



THE POSTERIOR RESIN COMPOSITE AND
GLASS IONOMER 'SANDWICH' RESTORATION

RESEARCH REPORT SUBMITTED
IN PARTIAL FULFILMENT
FOR THE DEGREE OF
MASTER OF DENTAL SURGERY

ARNIS LIDUMS, B.D.S. (ADELAIDE)

THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF DENTISTRY
SOUTH AUSTRALIA

MARCH, 1993.

Awarded 1993

THE POSTERIOR RESIN AND GLASS IONOMER 'SANDWICH' RESTORATION

**Research report submitted for the degree of
Master of Dental Surgery
in
The University of Adelaide
(Department of Dentistry)**

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

SIGNED:DATE: 22.12.93

Acknowledgements

I wish to acknowledge Dr R.J. Smales for his considerable assistance and guidance in preparation of this research report, and Dr G.J. Mount AM for his advice on the handling of glass polyalkenoate (ionomer) cements.

CONTENTS

	Page
ACKNOWLEDGEMENTS	4
ABSTRACT	10
1. INTRODUCTION	12
2. LITERATURE REVIEW	14
2.1. INTRODUCTION	15
2.2. DEVELOPMENT OF GLASS IONOMER CEMENTS	17
2.3. SANDWICH TECHNIQUE	23
2.4. ALTERNATIVES	30
2.5. ADHESION	32
2.6. DENTINE CONDITIONING	35
2.7. ETCHING GLASS IONOMER CEMENTS - PHYSICAL EFFECTS	42
2.8. GLASS IONOMER CEMENT SUITABILITY FOR SANDWICH TECHNIQUE	50
2.9. BONDING RESIN COMPOSITE TO GLASS IONOMER CEMENT	56
2.10. DESCRIPTION OF TECHNIQUE FOR OPTIMUM RESULTS	62
2.11. CLINICAL APPLICATIONS	65
2.12. CLINICAL EVALUATION	71
2.13. SUMMARY	72
2.14. CONCLUSION	75
3. OBJECTIVES	76
4. CRACKING AND CRAZING WITHIN GLASS IONOMER CEMENT DUE TO ACID ETCHING - PILOT STUDY	79
4.1. INTRODUCTION	79
4.2. MATERIALS AND METHODS	81

	Page
4.3. RESULTS	85
4.3.1. SELECTION OF RATING CRITERIA	85
4.3.2. OBSERVATIONS AND DATA	86
A. CAPSULATED KETAC-BOND	86
B. 3M GLASS IONOMER CEMENT	92
4.4. DISCUSSION	97
4.4.1 CHOICE OF SURFACE TREATMENT	97
A. CAPSULATED KETAC-BOND	97
B. 3M GLASS IONOMER CEMENT	99
4.4.2. CRACKING FREQUENCY	101
4.4.3. SIGNIFICANCE OF CRACKING	102
4.5. CONCLUSION	104
4.6. SUMMARY OF FINDINGS	106
5. THICKNESS OF GLASS IONOMER CEMENT REQUIRED TO SUPPORT RESIN COMPOSITE UNDER LOAD - PILOT STUDY	107
5.1. INTRODUCTION	107
5.2. MATERIALS AND METHODS	109
5.2.1. PREPARATION OF SAMPLES	109
5.2.2. LOADING TEST	110
5.3. RESULTS AND DISCUSSION	112
5.3.1. DATA AND OBSERVATIONS	112
5.3.2. RESULTS	112
5.3.3. DISCUSSION	113
5.4. SIGNIFICANCE	115
5.5. CONCLUSION	116
5A. FREE STANDING SAMPLE - SHORT EXPERIMENT	117
5.A.1. AIM	117
5.A.2. METHODS AND MATERIALS	117

	Page
5.A.3. RESULTS	117
5.A.4. DISCUSSION	118
5.A.5. CONCLUSION	118
6. EVALUATION OF CLINICAL TECHNIQUES IN VITRO	119
6.1. INTRODUCTION	119
6.2. MATERIALS AND METHODS	120
6.2.1. PREPARATION OF SAMPLES	120
6.2.2. PLACEMENT TECHNIQUES	120
6.2.3. MINI-MICROLEAKAGE TEST	124
6.2.4. SECTIONING	127
6.2.5. RECORDS	128
6.2.6. OBSERVATION AND RECORDING	
METHOD	129
A. MICROLEAKAGE	129
B. POROSITY	133
C. FILLING DEFECTS	134
D. SURFACE DYE PENETRATION AND	
DEPTH OF CRACKS (GLASS	
IONOMER CEMENT ONLY)	135
6.3. RESULTS AND DISCUSSION	136
6.3.1. DIRECT VISUAL AND	
RADIOGRAPHIC OBSERVATIONS	136
6.3.2. MICROLEAKAGE	140
6.3.3. POROSITY	141
6.3.4. FILLING DEFECTS	142
6.3.5. SURFACE DYE PENETRATION AND	
CRACK DEPTH	143
6.4. SIGNIFICANCE	144
6.4.1. MICROLEAKAGE	144

	Page
6.4.2. POROSITY	145
6.4.3. FILLING DEFECTS	145
6.4.4. CRACKS AND SURFACE STAINING	146
6.4.5. THERMAL CYCLING	146
6.5. CONCLUSION	148
7. CLINICAL CHARACTERISTICS OF SANDWICH TECHNIQUE RESTORATIONS PLACED IN VIVO	149
7.1. INTRODUCTION	149
7.2. MATERIALS AND METHODS	150
7.2.1. NUMBERS OF RESTORATIONS	150
7.2.2. PATIENT SELECTION/POPULATION	150
7.2.3. RESTORATION PLACEMENT SEQUENCE	151
7.2.4. MATERIALS	153
7.2.5. METHODS	153
A. CLASS I KETAC SILVER RESTORATIONS	153
B. CLASS I SANDWICH TECHNIQUE RESTORATIONS	155
C. CLASS II SANDWICH TECHNIQUE RESTORATIONS	157
D. CLASS I AND II AMALGAM CONTROLS	158
7.2.6. DATA COLLECTION	158
A. PATIENT DATA CARD	159
B. RESTORATION DATA PROFORMA	159
C. BASELINE	160
D. CLINICAL PARAMETERS	163
E. RESTORATION FAILURE AND GENERAL TOOTH STATUS	167
7.3. RESULTS	170

