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# A Laboratory Evaluation of a New Pit and Fissure Sealant

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## SUMMARY

*A variety of pit and fissure sealants are used clinically to protect the occlusal surfaces of teeth against dental caries. A new chemically activated bis-GMA type sealant, Delton Pit and Fissure Sealant, has recently become commercially available. The Delton Etching Solution supplied with the sealant contains 35 per cent orthophosphoric acid. The tensile bond strength of this sealant to etched enamel surfaces was determined by means of two techniques. Tensile bond strengths of 9,2 ± 2,1 MPa and 7,6 ± 1,2 MPa were obtained respectively. All the test specimens failed within the sealant and not at the interface. The effects of the Delton Etching Solution on distolingual grooves and lingual surfaces of maxillary molars and mesiobuccal grooves and buccal surfaces of mandibular molars were studied by scanning electron microscopy. Adequate resin penetration into the etched enamel was observed immediately adjacent to these grooves. Sealed teeth were subjected to 8,500 cyclic temperature changes with a temperature differential of 43°C, and the marginal leakage subsequently evaluated by means of a fluorescent dye technique. Marginal leakage was not observed at the sealant-etched enamel interfaces. These results suggest that Delton Pit and Fissure Sealant has the potential to perform well in clinical application.*

## OPSOMMING

*Verskeie put- en fissuurseëlmiddels word tans klinies benut om okklusale tandoppervlaktes teen karies te beskerm. Delton put- en fissuurseëlmiddel, 'n nuwe chemies-geaktiveerde bis-GMA-tipe seëlmiddel, is onlangs in die handel beskikbaar gestel. Die bypassende etsoplossing van Delton bevat 35 persent ortofosforsuur. Die tensiele bindsterkte van hierdie seëlmiddel is volgens twee tegnieke bepaal en bindsterktes van 9,2 ± 2,1 MPa en 7,6 ± 1,2 MPa is onderskeidelik verkry. Die toetsmonsters het almal in die seëlmiddel gebreek en nooit by die aansluitingsvlakke nie. Die invloed van Delton etsmiddel is op die distolinguale groewe en die linguale vlakke van maksillêre molare, asook op die mesiobukkale groewe en die bukkale vlakke van mandibulêre molare met 'n aftaselektronmikroskoop ondersoek. Voldoende harspenetrasie het geskied in geëtste glasuur direk aanliggend tot die betrokke groewe. Verseëlde monsters is vir 8,500 keer aan temperatuurwisselings van 43°C onderwerp en daarna is die randseël met behulp van 'n fluoreserende kleurstof getoets. Die aansluitingsvlakke tussen seëlmiddel en geëtste glasuur het geen lekkasie getoon nie. Volgens resultate toon Delton put- en fissuurseëlmiddel 'n potensiaal vir doeltreffende kliniese toepassing.*

## INTRODUCTION

Dental caries is rampant in white South African school children. Eighty-five per cent of 78,000 white school children examined suffered from dental caries (Ockerse, 1947). Retief, Cleaton-Jones and Walker (1975) found that only 5,6 per cent of male and 2,0 per cent of female 16 - 17 year old white pupils were free from dental caries. More than 40 per cent of all carious or filled surfaces in the permanent dentition of children occur on the occlusal surfaces (Day and Sedwick, 1935; Knutson, Klein and Palmer, 1940).

The regulation of the fluoride content of the public water supplies to 1,0 ppm of fluoride is the safest, most practical and effective means of preventing dental decay (Doherty, 1968). The reduction in caries prevalence is less evident on the occlusal surfaces of teeth. Backer Dirks (1963) noted that caries of the first permanent molars in 12 year old children was reduced by only 14 per cent in pits and fissures but by 59 per cent on mesial surfaces, 82 per cent on distal surfaces and 73 per cent on smooth buccal surfaces. Ludwig (1971) reported that after 16 years of water fluoridation, there was a 91 per cent reduction in dental caries on gingival tooth surfaces, a 76 per cent reduction on approximal tooth surfaces but only a 46 per cent reduction on occlusal tooth surfaces in 13 year old children.

In an attempt to reduce caries incidence on occlusal surfaces, Miller (1905) applied silver nitrate to the pits and fissures; Hyatt (1923) proposed a method known as "prophylactic odontotomy" where amalgam restorations were placed in all occlusal surfaces as soon as possible after the teeth had erupted and Bodecker (1964) suggested the eradication of enamel fissures by smoothing and rounding the occlusal fissures mechanically without filling them.

A more recent approach in the prevention of occlusal caries is the application of sealants to non-carious pits and fissures to seal them off from the destructive oral environment. The first comprehensive report of the successful clinical use of an adhesive to seal the highly susceptible pits and fissures of teeth against dental caries was that of Cueto and Buonocore (1967). They used an alkyl cyanoacrylate as the resin system. Alkyl cyanoacrylates have been used in further clinical trials to evaluate their efficacy as caries-reducing agents (Ripa and Cole, 1970; Parkhouse and Winter, 1971). Reports on the effectiveness of alkyl cyanoacrylates to seal pits and fissures effectively and produce a significant reduction in caries incidence were contradictory. This could possibly be due to the finding that cyanoacrylates decompose by hydrolysis on exposure to the oral environment (Buonocore, 1973).

A polyurethane sealant containing sodium monofluorophosphate was introduced by Lee and Swartz (1971). Clinical trials showed that polyurethane sealants lost retention from tooth surfaces completely within a short period (Rock, 1972; Merril *et al*, 1975). The polyurethane sealants are of the chemical type because of the incorporation of fluoride within the resin and rely for long-term caries prevention upon the introduction of high levels of fluoride into the enamel lining the pits and fissures.

