material is place in the tooth on one side while a control material is used on the other. In a 'double blind trial' the operators, and those evaluating the restorations, do not know which is the new and which is the old material. This design could not be applied to the management of fissure caries because the whole point of the enamel biopsy technique is that it seeks to resolve

Table 4 Areas of fissure sealant loss after 2 years from the various tooth and restoration surfaces

Type 1						
	Occlusal	*Buccal*	*Palatal*			
Retained	12 (100%)	8 (100%)	1 (50%)			
Lost	0	0	1 (50%)			
Type 2						
	Restoration	*Occlusal*	*Buccal*	*Palatal*		
Retained	15 (100%)	15 (100%)	2 (100%)	13 (100%)		
Lost	0	0	0	0		
Type 3						
		Restoration		*Occlusal*	*Buccal*	*Palatal*
	Light cured	*Encapsulated*	*Total*			
Retained	8 (61%)	11 (85%)	19 (73%)	26 (100%)	14 (93%)	7 (100%)
Lost	5 (39%)	2 (15%)	7 (27%)	0	1 (7%)	0
Type 4						
	Restoration	*Occlusal*	*Buccal*	*Palatal*		
Retained	65 (70%)	91 (98%)	58 (98%)	31 (100%)		
Lost	28 (30%)	2 (2%)	1 (2%)	0		

Statistical comparisons
Significant difference in retention of fissure sealant to the surface of the light cured glass ionomer cement surfaces compared with adjacent occlusal fissures ($P < 0.02$).
Significantly greater loss of fissure sealant from the surface of the composite resin restorations in the type 4 restorations than from adjacent occlusal surfaces ($P < 0.001$).

the increasing difficulty that has been reported in determining the presence and extent of fissure caries.

The materials chosen were representative of the main types of composite resins, glass ionomer (polyalkenoate) cements and fissure sealants in use at the time of the study. Material combinations for the individual restorations were selected on an entirely random basis during the trial. The materials chosen included a fissure sealant and a hybrid composite (Concise and P50, 3M, St. Paul, USA) from the same manufacturer. Walls *et al.* considered this important in allowing a simultaneous cure of the materials.[21]

Three glass ionomer (polyalkenoate) cements were chosen: two encapsulated materials and a light cured cement. Encapsulated cements were selected for their ease of handling. The light cured material has shown improvement in shear bond strength with fissure sealants compared with conventional materials.[19] Since the introduction of both compomer filling materials and the total etch technique, the selection of either a compomer or a composite resin may now provide a further alternative for Type 3 sealant restorations.

Filled fissure sealants were selected because they have been shown *in vitro* to exhibit superior wear and abrasion resistance while still showing similar retention to etched enamel surfaces.[22] Some operators (and the General Dental Service regulations) favour the use of opaque fissure sealants because of the ease with which they may be checked at periodic recall.[23]

Use of visual inspection and bitewing radiographs and the enamel biopsy technique: management of enamel lesions

It could be argued that in the small intra-enamel Type 2 sealant restorations, the lesion could be managed by the application of a fissure sealant alone as the caries had not progressed into dentine.[24] The rationale for this treatment is the reduction on the viable bacterial count observed after dentine caries is sealed using fissure sealants and the change in the texture of the re-investigated lesions.[24,25] There is a lack of enthusiasm, however, among many dentists for the concept of sealing fissures where there is a suspicion of active caries.[18] In the treated teeth it is important to note that only carious enamel was removed during the biopsy procedure. This means that no unnecessary weakening of the residual tooth substance had resulted.

Use of fissure sealant alone over stained and decalcified pits and fissures (Type 1 sealant restorations)

Twelve suspect fissures were treated by the application of fissure sealant alone without the preparation of an investigative cavity (Table 2). Complete retention of sealant was noted after 2 years in all occlusal and buccal surfaces treated. The only sealant loss observed was from one palatal fissure. This occurred between 12 and 24 month after placement. The loss of this area of fissure sealant was unlikely to be due to technique errors that manifested after such a prolonged time. It is more likely to be related to this cusp being in functional occlusion and subject to stress.

Performance of the Types 2, 3 and 4 sealant restorations

All of the restorations were present after 2 years. The only problem noted with any of the sealant restorations was partial loss of the fissure sealant overlying the filling material.

The tripodal nature of occlusal contact of premolar/molar cusps meant that the smaller type 2 and 3 restorations were out of direct occlusal contact. Therefore, it was not surprising that etching of the enamel alone provided adequate retention for the composite resins and that the combination of undercut and adhesion was satisfactory for the small glass-ionomer restorations. Where fissure sealant had been lost from the surface of the light cured glass-ionomer cement restorations, crevice formation and surface wear was noted in 15% of the teeth. This was associated with marginal discoloration in these restorations. This type of light cured glass-ionomer cement is no longer available and could not have been recommended for this type of restoration.