	Page
CLASS I RESTORATIONS - FILE 37	
A. BASELINE DISTRIBUTION PARAMETERS	170
B. FAILURES	170
C. DETERIORATION	175
D. CORRELATIONS BETWEEN SELECTED CLINICAL FACTORS	180
E. DETERIORATION OVER TIME	180
CLASS II RESTORATIONS - FILE 36	
A. BASELINE DISTRIBUTION PARAMETERS	182
B. FAILURES	182
C. DETERIORATION	185
D. CORRELATIONS BETWEEN SELECTED CLINICAL FACTORS	189
E. DETERIORATION OVER TIME	190
7.4. DISCUSSION	192
7.4.1. DESIGN OF THE STUDY	192
7.4.2. CLASS I RESTORATIONS	194
7.4.3. CLASS II RESTORATIONS	208
7.4.4. GENERAL	210
7.5. CONCLUSION	211
8. BIBLIOGRAPHY	212
9. APPENDICES	227
APPENDIX A	227
APPENDIX B - CLASS I	237
- TABLES	237
- FIGURES	242
- CLASS II	248
- TABLES	248
- FIGURES	252

ABSTRACT

Resin composite/glass polyalkenoate (ionomer) cement Sandwich Technique restorations have been suggested as an alternative to the traditional use of dental amalgam for restoring Class I and II cavity preparations.

Two laboratory studies were set up in 1989 to test some of the behaviour and the physical properties of these materials with the emphasis being placed on observing the glass ionomer cement.

In the first experiment, two brands of glass ionomer lining cement were subjected to different acid etching times and immersed in methylene blue dye. Variable patterns of dye uptake and retention were seen. Acid etching of glass ionomer cement did not cause an increased penetration or retention of the dye.

In the second experiment, various combinations of thicknesses of glass ionomer cement/resin composite samples were subjected to loading to destruction in an attempt to simulate potential masticatory forces. Glass ionomer cement was found to have poor strengths when used alone, or when a thick section was placed under a thin section of composite.

Sandwich Technique Class II restorations were also placed in vitro in extracted teeth. The cavities extended beyond the cemento-enamel junction and the restorations were placed to simulate clinical techniques. The restorations were placed in methylene blue dye and the teeth then sectioned to observe microleakage and the physical structure of the sectioned restorations. Two types of Sandwich Technique restorations were used; an "open" technique where the glass ionomer cement formed part of the external surface of the proximal box, and a "closed" technique where all the glass ionomer cement was enclosed by composite resin. Regardless of the technique, voids were created within either the glass ionomer cement or resin

composite placed in the depth of the box, and microleakage occurred along the gingival floor to varying degrees. In the "open" Sandwich Technique the external glass ionomer cement also showed the presence of surface defects including very deep cracks.

Finally, a clinical study was set up in 1989 to compare the clinical behaviour of a posterior resin composite used with the "closed" Sandwich Technique and a high copper content amalgam for restoring conventional Class I and II cavity preparations. Glass ionomer silver cermet restorations were also placed in some Class I cavities. Restorations were assessed at 6-monthly intervals over two years. The Sandwich Technique restorations performed satisfactorily as did the amalgam controls. However, the silver-cermet restorations exhibited occlusal wear and a high percentage of surface cracking and crazing.

Under the experimental conditions used the following conclusions can be made. Acid etching does not cause cracking or crazing of the glass ionomer cement surface with the materials tested. For maximum strength under simulated occlusal loading, Sandwich Technique restorations should have a thin (0.5 mm) glass ionomer cement lining. In Class II "open" Sandwich Technique restorations the external glass ionomer cement showed surface defects some of which were present as deep cracks extending deep into the restoration, and therefore, this type of restoration is unsuitable. Ketac-Silver is unsatisfactory to restore Class I cavities, due to excessive wear, and cracking and crazing.

The ideal Sandwich Technique restoration should, therefore, have a thin (0.5 mm) glass ionomer cement lining not extending to the external surface. The lining can be acid etched without risk of excessive damage.

1. INTRODUCTION

Recently, there has been an increased usage of resin composite restorative material as an alternative to amalgam. Amalgam has served well as a posterior restorative material mainly because of its generally adequate strength and wear resistance, antibacterial effect and good self-sealing ability due to corrosion products and fairly consistent results despite operator variability. Minimising microleakage has been of great value in keeping secondary caries at relatively low levels.

Wear and longevity of newer resin composite products has proven to be comparable to amalgam in the relatively short term, when the composites are placed in small cavities in areas of low occlusal stress, and when all margins are placed in good quality acid-etched enamel. However, microleakage is still the most significant failure mechanism when this bond fails, and may lead to sensitivity and secondary caries.

The resin composite restoration placed with a margin in dentine is less forgiving. Microleakage may cause post-operative sensitivity, and staining from the percolation of oral fluid, ultimately resulting in secondary caries if it goes unchecked. The composite material has little antibacterial effect. Dentine-bonding agents have decreased the amount of microleakage in vitro, but most of the newer systems are unproven clinically and long-term, especially in the presence of moisture and positive pulpal fluid pressure. Glass polyalkenoate (ionomer) cement is known to give an excellent stable long-term seal to dentine. The glass ionomer cement can act as an intermediate layer between dentine and resin composite in the Sandwich Technique restoration.