A resin developed by Bowen (1962) consisting of the addition product of bis (4-hydroxyphenol) dimethylmethane and glycidylmethacrylate (bis-GMA) has been modified for use as pit and fissure sealants. The bis-GMA resins currently used as sealants contain reactive diluents and are either chemically activated or catalyzed by ultraviolet light. Extensive clinical trials have been carried out to evaluate the retention of these materials to occlusal surfaces of teeth and to determine their efficacy as caries-protective agents (Roydhouse, 1968; Buonocore, 1970, 1971; Rock, 1972, 1973, 1974a; McCune *et al*, 1973; Luoma *et al*, 1973; Horowitz, Heifetz and McCune, 1974; Hinding and Buonocore, 1974; Merril *et al*, 1975; Burt *et al*, 1975; Going *et al*, 1976a; Going *et al*, 1976b).

The results of these clinical trials indicated that the retention and caries-protective effects of the ultraviolet light polymerized resins were generally superior to those of the chemically activated bis-GMA resins. The Council on Dental Materials and Devices (1974) considers the use of pit and fissure sealants to be one of the dental caries prevention measures which may be employed. The effectiveness of these inert materials may be only due to the fact that they provide physical barriers. The Council recognizes the short-term benefits shown by such materials but believes that factors relating to their long-term use and effectiveness have not been completely answered.

An adhesive glass ionomer cement has recently been evaluated as a pit and fissure sealant (McLean and Wilson, 1974). The authors reported that this cement was ideal for application to selected fissures of more than 100 $\mu$m in width. A diluted bis-GMA type composite restorative material was used by Ulvestad (1976) as a sealant. Apart from the occlusal fissures, the fissures which extended to the lingual surfaces in permanent maxillary first molars and to the buccal surfaces including the buccal pit in permanent mandibular molars were also sealed. This was the first report in which specific mention was made of the sealing of these fissures.

Conditioning of the occlusal surfaces of teeth with various etching agents is carried out prior to the application of the bis-GMA type of sealants to improve the bond strength of the resins to enamel surfaces. The etching pattern on cuspal slopes and pits and fissures on occlusal surfaces and the extent of resin penetration into pits and fissures have been studied by scanning electron microscopy (SEM) (Gwinnett and Buonocore, 1972; Hinding and Sveen, 1974; Silverstone, 1974; Ermin, 1975; Ferreira, 1975; Marshall, Olson and Lee, 1975). The present authors, however, could not find any references in the current literature on the effects of acid etching on the buccal and lingual surfaces of permanent mandibular and maxillary molar teeth and the grooves on these surfaces.

A new pit and fissure sealant has recently become commercially available. Delton Pit and Fissure Sealant* is an unfilled, selfcuring resin containing bis-GMA blended with dimethacrylate monomers. Delton Etching Solution contains 35 per cent phosphoric acid ($H_3PO_4$) and the mixed resin is delivered from a specially designed Sealant Applicator.

The purpose of this investigation was three-fold; firstly, to evaluate the tensile bond strength of Delton Pit and Fissure Sealant to etched human teeth; secondly, to study by SEM the effects of the etching solution on the buccal surfaces of mandibular molars and the lingual surfaces of maxillary molars, the associated grooves and the sealant-etched enamel interfaces on these surfaces; and thirdly, to evaluate marginal leakage of the sealant after rigorous temperature cycling of sealed teeth.

## MATERIALS AND METHODS

### a. Tensile bond strength

Freshly extracted, sound human maxillary central incisors were cleaned and stored at -4°C until required. The labial surfaces were polished with 180 grit silicon carbide discs on a Kent Mk 2 polishing machine** with adequate water lubrication. The roots of the teeth were cut off and undercut wedge-shaped grooves prepared on the lingual aspects of the crowns with a diamond separating disc. This procedure provided for mechanical retention of the teeth in the embedding medium during the testing procedure. The crowns of 10 teeth were placed in moulds with a diameter of 1,8 cm and a similar number in moulds with a diameter of 1,2 cm. The moulds were placed on a smooth, firm polyethylene sheet and the teeth positioned in the moulds so that the polished surfaces faced the plastic sheet. The moulds were filled with a clear self curing acrylic resin*** and the embedded teeth removed after the resin had set. The specimens were always stored wet. Final wet polishing of the exposed enamel surfaces was done just prior to the preparation of the experimental test specimens with 320, 400 and 600 grit silicon carbide discs respectively on the polishing ma-

* Johnson & Johnson Dental Products Company, East Windsor, N.J. 08520, U.S.A.
** Engis Ltd, Maidstone, England.
*** Lang Dental Manufacturing Co., Chicago, Illinois, U.S.A.

chine. The enamel surfaces were dried with a chip syringe and etched with the Delton Etching Solution for 60 sec. The acid was flushed with tap water and the teeth dried.