The results with the larger laminate restorations were comparable to those reported by Walls *et al.*[21] and Welbury *et al.*[26]

Retention of fissure sealant over occlusal composite and glass-ionomer restorations

General comments on sealant loss. Loss of fissure sealant has been reported from other studies of similar or longer duration.[21,26–31] Partial loss of fissure sealant is a common finding but different criteria have been used to measure success of sealant restorations. In some studies this was defined as complete retention of fissure sealant while in others it was considered to be the prevention of further caries in the treated tooth.

The problems of comparing data from the various studies are further compounded by the practice of replacing missing areas of fissure sealant during the trial period: 28% of the sealant restorations reviewed by Walls *et al.* required additions of sealant at the 6-monthly reviews during the clinical trial[21] — 25% of those needed further additions during the follow up period.[26]

The necessity for replacing missing areas of fissure sealant is a difficult clinical judgement to make. In the current study this decision was based on the perceived risk of further caries developing with the fissure sealant only partially intact. Further additions of sealant were deemed necessary only if the missing zone had exposed fissures that showed signs of staining and decalcification or if the patient was considered to be in a high caries risk group.

It was interesting to note the timing of the loss of sealant from the treated teeth. The data in Table 3 suggest that the greatest loss occurred between the 6 and 12-month examinations. This would support the need for 6-monthly checks on sealant restorations. Whether the replacement of small areas of missing sealant is strictly necessary will depend on an assessment of the caries risk of individual patients.

Fissure sealants in combination with composites

It was considered possible that the presence of an occlusal restoration might have reduced the retention of fissure sealant. In the current study, small composite fillings placed as part of a sealant restoration did not affect the overall retention of the pit and fissure sealant over the 2-year observation period. A similar observation was made by Radaal who noted higher rates of sealant retention in sealant restorations.[31]

The small number of cases where loss of fissure sealant from the surface of composite had occurred was predominantly in the larger laminate restorations. On close examination of these restorations, the fissure sealant had been lost from the filling surface, leaving a ledge of sealant around the periphery of the cavity where it had adhered to the etched enamel surface. This appearance suggests that an adhesive failure had occurred between the restorative material and the overlying fissure sealant. The presence of resin at the margin of the filling is desirable to reduce the amount of microleakage. No differences were observed in the rate of sealant loss from the various combinations of fissure sealant and composite resin.

Fissure sealants in combination with glass ionomer cements

The loss of sealant from the surface of glass-ionomer (polyalkenoate) cement fillings was greater than that observed with the similarly sized small composite/fissure sealant restorations. Fissure sealant loss from the surface of the encapsulated glass-ionomer fillings was not dissimilar to that observed with the small composite restorations but was significantly poorer than that obtained when a visible light cured glass-ionomer cement was used. *In vitro* testing of the shear bond strength of these materials to fissure sealant has shown similar values to those obtained with composite resin.[32] Plastic deformation of light cured glass-ionomer cements has been reported after storing in water.[33] It appeared that the failure was not of adhesion. The surface of the glass-ionomer cement was not etched in an attempt to improve the retention of sealant. Taggart and Pearson showed a deterioration in the mechanical properties of the cement following an etch regimen.[16] In the current study, a bonding resin of phosphorylated ester of bisGMA was applied to the surface to improve the bond of the sealant to the underlying cement.[19]

The data from a field trial in which glass-ionomer cement and fissure sealant restorations were placed by a group of clinical dental officers in the Community Dental Services has been reported previously.[20] The restorations were scored by the same two assessors (GBG and RCP). Complete fissure sealant retention of only 13.1% was recorded after 1 year. This was attributed to the fact that a rigid protocol (including the use of rubber dam) was not followed.

Effect of sealant loss on underlying restorations

Where the fissure sealant covering had been lost, no deterioration in the marginal integrity of the composite or glass-ionomer materials was noted. Walls *et al.* reported the incidence of wear on composite/fissure sealant restorations to be low.[21] They observed loss of anatomical contour only in restorations that occupied the greatest surface area. In their study, a small particle size composite resin was used that was intended for the restoration of anterior teeth. In the current study, hybrid materials suitable for the restoration of posterior teeth were used. Clinically detected wear was not observed in this trial 2 years after placement of the restorations. This would accord with the findings of a study of occlusal and class II urethane dimethacrylate composite resins placed in a hospital clinical trial.[34]

Further additions of sealant will allow the continued protection of the remaining tooth structure. If an approximal caries lesion develops, it should be possible to restore it — using a small box preparation — with little involvement of the occlusal surface.

Conclusions

In considering the initial hypotheses set out in the introduction:

- Fissure sealant was adequately retained when placed over the small number of early non-cavitated fissure lesions
- Small composite restorations were retained adequately through acid etching of the enamel alone in the non-undercut occlusal cavities prepared during the enamel biopsy technique
- Unlined glass-ionomer cement restorations are clinically satisfactory materials for the restoration of small occlusal cavities in young adults, providing their margins are out of occlusion
- The 'laminate' or 'sandwich' restoration, consisting of a structural base of glass-ionomer cement and a posterior composite filling is a durable restorative method for the management of fissure caries, and
- Fissure sealant partially adhered to restorations of glass-ionomer cement and composite resin placed in occlusal cavities — further studies are necessary to improve such adhesion.

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