The results of laboratory studies using the Sandwich Technique have been very variable. The conditions of placement have also been very variable:- brand of material, powder:liquid ratio of glass ionomer cement, setting time, etching time,

bonding resin wetting ability, curing contraction of composite resin, ambient temperature and humidity, and exposure to water and dehydration.

The literature shows very variable in vitro results using the Sandwich Technique, and few clinical trials have been carried out. Historically, many clinical failures of glass ionomer cement may be attributed to poor understanding of its chemistry and manipulative variables and, thus, the material is frequently abused. More recently, the better quality materials are delivered in mechanically-mixed capsulated form giving a consistent, high powder:liquid ratio, and thus greater strength with less operator variability. In the past, cracking and crazing of the cement was often seen, which is now attributed to over-drying or desiccation of the cement. To gain greater mechanical interlock, etching of the cement surface with 37% phosphoric acid, prior to the placement of a bonding agent and resin composite, has been recommended. However, excess etching may destroy the cement. Taking these factors into account, it would now seem possible to design a sound restoration with minimal leakage at the dentine margins. (These matters will be discussed in more detail in the Literature Review).

The present research report is intended to improve understanding of the Sandwich Technique so as to produce better and more consistent results when restorations are placed clinically.

2. LITERATURE REVIEW

FOREWORD

The purpose of this essay is to review the rationale and use of the Sandwich Technique restoration. Studies of physical and mechanical properties are reviewed, and special emphasis is given to the effect of acid etching of glass ionomer cements prior to placement of resin composite. The most difficult aspect when conducting the review was the wide variation of laboratory and clinical techniques used. This lack of uniformity in procedure led to a wide variation in the strength of the union between resin composite and the glass ionomer cement depending on the material used and method of handling.

2.1. INTRODUCTION

Microleakage is one of the major problems in restorative dentistry. Amalgam, through its corrosion products is antibacterial and self-sealing to a certain degree, and thus limits microleakage and subsequent carious lesions. Resin composite is being used to a greater extent, but microleakage and wear still remain the greatest threat to long-term survival of these restorations. Acid etching of enamel, as first described by Buonocore (1955), allows mechanical retention of the composite to enamel, but adhesion to dentine remains a problem. Therefore when the composite restoration margin finishes in dentine the long-term sealing quality may be dubious.

Simonsen and Stallard developed the preventive resin restoration (PRR) in 1977, using diluted Concise (3M Dental Divis.), which simultaneously restored minimal occlusal carious lesions and prevented further carious lesions using the acid-etch technique in the remaining fissures. The cavity extended just far enough to eliminate caries, possibly not penetrating the dentine. Today, a posterior resin composite is placed using a bonding agent, and a fissure sealant covers the composite and the remaining pits and grooves. Restorations extending into dentine require either a liner, or a bonding agent which will bond to dentine as well as to enamel.

Dentine bonding agents are available but due to their hydrolytic instability their long-term bond is considered unreliable and there is a lack of long-term clinical data for newer systems. Bonding between dentine and composite is not as intimate as that between enamel and composite, Suzuki et al. (1986), and microleakage has been reported to occur under 39% of fissure sealants, Hicks and Silverstone (1982). Glass ionomer cement adhesion to dentine and enamel is accepted as being long-term, Mount (1986), and it has been shown that a mechanical union is also possible between composite and glass ionomer cement. In order to overcome the problems of poor bonding of resin to dentine, and subsequent microleakage, McLean and Wilson (1977a) first described the "Double-Laminate" or "Sandwich Technique"

where glass ionomer cement replaces carious dentine. Both cement and enamel are acid etched prior to placement of light-cured composite, to improve bond strength.

Glass ionomer cements are used as an intermediate layer because of their adhesive properties to dentine and composite, and fluoride release resulting in less secondary caries. Microleakage is reduced and composite restoration retention is improved.

2.2. DEVELOPMENT OF GLASS IONOMER CEMENTS

In 1968, Smith was working on developing cements based on polyacrylic acid. The glass ionomer cements were first described in the dental literature by Wilson and Kent (1972) and developed for clinical use by McLean and Wilson (1977a, 1977b). The cement consists of polyacrylic acid and an ion-leachable aluminosilicate glass to provide ions to cross-link the polyacid chains.

The setting reaction of the glass ionomer cement is an acid-base reaction between two materials: a glass (base) and a polyelectrolyte (acid) which yields two polymers: a polysalt hydrogel which acts as a matrix, and silica gel, McLean (1987).

The glass ionomer cements will adhere to dentine in the presence of water because, unlike composites, they are polar polymers that can compete with water for the polar tooth surface. Glass ionomer cements are strong in compression (compressive strength 140-200 MPa). They exhibit excellent adhesion, bio-compatibility and cariostatic properties. They are translucent to a varying extent, exhibit minimal shrinkage, and good resistance to acid attack in vivo, McLean (1987).

Their major defects are early moisture sensitivity, lack of resistance to abrasion on large occlusal contact areas, and susceptibility to fracture under moderate shearing stress. They are also porous and difficult to finish to a smooth surface, McLean (1987). Newer dual-cured glass ionomer cements show improved physical and handling properties, but remain untested as restorations in long-term clinical trials.

2.2.1. SETTING REACTION

The surface layer of the glass particles is attacked by the polyacid resulting in limited degradation of the glass with release of calcium, aluminium and fluoride ions. In the gelation phase, the initial clinical "set" is brought about by ionic cross-linking with the more mobile and readily available calcium ions. Over the next 24 hours a maturation phase occurs during which the less mobile trivalent aluminium ions become inextricably bound within the cement matrix, leading to more rigid cross-linking between the polyacrylic acid chains. This is associated with progressive hydration of the matrix salts and is responsible for an initial short rise in the physical properties of the material, Causton (1981), Wilson et al. (1981), Walls (1986).