The preparation of the experimental test specimens on the teeth embedded in the 1,8 cm diameter moulds and the subsequent evaluation of the tensile bond strengths were carried out according to a method developed by Phillips, Swartz and Rhodes (1970). Circular matrices with an inside diameter of 6 mm and a thickness of 1,5 mm were prepared with a polyether rubber impression compound* in a brass mould. These were cut on one side with a sharp scalpel to provide split ring matrices. A split ring rubber matrix was placed on an etched embedded tooth surface and a close-fitting brass ring slipped over the matrix to maintain its form and inside diameter during the preparation of the experimental bonds. The Delton Pit and Fissure Sealant was mixed and the ring matrix filled with a portion of the mixed resin. The remainder of the resin was placed in an undercut recess in a 12,5 mm diameter bronze ball bearing. The ball was carefully aligned on the matrix. The resin was allowed to set at room temperature for 15 min, the metal bands and split matrices removed and the prepared specimens stored in water at 37°C for 24 hours. The specimens were mounted in a test jig which was developed by Hanke (1968) and modified by Phillips *et al* (1970). It was designed to allow proper alignment of the test specimens in the tensile testing machine during the application of the load and to eliminate as nearly as possible all other forces except tensile during the test procedure.

The test specimens on the teeth embedded in the 1,2 cm diameter moulds were prepared and the tensile bond strengths determined according to a method developed by Lee, Swartz and Culp (1969). The mixed sealant was placed into the undercut recess on a threaded stainless steel cylinder. The diameter of the recess was 0,54 cm. The cylinder with sealant was pressed onto the etched enamel surface and the excess resin removed from the periphery of the cylinder. A notched washer was placed on the tooth surface. The washer was notched to permit water to contact the sealant-etched enamel interface during immersion of the test specimens in water at 37°C. Next a silicone grommet was slipped over the cylinder followed by the top steel washer. A retaining nut was then threaded onto the cylinder until it just made contact with the top washer. The assembled specimens were stored in water at 37°C for 24 hours. The test specimens were assembled in a device containing pneumatically operated grips. The fingers of the grips were expanded to grasp the two steel washers on the test specimen. The device contains an upper and lower swivel to reduce the influence of other forces other than tensile during the application of the load.

The tensile tests were carried out on an Instron Table Model 1026 tensile testing machine**. The load was applied at a speed of 0,05 cm $min^{-1}$ and the force required to break an experimental bond automatically recorded. The test specimens were examined to determine the site of failure. The tensile bond strengths were calculated and expressed in megapascals (MPa).

b. **Scanning electron microscopy**

The crowns of 4 mandibular and 4 maxillary first molar teeth were polished with a bristle brush and a water slurry of pumice. The crowns were separated from the roots with a diamond disc, washed well and dried with compressed air. The buccal surfaces of the crowns of the mandibular and the lingual surfaces of the maxillary teeth were conditioned with the Delton Etching Solution for 60 sec, washed well in running water and dried.

Delton Pit and Fissure Sealant was applied with the Delton Applicator to the mesiobuccal grooves on the buccal surfaces of 2 of the mandibular teeth and the distolingual grooves on the lingual aspects of 2 of the maxillary teeth. The sealant was allowed to cure. Transverse mesiodistal sections were cut through the grooves on the buccal and lingual aspects of the crowns of the teeth with a diamond disc to expose the sealant within the grooves. The exposed resin and adjacent enamel was isolated by applying dental sticky wax to all other surfaces. The sections were then placed in 10 per cent hydrochloric acid for 10 min, rinsed well in running water, dried and the sticky wax removed. This effectively exposed the resin-enamel interface.

The crowns of the teeth and the etched sections were mounted on aluminium stubs, coated with silver in an Edward Coating Unit Model E12E4* and viewed in a Cambridge Stereoscan S4 scanning electron microscope** operated at 20 kV. The beam-specimen angle was varied and the specimen stage rotated to obtain the best surface topography.

c. **Marginal leakage at the enamel-sealant interface**

Marginal leakage at the enamel-sealant interface was evaluated by means of a fluorescent dye technique. Six selected mandibular and 6 maxillary first molars were used in this part of the study. The crowns of the teeth were cleaned with a bristle brush and a water slurry of pumice and washed well in running tap water. The teeth were dried with a chip syringe and the occlusal surfaces of 4 teeth in each group etched with the Delton Etching Solution for 60 sec. In the mandibular teeth the etching was extended onto the buccal surfaces to include the mesiobuccal grooves and in the maxillary teeth onto the lingual surfaces to involve the distolingual or distal oblique grooves. The occlusal surfaces of the remaining 2 mandibular teeth were etched buccal to the central groove. In the maxillary teeth the etching was confined to the lingual aspect of the occlusal surface. In these 4 teeth the etching solution was applied with a finely-pointed camel hair brush. The etched surfaces were washed well in running tap water and dried with compressed air.

The 2 components of the sealant were mixed according to the manufacturer's instructions and applied to the etched surfaces by means of the Delton Applica-

* Impregum, ESPE, Seefeld/Oberbay, West Germany.
** Instron Limited, High Wycombe, England.

* Edwards Ltd., Cramley, Kent, England.
** Cambridge Scientific Instruments Ltd., Cambridge, England.

tor. The sealant was allowed to set for 15 min before mounting the teeth in a thermal cycling machine*. The teeth were subjected to 8500 cyclic temperature changes. Each cycle consisted of alternate immersion in water at 7°C and 50°C respectively for 30 sec.

The teeth were dried after temperature cycling and covered with 2 applications of nail varnish. A small area surrounding the margins of the sealant was not coated. This procedure excluded the subsequent penetration of the dye at any site of entry other than the sealant-enamel interface. The prepared teeth were placed in a solution containing one tablet of red fluorescent dye** in 25 ml of water at 37°C for 7 days. The teeth were removed, washed well in running water and the nail varnish with its attached dye carefully scraped from the tooth surfaces. The crowns were separated from the roots with a diamond disc and embedded in a clear polyester resin. Longitudinal buccolingual and transverse mesiodistal serial sections, approximately 225 $\mu$m thick, were cut with an Isomet low speed saw***. The sections were examined microscopically by transmitted ultraviolet radiation.