2.2.2. RATE OF REACTION

The rate of reaction is controlled by four interacting variables. Walls (1986):

1. Temperature.

Mount and Makinson (1978) reported an increase in working time when the mixing slab and powder were cooled. However, if polyacid liquid is cooled it will precipitate gelation during storage. It is important to note that there will be a longer setting time when conducting bench studies.

2. Physical presentation of the powder.

Crisp et al. (1976a) found that working and setting times were shorter and physical properties improved with a more finely ground glass powder.

3. Availability of free fluoride ions.

Large fluoride inclusions found in low fusion temperature glasses give a longer working time with a relatively sharp set, Crisp and Wilson (1974), Barry et al. (1979). However, a more opaque glass is produced.

4. Constituents of liquid.

One problem with early cements was a slow setting reaction. Wilson and Crisp (1975) found that optically active isomers of tartaric acid extended the working time, greatly increased the setting rate and increased the strength of the cement. Lower fluoride-containing glasses, which were less opaque, could be used because tartaric acid greatly enhanced the rate of extraction of fluoride and aluminium from the glass. Itaconic acid can be added to increase the reactivity of polyacrylic acid with the glass, Mount (1984). Ketac-Fil (Espe GmbH) which uses polymaleic acid has a short setting time. An increased molecular weight polyacid also shortened the setting time and increased the strength, but since it would have been too viscous to mix, it was developed in dry (anhydrous) form and included with the powder. Either water or tartaric acid solution are then used as the liquid, McLean (1988).

The set cement has been described as a composite structure consisting of unreacted glass particles surrounded by a silaceous hydrogel (the residuum of the glass particles after acid-mediated ion leaching). These "core" particles are embedded in a matrix of cross-linked polyacrylic acid molecules, Barry et al. (1979).

2.2.3. WATER CONTENT

Water is the transport medium for the ionic reaction. Both the matrix and siliceous hydrogel are hydrated at the end of the setting reaction, with the result that the cement is susceptible to desiccation if not protected by a suitable surface coating. Conversely, early contamination with water leads to water uptake, with reduction in physical properties and a rough surface with altered perceived colour. Susceptibility of the cement to both of these phenomena decreases with increased cement age, since the water is largely absorbed in the first 24 hours, although there is some uptake at a lower rate over at least 7 days, Crisp et al. (1976b, 1980), Wilson et al. (1981), Walls (1986).

2.2.4. PHYSICAL PROPERTIES

There are four factors which affect the physical properties of the glass ionomer cement, Walls (1986).

1. Variation in the glass powder.

The incorporation of a variety of crystalline inclusions, Prosser et al. (1986) and sintered metal-glass compositions (called cermets), McLean and Gasser (1985), improved the flexural strength and abrasion resistance of the set cement, Wilson and Prosser (1984), Moore et al. (1985), Prosser et al. (1986). The improved bond between the sintered metal filler and glass dramatically raised the abrasion resistance of the glass ionomer cement, and also made them fast-setting and more resistant to early water contamination.

2. Powder:liquid ratio.

An increased powder:liquid ratio gave shorter working and setting times and increased the hardness of the cement, Crisp et al. (1976b), Mount and Makinson (1978).

3. Hydration of the cement mass.

An increased degree of hydration i.e. an increased ratio of "tight" to "loose" bound water also increased the strength, Wilson et al. (1981).

4. Porosity.

An early glass ionomer cement (ASPA) was four times as porous when set as a chemically activated two-paste composite resin (Concise), Smales and Joyce (1978), which may lead to fracture at loads considerably below the actual strength of the material because of stress foci, Walls (1986).

2.2.5. FLUORIDE RELEASE

It has been shown that fluoride ions are released from glass ionomer cement for at least 2 years, Wilson et al. (1985), Crisp et al. (1976b), Causton (1981), Forsten (1990). The fluoride originates from the aluminosilicate glass, Kent et al. (1979). Not all the fluoride is available for release. It is released mainly as a sodium salt which is not a matrix forming species and thus, the cement is not weakened, Walls (1986). A thicker mix has a higher powder:liquid ratio and therefore more fluoride available. The fluoride released replaces the hydroxyl ion in the apatite lattice of tooth structure and produces an anticaries effect in four ways, Wilson and McLean (1988):

1. An increased fluoride level at the enamel surface gives an increased resistance to plaque acid.
2. The surface energy of the apatite is reduced which makes it more difficult for plaque to adhere.
3. Fluoride aids remineralisation of damaged enamel.
4. Fluoride alters microbacterial metabolism.

Significant amounts of fluoride are taken up by enamel, dentine and cementum at a distance from the restoration, Retief et al. (1984), Retief (1988). This gives a zone of resistance to demineralisation at least 3 mm wide around the glass ionomer cement, Hicks et al. (1986). The rate of fluoride release from the cement decreases with time, Swartz et al. (1984), Forsten (1990). Should the cement disappear, it is postulated the retained fluoride would prevent caries, Shimokobe et al. (1987).

In effect, the restoration provides a continuous topical application of fluoride, thus preventing caries, Phillips (1988). In addition, a recent study reported that the cement could also take up fluoride to act as a reservoir, Forsten (1991).

2.3. SANDWICH TECHNIQUE

2.3.1. BRIEF DESCRIPTION OF SANDWICH TECHNIQUE

In the Sandwich Technique a glass ionomer cement is used as a cavity base before placement of a resin composite. After cavity preparation the dentine walls are conditioned with a suitable solution such as polyacrylic acid to remove some of the smear layer, and to improve cement bonding to the dentine.

The cement is placed into the base of the cavity and allowed to set for 4-6 minutes. When it has hardened, excess may be cut back to expose any covered enamel walls. The enamel and cement may then be etched with phosphoric acid solution or gel, and a resin composite material inserted.

Most authors suggest a lining of calcium hydroxide cement should be used in cases where there is less than 0.5 mm remaining dentine thickness. The entire procedure should be done under dry conditions and hence rubber dam is recommended.

2.3.2. CLINICAL APPLICATION

While the glass ionomer cement may often be regarded as a satisfactory restoration in its own right, there are situations where reinforcement with resin composite is desirable. In these cases, when the Sandwich Technique is selected and the margin finishes in dentine, glass ionomer cement protects the dentine and the pulp and, providing a glass ionomer cement with a high powder:liquid ratio has been used, it has been suggested that it may provide the first 2-3 mm of the external surface of the restoration where it is in contact with the gingival margin, McLean et al. (1985), Mount (1989d). The abrasion resistance of cement required in this area is unknown.

McLean et al. (1985) regarded glass ionomer cement as "replacement dentine", the surface of which can be acid etched in a similar way to enamel to gain micromechanical retention.

The superior marginal seal and cariostatic action of glass ionomer cement can be used to overcome the effects of any marginal leakage and secondary caries under resin composite restorations.

The Sandwich Technique may be used in some Class I, II, III, IV and V cavities as well as with resin composite veneers, or laminates.

2.3.3. MICROLEAKAGE

Acid etching of enamel enables resin composite to be attached to enamel which has a well-defined prism structure, and this gives an effective marginal seal. However, the bond can be affected by the complete absence of enamel, or enamel which structurally does not lend itself to being etched, Van Noort (1983). Enamel in the depths of grooves or fissures, cervical enamel, and previously etched and bonded enamel, can all be devoid of characteristic prism markings, Gwinnett (1967). In fact, any restoration may have deep areas extending into dentine which do not lend themselves to being etched.

These situations can provide problems in retention of the composite restoration and may result in marginal leakage and post-insertion pain, as well as secondary caries, Retief (1986). The use of the Sandwich Technique of glass ionomer cement with composite veneers can provide a solution to these problems as well as giving several other advantages over conventional composite restorations.

Glass ionomer cement adheres very well to dentine, and can be used as a base to prevent microleakage. When glass ionomer cement is etched, it gives a roughened surface for stronger mechanical attachment of resin composite. A low viscosity liquid resin is applied that penetrates into the surface irregularities, McLean et al. (1985).

There have been mixed results in measuring microleakage and marginal integrity of the glass ionomer cement/resin composite restoration. Many conflicting results occur and may be due to poor handling of the material. Marginal leakage of composite used with dentine bonding resins has been seen after one to two years clinically, with marginal staining occurring especially at cervical margins, Ziemiecki et al. (1985), Dennison et al. (1986). Dentine margins of Class V Sandwich Technique restorations were superior to composites used with dentine bonding agents, as

assessed quantitatively under the scanning electron microscope (SEM), Roulet et al. (1986).

Hembree (1987) showed that less marginal leakage occurred at the gingival margin of Class II restorations when a glass ionomer cement was used as a liner in vitro. In vitro studies of Class V restorations showed that microleakage did not penetrate beyond the etched glass ionomer cement lining, Mathis et al. (1988), Leary et al. (1989).

Perkins et al. (1988) showed that where the glass ionomer cement base extended to the gingival margin, this did not increase microleakage. Wasserstein and Gordon (1988) showed that this design actually exhibited less microleakage.

These data suggest that the use of glass ionomer cement under resin composite restorations significantly reduces marginal leakage at the gingival aspect. If microleakage were to occur under a Sandwich Technique restoration, the cariostatic nature of the glass ionomer cement should prevent an untoward result, Garcia-Godoy and Malone (1988). The worst outcome would be discolouration along the resin composite/cement interface, Garcia-Godoy (1987). However, a recent, extensive review of the Sandwich Technique suggested "that the technique may not be as successful clinically as theory may support", Woolford (1993).

2.3.4. RATIONALE FOR GLASS IONOMER CEMENTS

The advantages of glass ionomer cement restorations reported include fluoride release, cariostatic action, biocompatibility, no microleakage, good colour, gingival compatibility, low solubility, good dimensional stability, strong bond to tooth structure, adequate compressive strength and abrasion resistance (in areas not under heavy occlusal load), and radiopacity, Causton et al. (1987), McLean (1987), Mount (1989b). Clinical results regarding longevity of glass ionomer cement restorations have varied greatly, McLean and Wilson (1977a, 1977b), Smales (1981), Knibbs and Plant (1986), Knibbs et al. (1986), McLean and Wilson (1977a, 1977b), Ngo et al. (1986). Earlier reports of prohibitive failure rates can be attributed to a lack of comprehension of chemical adhesion and setting mechanisms. Regimented manipulation can produce excellent longer term results, Mount (1986).

Glass ionomer cements are not ideal in several respects. The present formulations achieve their ultimate physical properties too slowly, and resistance is too low to permit their use in the restoration of occlusal surfaces or stress bearing areas. Improvements are also required in the of quality of colour and early resistance to water contamination, Mount (1984).

In areas where glass ionomer cement alone is inadequate, it can be used in conjunction with a composite veneer i.e. the Sandwich Technique. This includes areas where there is occlusal loading or the aesthetics of a glass ionomer cement would be inadequate. The colour and surface appearance of resin composite is superior to chemically cured glass ionomer cement.

The glass ionomer cement can provide 2 mm of the external surface at the gingival margin in cases where the margin is in dentine, as the cement is compatible with the health of the gingival tissue, Garcia et al. (1981). Contact of the restoration with the

gingiva does not result in any deterioration in the gingival condition, Knibbs et al. (1986).