## RESULTS

### a. Tensile bond strength

The mean tensile bond strengths of Delton Pit and Fissure Sealant to polished, etched enamel surfaces recorded with the 2 test methods are given in Table 1. When a statistical analysis of the results was carried out by means of the Student's t-test, it was found that the difference in the tensile bond strengths obtained with the 2 methods was not significant ($p > 0,05$).

All the test specimens failed within the sealant.

*Table 1.*

**Mean tensile bond strengths of Delton Pit and Fissure Sealant to etched enamel surfaces**

| Test method | Number of specimens | Mean tensile bond strength ± S.D. (MPa) | Coefficient of variation % |
|---|---|---|---|
| Phillips *et al* (1970) | 10 | 9,2 ± 2,1 | 22,4 |
| Lee *et al* (1969) | 10 | 7,6 ± 1,2 | 15,6 |

### b. Scanning electron microscopy

The mesiobuccal groove with its termination in the buccal pit on the buccal surface of a mandibular molar is shown in Fig. 1. A higher magnification of the central part of this groove clearly demonstrates the debris at the base of the groove, absence of an etching pattern on the walls in the deeper aspects of the groove and a marked etching effect on the superficial aspect of the walls of the groove (Fig. 2). The lack of etching is more apparent on the walls of this distolingual groove on the lingual aspect of a maxillary first molar (Fig. 3). A variable etching pattern of the enamel surfaces immediately adjacent to the grooves on the buccal and lingual aspects of mandibular and maxillary molars respectively, was observed. Etching patterns characteristic of prismless or aprismatic enamel (Fig. 4) and preferential dissolution of prism peripheries (Fig. 5) predominated in these areas. Preferential etching of prism cores (Fig. 6) was only observed in small isolated areas of these surfaces. Exposure of the sealant aspect of the resin-enamel interface immediately adjacent to a distolingual groove shows tags of sealant extending into the etched enamel (Fig. 7). The resin that had cured on etched buccal or lingual molar surfaces adjacent to the grooves was similarly exposed by hydrochloric acid dissolution. The sealant aspect of the resin-enamel interface is a replica of the underlying etched enamel and reveals the extent of resin penetration (Fig. 8).

*Fig. 1.* **Mesiobuccal groove on buccal surface of mandibular first molar tooth (SEM X 40).**

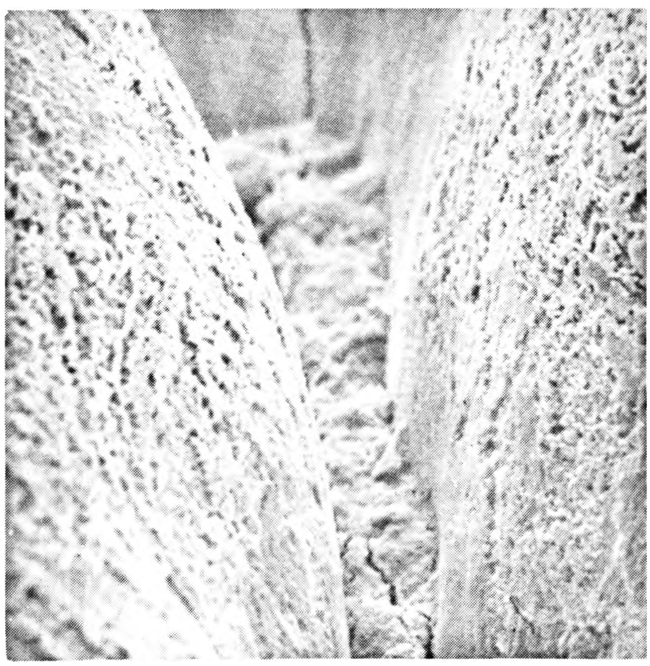

*Fig. 2.* **Debris at the base of the groove and etching patterns on the walls of the groove (SEM X 180).**

* Mediquip Engineering, P.O. Box 56360, Pinegowrie, Randburg, Republic of South Africa.
** Blak Ray, Ultra-Violet Products Inc., San Gabriel, California, U.S.A.
*** Buehler Ltd., 2120 Greenwood St., Evanston, Illinois, U.S.A.

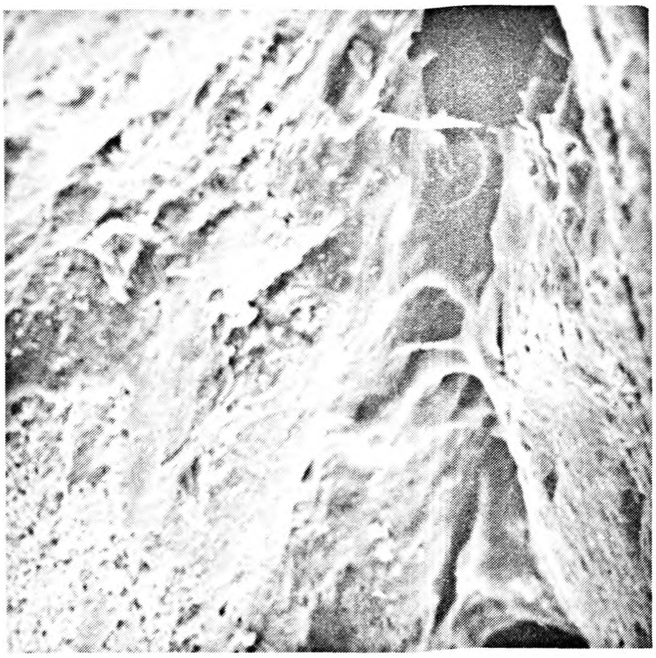

*Fig. 3.* **Lack of etching of the walls of the distolingual groove of a maxillary first molar (SEM X 180).**