Chemical analysis and scanning electron micrographs show that phosphoric acid etches the cement by dissolving the matrix, resulting in the glass particles standing proud. This treatment roughens the surface, effectively increasing the area available for attachment, and allows low viscosity resin to penetrate into the irregularities between the proud particles, where it hardens and forms retentive tags, Hinoura et al. (1989a).

Mechanical testing of the strength of the adhesive bond between the two materials using flexural, shear, and tensile strength tests, revealed that the bond strength between resin and cement was greater than the cohesive strength of the cement, McLean et al. (1985), Sneed and Hooper (1985), Hinoura et al. (1987a), Mount (1989b). Bond strength is determined by the cohesive strength of the cement and depends of the combination of glass ionomer cement, composite resin, and surface treatment used. Hence, tensile bond strength values can vary widely. There is potential for cuspal reinforcement in Class II Sandwich Technique restorations since Ketac-Silver and composites individually have been shown in vitro to decrease cuspal flexure, Donly et al. (1988).

2.3.5. STRENGTH OF RESIN COMPOSITE TO GLASS IONOMER CEMENT BOND

The mechanical advantage gained in etching glass ionomer cement has been found to be clinically significant, Tyas et al. (1989). There are five main factors which affect the strength of resin composite bond to glass ionomer cement in the Sandwich Technique restoration, Hinoura et al. (1987a), Mount (1987), (1986):

1. The cohesive strength of the cement itself; which is affected by the powder:liquid ratio.
2. The effect of etching of the cement surface.
3. The resin bonding agent's viscosity and wettability.
4. The ability of the resin composite to be closely adapted to the cement without voids.
5. Dimensional change of the composite with polymerisation shrinkage and temperature change.

These factors will be discussed in more detail later.

2.4. ALTERNATIVES

Hagger (1951), developed the first dentine bonding agent based on glycerophosphoric acid dimethacrylate. The material was marketed under the trade name Sevriton Cavity Seal (De Trey/Dentsply), and was found to bond to calcium in the dentine via phosphate groups, Kramer and McLean (1952). Unfortunately, like most of its successors, this bonding agent proved hydrolytically unstable and bond failures were reported during clinical testing, McLean (1987).

The main concern with the use of various resin dentine bonding agents is the possible, limited longevity of the union, because of long-term hydrolytic breakdown at the filler-matrix or tooth interface and, therefore, limitation in strength of the attachment to dentine, McLean (1987), Mount (1989b). The dentine bond may also fail due to stress from high polymerisation shrinkage of the restorative resin matrix, Causton et al. (1985).

Powis et al. (1985) showed that resin bonding agents may be associated with microleakage. The resin composite does not adhere to dentine perfectly and may form a contraction gap between 7.1-21.9 μm at the cervical margin, which can later be invaded by bacteria from the oral environment, and pulpal inflammation can ensue, Brännström (1981), Torstenson and Brännström (1986).

The glass ionomer cements have been used since 1976 and they have shown an excellent success rate in several studies, Mount (1986), Tyas (1992). The measured dentine bond strengths of glass ionomer cement are lower than those for several resin dentine bonding agents, though glass ionomer cements have shown superior clinical longevity. The glass ionomer cements have the advantage of fluoride release, little or no microleakage and are biocompatible with the pulp, Mount (1984).

Some in vitro studies show resin dentine bonding to have superior bond strength when compared with glass ionomer lining cement bonding, Joynt et al. (1988). However, this result may not indicate their long-term relative clinical success, since the tests were conducted in artificial conditions which do not represent the oral situation. When in vitro tests are conducted which attempt to produce physiological intrapulpal pressure, and thus dentinal fluid flow, resin dentine bonding agents usually exhibit considerably lower bonds strengths. However, glass ionomer cement results are largely unchanged, Mitchem and Terkla (1987), Andraeus et al. (1988, 1989), Mitchem and Gronas (1989).

2.5. ADHESION

2.5.1. SIGNIFICANCE

One of the most important properties of glass ionomer cements is that they adhere to moist enamel and dentine. Since percolation of bacteria along the cavity wall/restoration interface is regarded as a cause of pulpal inflammation, Brännström (1981), adhesion has important implications for biocompatibility.

It is uncertain whether the cement penetrates the acquired pellicle on intact enamel or bonds to it, but it does react with the cut dentine. This chemical adhesion allows a conservative approach to restoration, because removal of sound tooth merely to gain mechanical retention is unnecessary in low stress bearing areas, Wilson and McLean (1988). Acid etching or other surface roughening procedures are unnecessary, for the bonding is chemical rather than micromechanical, Wilson and McLean (1988).

2.5.2. BIOCOMPATIBILITY

To achieve maximum adhesion, the glass ionomer cement must be in intimate contact with the dentine and enamel. The use of additional lining materials, such as calcium hydroxide for indirect pulp-capping, should be kept to a minimum, to achieve the maximum surface area of glass ionomer cement bond. Thus, the biocompatibility of glass ionomer cement is of the utmost importance to minimise the need for additional liners.

Despite the low pH of freshly mixed glass ionomer cement, there is only a mild pulpal response. This may reflect both the low mobility of the large polyacrylate molecules which have a propensity for binding to calcium, and the natural buffering ability of dentine. Thus, where there is a reasonable layer of residual dentine (0.5 mm) protecting the pulp, no lining is necessary, Walls (1986), Hume and Mount (1989).

2.5.3. BARRIERS TO ADHESION

Water is the principal barrier to effective adhesion to tooth structure. Organic adhesives are either insufficiently polar to compete with water or, if highly polar, the bond they form is hydrolytically unstable. By contrast, the hydrophilic highly ionic glass ionomer cement competes successfully with water because of its multiplicity of carboxyl groups which form hydrogen bonds with tooth substrate. Water is displaced or even incorporated into the cement, Wilson and McLean (1988).