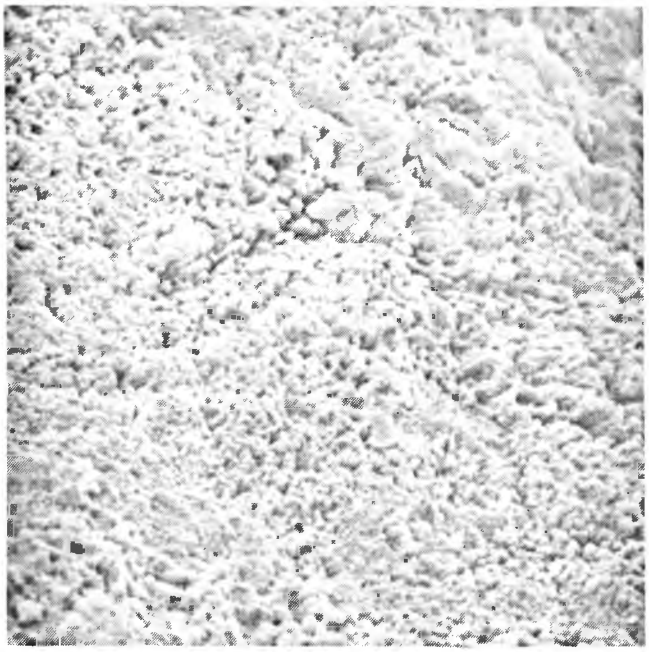

*Fig. 5.* **Preferential dissolution of prism peripheries by acid etching (SEM X 1800).**

*Fig. 4.* **Phosphoric acid etching of prismless enamel (SEM X 1800).**

*Fig. 6.* **Preferential etching of prism cores (SEM X 1800).**

### c. Marginal leakage at the enamel-sealant interface

Slight marginal leakage of sealed etched enamel surfaces was observed in only one of all the serial sections examined. This was seen on the lingual aspect of the occlusal surface of a mandibular molar (Fig. 9). Complete sealant penetration occurred in the narrow mesial pit (Fig. 10) and the shallow central groove (Fig. 11) of an etched mandibular molar occlusal surface and the mesial groove on the occlusal surface of an etched maxillary first molar (Fig. 12). Debris in the deeper regions of pits, fissures and grooves prevented complete sealant penetration (Fig. 13). Marginal leakage was only observed in the specimens with unetched enamel-sealant interfaces. Dye penetration ranged from moderate (Fig. 14) to severe (Fig. 15) at the unetched buccal aspects of the occlusal surfaces but no marginal leakage occurred at the opposing sealant-etched lingual enamel interfaces on these occlusal surfaces. Marginal leakage could not be demonstrated on etched distolingual grooves (Fig. 16) on the lingual surfaces of maxillary molars or the etched mesiobuccal grooves on the buccal aspects of mandibular molar teeth.

## DISCUSSION

The tensile bond strengths of Delton Pit and Fissure Sealant to etched enamel surfaces which were obtained in this study are not a true reflection of the bond strength as all the test specimens failed within the material. The values obtained are more representative of the cohesive strength of the sealant rather

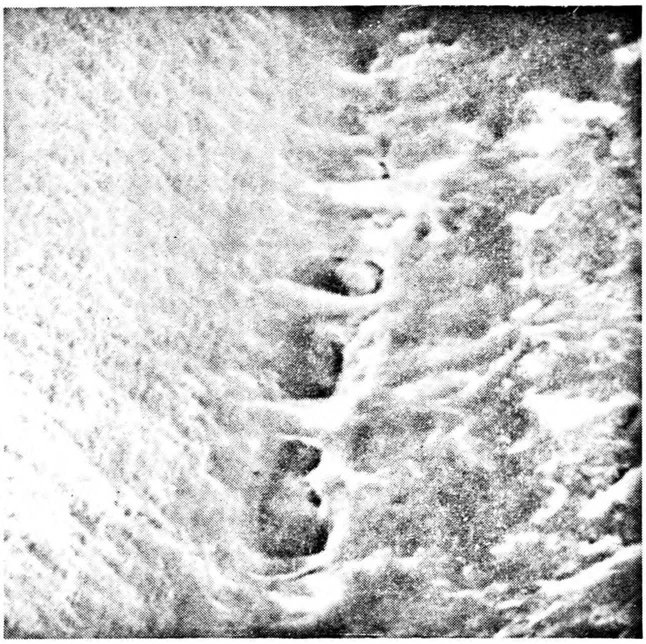

*Fig. 7.* **Sealant tags extending into the etched enamel surface (SEM X 600).**

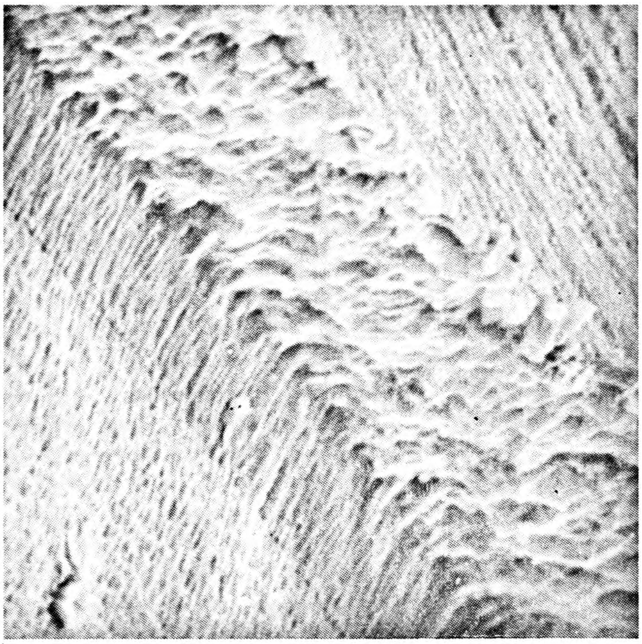

*Fig. 8.* **Sealant interface that had cured on etched enamel (SEM X 375.**

than the force required to bring about interfacial separation. It may therefore be assumed that the tensile bond strength of the sealant to etched enamel should be greater than the results obtained in this study. This assumption was confirmed by Kemper (1976) who found that the tensile bond strength of Delton Pit and Fissure Sealant to etched enamel was 16,45 ± 6,64 MPa. The methods used to determine tensile bond strengths in this investigation (Phillips *et al*, 1970; Lee *et al*, 1969) were developed to determine the bond strengths of restorative materials to enamel and may have limitation in the evaluation of the bond strengths of pit and fissure sealants.

The tensile bond strengths of an ultraviolet light catalyzed and a chemically activated bis-GMA sealant have been evaluated by several investigators. Rock (1974b) reported that the tensile bond strength of an ultraviolet light catalyzed resin to enamel surfaces etched with 50 per cent buffered $H_3PO_4$ for 60 sec was 3,07 N $mm^{-2}$ (MPa) and 4,64 MPa to enamel surfaces etched with 30 per cent $H_3PO_4$ for a similar time interval. The tensile bond strength of the chemically activated resin to enamel surfaces etched with 50% $H_3PO_4$ for 30 sec was 4,15 MPa. Williams, Von Fraunhofer and Winter (1974) found that the tensile bond strength of the ultraviolet light catalyzed sealant was 25,7 kg $cm^{-2}$ (2,5 MPa) when the test specimens were immersed in water at 37°C for 7 days. The tensile bond strength increased to 34,6 kg $cm^{-2}$ (3,4 MPa) after storage in water for 6 months. Under similar experimental conditions, the tensile bond strength of the chemically activated sealant decreased from 42,3 kg $cm^{-2}$ (4,1 MPa) to 16,1 kg $cm^{-2}$ (1,6 MPa). The tensile bond strength of the ultraviolet light catalyzed resin to enamel after 7 days in water at 37°C was found to be 36,6 kg $cm^{-2}$ (3,6 MPa) (Low, Davies and Von Fraunhofer 1975). In a subsequent publication, Low and Von Fraunhofer (1975) determined the shelf life of the activated ultraviolet light catalyzed sealant. They determined the tensile bond strengths of the activated sealant stored at room temperature (20 ± 2°C) immediately after activation and at daily intervals up to 14 days after activation. They found that the activated resin could be used for up to 6 days (tensile bond strengths ranged from 82,79 kg $cm^{-2}$ (8,12 MPa) to 68,28 kg $cm^{-2}$ (6,70 MPa). Young, Hussey and Stephen (1975) determined the tensile bond strengths of the ultraviolet light catalyzed resin to enamel surfaces etched with various concentrations of $H_3PO_4$. They found that optimal bond strengths were obtained on enamel surfaces etched with 30 per cent $H_3PO_4$ (171 kgf $cm^{-2}$ ≡ 16,8 MPa) and 50 per cent $H_3PO_4$ (165 kgf $cm^{-2}$ ≡ 16,2 MPa). The results of all these investigations indicate the great variation in tensile bond strengths recorded for the 2 bis-GMA sealants under different experimental conditions.

Testing the experimental specimens in tension does not necessarily duplicate *in vivo* forces encountered in the oral environment where components of shear and compression would be much more favourable to mechanical retentive forces than tensile loading (Lee *et al*, 1972).

Since the introduction of the concept of conditioning enamel surfaces to obtain increased bonding of dental materials to enamel by Buonocore (1955), numerous papers have been published on the effects of different etching agents on enamel surfaces, pits and fissures on occlusal surfaces and resin-etched enamel interfaces. Scanning electron microscopy has been used extensively in these studies. These publications have been reviewed by Ferreira (1975) and Retief (1975).

Acid etching produces a marked increase in enamel surface area available for bonding, decreases the free surface energy of the enamel surface thus allowing increased penetration of the curing resin into the micropores created in these surfaces. On polymerization of the resin, mechanical bonding is responsible for the increased retention of dental resins to etched enamel surfaces. Surface characteristics produced by acidic conditioning agents include preferential etching of prism cores, selective etching of prism peripheries and

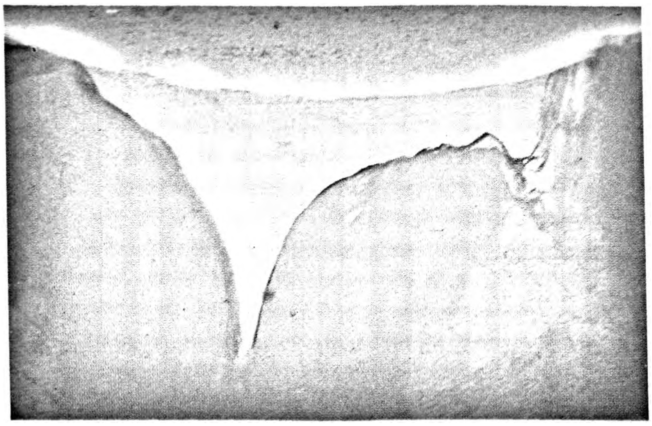

*Fig. 9.* Slight marginal leakage at the lingual aspect of the sealed occlusal surface of a mandibular molar (X13).