Another barrier to adhesion is the dynamic nature of tooth material. Wilson and McLean (1988) suggest that, because dentine is a living substrate, any adhesive bond to it must be of a dynamic nature to allow bonds to be reformed if broken. Dentine adhesives fail because their covalent chemical bonds cannot be reformed. By contrast, the glass ionomer cement has ionic and polar bonds which can be re-established, to give the cement its unique property of being permanently adhesive under oral conditions, Wilson and McLean (1988).

There is no consensus of opinion on the precise mechanism of adhesion of glass ionomer cement to dentine. Numerous theories have been postulated, and for more detail refer to Wilson and McLean (1988), and Wilson et al. (1983).

2.5.4. BOND STRENGTH

There are four factors which influence measured bond strengths, Walls (1986):

1. Physical strength of the material.

The strength of the bond to dentine is limited by the cohesive strength of the cement itself since failure is cohesive within the cement, Wilson and McLean (1988).

2. Nature of the substrate.

The tensile bond strength to enamel is greater than to dentine. The bond strength to enamel varies from 2.6 to 9.6 MPa, depending on the material and from 1.1 to 4.5 MPa to cut but untreated dentine, Wilson and McLean (1988).

3. Surface contamination.

Salivary contamination of a freshly prepared untreated dentine surface results in a marked decrease in the bond strength, Aboush and Jenkins (1987). The surface energy of the cement is altered and probably interferes with adequate wetting of the contaminated surface, Walls (1986).

4. Surface treatments (refer next section).

2.6. DENTINE CONDITIONING

A number of research workers have sought to improve adhesion of glass ionomer cement to tooth structure by pretreatment of its surface. McLean and Wilson (1977b) first coined the term "surface conditioning" in order to differentiate this treatment from traditional enamel acid-etching. Conditioning is needed to eliminate the wide variation found in the structure of the tooth surface following cutting. Rough surfaces are contraindicated, since the smoother the surface the stronger the bond, Powis et al. (1982), Aboush and Jenkins (1987). Various surface conditioners have different actions on the tooth surface, but all tend to smooth it giving intimate intermolecular contact and improved wetting which is important for adhesion, Kinloch (1980). Smoothing of surface irregularities prevents air entrapment and minimises sites where stress concentrations may occur, Wilson and McLean (1988).

2.6.1. IDEAL REQUIREMENTS

Mount (1984) suggested that the ideal requirements for a conditioner are the following:

1. Isotonic to minimise osmotic effects.
2. pH ranging from 5.5 to 8.0, that is, broadly neutral.
3. Non-toxic to dentine, pulp and gingival tissues.
4. Compatible with the chemistry of the cement.
5. Water soluble and easily removable.
6. Not deplete enamel and dentine chemically.
7. Enhance the surface chemically in preparation for bonding.

The most effective conditioners are those capable of forming hydrogen bonds with the tooth surface, so aiding wetting. They may also consolidate the smear layer,

Wilson and McLean (1985) and have the potential to react chemically with dentine collagen.

Powis et al. (1982) did the most comprehensive study of conditioners using adhesion tests and SEM. The best agents for improving adhesion were high molecular weight substances with many functional groups: 25% polyacrylic acid, 25% tannic acid, and 0.9% dodicin. Until the inherent tensile strength of the glass ionomer cement is improved, it is impossible to compare adhesion developed by any of these three conditioning liquids.

2.6.2. ACID ETCHING

Surface conditioning must be distinguished from more aggressive dentine etching which causes surface demineralisation and is undesirable for the bonding of glass ionomer cements, Powis et al. (1982). Decalcifying freshly cut dentine opens up and widens dentinal tubules, allowing ingress of bacteria and subsequent pulpal inflammation, Brännström (1981).

2.6.3. CITRIC ACID

The earliest surface conditioner used was citric acid (50%), McLean and Wilson (1977a, 1977b). It may moderately improve adhesion, depending on the type of glass ionomer cement used. Powis et al. (1982) found its effect to be drastic. It heavily etched enamel, removed the dentine smear layer and opened up dentinal tubules.

Any advantage which may have been gained due to micromechanical attachment to the opened up tubules was offset by decreased chemical adhesion from demineralisation. The rough etched surfaces also entrapped air, thus weakening adhesion. Tobias et al. (1978) found that the use of citric acid gave an increased inflammatory response to glass ionomer cement which may result in an irreversible pulpitis. Therefore citric acid is contra-indicated as a surface conditioner. (If it is to be used, Brännström (1981) recommends a treatment time of only five seconds with 50% citric acid solution.)

2.6.4. SURFACE-ACTIVE AGENTS - DODICIN

Dodacin is a surface-active detergent containing fluoride which is not chemically compatible with the cement, but which is readily washed off.

Dodacin, by itself or as a component of the old-style Tubulicid formulation, smoothes out grooves and reduces the smear layer without opening up tubules, Powis et al. (1982). It is approximately neutral and can be applied for 60 seconds.

2.6.5. POLYACRYLIC ACID

Mount (1989d) recommends application of an aqueous solution of 10% polyacrylic acid conditioner for only 10 seconds since it is acidic and complexes metal ions and therefore has a decalcifying effect. Prolonging exposure to the acid will chemically leach the surface of the dentine depriving the union of some of the required calcium and phosphorous ions, thus decreasing bond strength. Its action is less drastic than that of citric acid, but it does etch enamel slightly while removing polishing marks. On cut dentine it removes surface debris (smear layer) and smooths out surface irregularities, although it does open up dentinal tubules, Powis et al. (1982). Any slight residue of the acid left behind is compatible with the cement itself and will not interfere with the chemistry of adhesion, McLean and Wilson (1977a).