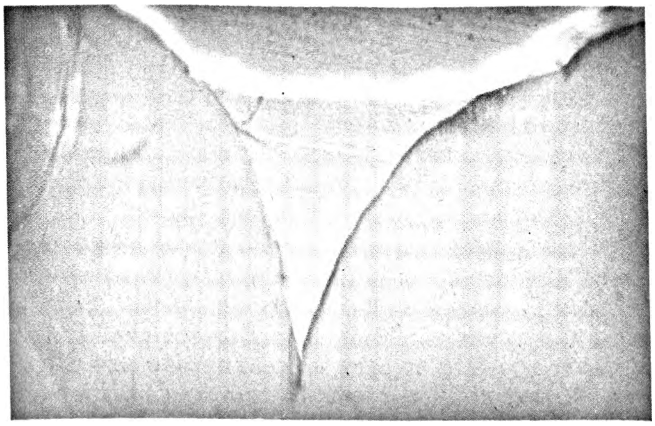

*Fig. 10.* Complete sealant penetration in the mesial pit of a mandibular molar tooth (X13).

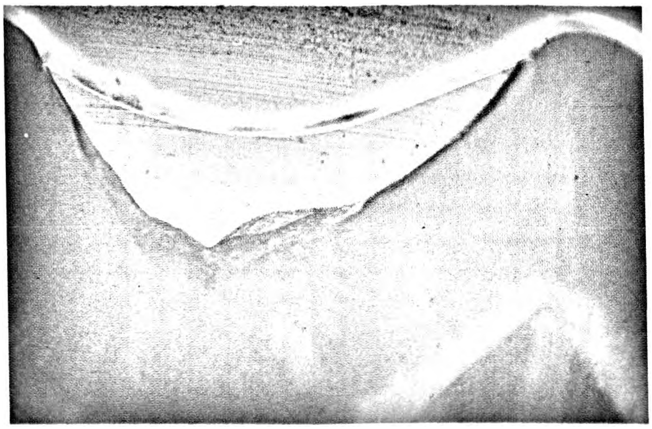

*Fig. 11.* Sealant penetration in the shallow central groove of a mandibular molar tooth (X8).

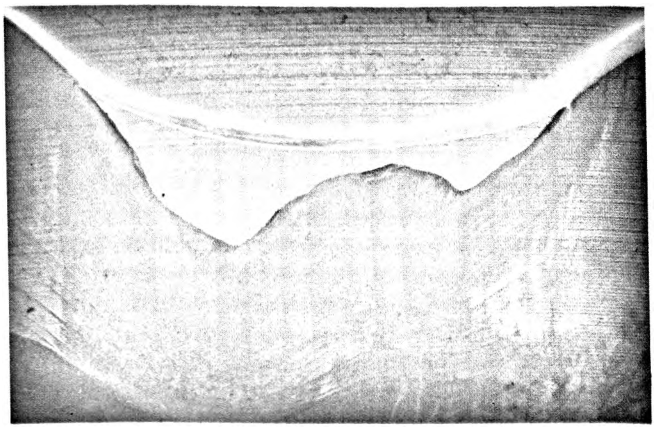

*Fig. 12.* Complete sealant penetration in the mesial groove of a maxillary molar tooth (X8).

*Fig. 13* Complete sealant penetration in the distal pit and distobuccal groove of a mandibular molar was prevented by debris in the deeper regions of the pit and groove (X13).

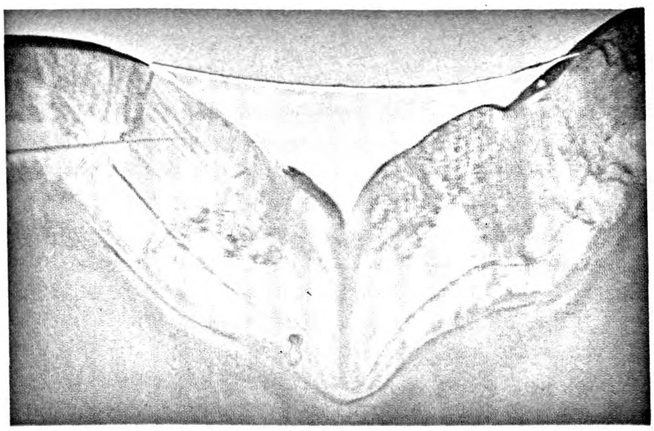

*Fig. 14.* Moderate dye penetration at the sealant-unetched enamel interface on the occlusal surface of a mandibular molar tooth (X13).

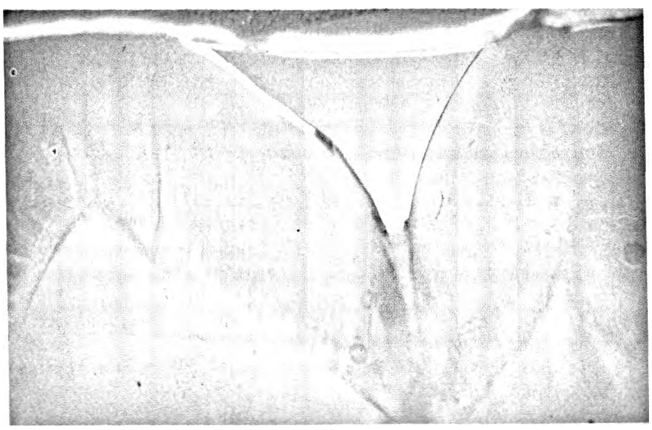

*Fig. 15.* Severe marginal leakage at the sealant-unetched enamel interface on the occlusal surface of a mandibular molar tooth (X8).

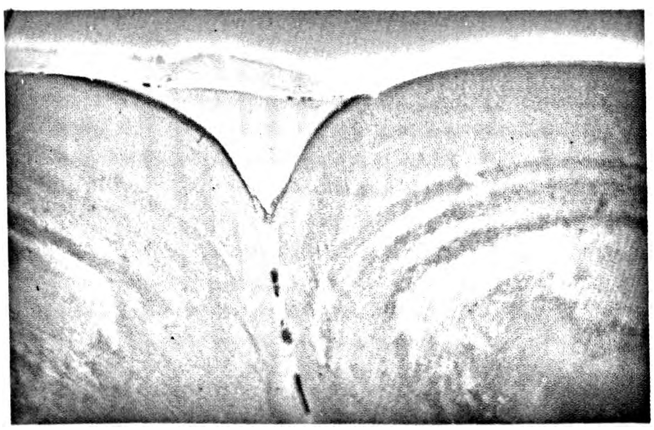

*Fig. 16.* A sealed distolingual groove on a maxillary molar tooth with no marginal leakage (X13).

pitted surfaces with no clear delineation of prism structure. The selective etching of prism cores was most commonly observed while the least common phenomenon was the absence of prism delineation in areas where the enamel prisms did not extend to the tooth surface.

No references could be found in the literature relating to the etching of buccal and lingual grooves on the buccal and lingual aspects of molar teeth. The absence of a definite etching pattern on the walls of the deeper parts of the grooves as seen in this study (Figs. 2 and 3) was similar to that previously described for pits and fissures on occlusal surfaces of molar teeth (Gwinnett and Buonocore, 1972; Hinding and Sveen, 1974; Ferreira, 1975). The superficial parts of the walls of the grooves showed a marked etching effect (Figs. 1 and 2). The most common etching patterns observed on buccal surfaces of mandibular molars and lingual surfaces of maxillary molars were absence of prism delineation (Fig. 4) and preferential etching of prism peripheries (Fig. 5). In contrast to reports that selective etching of prism cores was most commonly observed on other tooth surfaces, this etching pattern was only found in small isolated areas on the surfaces examined in this study (Fig. 6). Adequate resin penetration into the etched enamel surfaces occurred immediately adjacent to the buccal and lingual grooves (Figs. 7 and 8). The findings of Cons, Leske and Pollard (1976) are therefore surprising. They evaluated the sealant retention for different tooth sites on first permanent molars 3 years after the application of an ultraviolet light catalyzed resin and reported that 41,4 per cent of the occlusal surfaces of mandibular molars were completely covered, the distolingual grooves of upper molars were completely covered in 21,9 per cent of cases, while the buccal pits in lower molars were completely sealed in only 2,5 per cent of the cases.

Peterson, Phillips and Swartz (1966) recorded the temperature fluctuations on the labial surfaces of central incisors when hot coffee (60°C) and ice water (0°C) were drunk alternately. Under normal drinking conditions, the temperature on these tooth surfaces ranged from 15°C to 45°C. They found that an immersion time of 15 sec was adequate to ensure that the temperature change was transmitted through the resin. The extremes of temperature used in the present study (7° - 50°C) were more severe than would be encountered in the oral environment. It was subjectively estimated that 200 temperature changes could occur in the oral environment per day (Bishara, Khowassah and Oesterle, 1975). Calculated on this basis, the 8,500 temperature cycles used in the present investigation could be equated to approximately 42 days of exposure in the oral environment.

After temperature cycling, the sealed teeth were stored in a solution of the fluorescent dye at 37°C for at least 7 days. Slight dye penetration at the sealant-etched enamel interface was only observed in one of the serial sections (Fig. 9). The sealant penetrated to the full depth of the fissures (Fig. 10) or grooves (Figs. 11 and 12). Marginal leakage occurred at all the sealant-unetched enamel interfaces (Figs. 14 and 15). Woody, Moffa and McCune (1972) assessed the leakage of 4 pit and fissure sealants; an ultraviolet light catalyzed bis-GMA resin, a polyurethane sealant, a cyanoacrylate resin and a zinc polycarboxylate cement. They reported that all the materials failed to penetrate the full depths of the fissures and that, with the exception of the bis-GMA resin, all sealants failed to seal the occlusal fissures against microleakage after temperature cycling.

The findings in the present investigations can be summarized as follows: the tensile bond strength of Delton Pit and Fissure Sealant to etched enamel surfaces is high; the low viscosity sealant showed marked penetration into the etched enamel surfaces immediately adjacent to grooves on buccal and lingual surfaces and into the full depth of narrow fissures on occlusal surfaces; the absence of microleakage at the sealant-etched enamel interfaces after severe temperature cycling procedures. Delton Pit and Fissure Sealant has the potential to perform well in clinical application. Limited clinical studies conducted by Brooks *et al* (1976) with this material support this supposition.

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