Wilson and McLean (1988) are concerned that the opened tubules could allow movement of water and cause sensitivity, especially with the high pressures generated with the use of luting cements. However, polyacrylic acid has a high molecular weight and will not readily penetrate the tubules, and pressure is not a concern with glass ionomer cement bases used in the Sandwich Technique.

2.6.6. POLYACRYLIC ACID WITHIN THE CEMENT

Several studies have shown that the increase in bond strength with polyacrylic acid conditioning is not statistically significant, Beech et al. (1985), Caples et al. (1988).

Beech and co-workers state that the polyacrylic acid of the mixed cement will dissolve or incorporate the smear layer just as effectively as a separate application of

polyacrylic acid prior to cement placement. This assumes that the smear layer is composed simply of hydroxyapatite debris. Mount (1989d), asserts that this is an invalid observation for the clinical situation.

2.6.7. TANNIC ACID

Tannic acid is an organic tanning agent that reacts with collagen, and Powis et al. (1982) found 25% tannic acid in aqueous solution applied for 30 seconds to be as effective a conditioner as polyacrylic acid. It does not etch or decalcify, and serves to consolidate the smear layer, Vaidyanthan et al. (1984). A smooth featureless layer is formed on dentine and the tubules are not opened; in effect, forming a protective lining layer. For this reason, Wilson and McLean (1988) consider tannic acid to be the material of choice where large areas of dentine are involved, as in crown preparations. However, since tannic acid adheres to the smear layer the tensile strength of the bond achieved is limited by the low strength of the smear layer.

2.6.8. FERRIC CHLORIDE

A 2% aqueous/alcohol solution of ferric chloride causes extensive fissuring of enamel because it has a stronger acid effect than phosphoric acid, Powis et al. (1982). It has a very favourable effect on dentine giving a high bond strength. However, it cannot be recommended until it is prepared in a less acidic form, Wilson and McLean (1988).

2.6.9. MINERALISING SOLUTIONS

Causton and Johnston (1982) found that a calcifying solution such as ITS (isotonic solution) solution applied for two minutes enhanced bonding. The object was to increase the concentrations of calcium and phosphate ions within the smear layer. It was more effective for zinc polycarboxylate cement than for glass ionomer cement.

ITS solution is considered reasonably ineffective in its present form, Beech et al. (1985).

2.6.10. EDTA (ETHYLENE DIAMENETETRA-ACETIC ACID)

EDTA is an extremely powerful complexing agent with an effect broadly similar to that of citric acid. It is a decalcifying agent which reduces the bond strength of glass ionomer cement. It also attacks the cement matrix and is therefore incompatible with it, Wilson and McLean (1988).

2.6.11. MARGINAL LEAKAGE

The significance of the improved adhesion of glass ionomer cement, is that biocompatibility with tooth substance is improved because of the efficient dentine seal. A gap at the margin between restoration and cavity wall may result in ingress of bacteria and chemicals, and subsequent secondary caries, Wilson and McLean (1988). There has been much controversy regarding the numerous conflicting results obtained when testing the microleakage of various restorative materials. Many studies which use dye diffusion, show glass ionomer cement to exhibit much microleakage, especially with silver nitrate which has a high affinity for glass ionomer cement. However, Powis et al. (1985) found that glass ionomer cements effected a permanent seal against the diffusion of sucrose for at least a year. No other restorative material was as effective, and all, including composite applied to etched enamel, allowed leakage to some extent.

One of the main advantages of using glass ionomer cement is its ability to adhere chemically to tooth structure, which makes it extremely useful for restoring lesions where little or no inherent mechanical retention exists, Powis et al. (1982). Glass

ionomer cement adheres to reactive substrates such as enamel, dentine and base metals. Adhesion is due to ionic forces at the interface. Polyanions such as carboxylate groups from the glass ionomer cement displace phosphate groups, thus penetrating the apatite surface. This mechanism occurs most effectively when there is intimate intermolecular contact, and thus effective wetting of the tooth surface is required. A clean tooth surface gives a low surface tension which, together with a low viscosity glass ionomer cement with an affinity for the tooth structure, will aid the wetting process. Contaminants weaken the bond since they act as a weak intermediary layer, Mount (1991).

2.7. ETCHING GLASS IONOMER CEMENTS - PHYSICAL EFFECTS

2.7.1. ETCHING GLASS IONOMER CEMENTS

On exposure to acid, glass ionomer cement undergoes erosion with loss of matrix into the eroding solution. Attachment of composite to a glass ionomer cement is best achieved when acid etching removes just enough soluble polyacrylate matrix material to leave the unreacted glass particles proud on the surface, Wilson and McLean (1988). The matrix, containing calcium and aluminium ions for salt formation, is comparatively weak in the early stages of set and particularly prone to moisture contamination. For this reason, etching should be restricted to the minimum period to remove enough matrix to provide mechanical retention while preserving the strength of the underlying cement. Etching with a solution of 37% phosphoric acid for 10-30 seconds is generally recognised as optimum to achieve good bonding. The ability of citric acid to etch set glass ionomer cement is only a little better than the erosion caused when washing the surface with water, and therefore citric acid is an unsuitable etchant, Causton et al. (1987).

Etching glass ionomer cement with 37% phosphoric acid for 30 seconds generally gives an effect similar to the etching of enamel. Mount (1989d) suggests that the set cement should firstly be gently trimmed with fine diamond points to expose the enamel walls and to remove the matrix rich surface layer before etching. This will leave a surface with some glass particles, and voids or indentations in other areas. After etching, the cement will be chemically clean of debris and will have a high surface energy which is ideal for maximum wetting by the resin bonding agent.

The cement should not be left exposed to air for more than 15 minutes otherwise dehydration and cracking may occur. If etchant is applied to a thin, cracked cement lining then acid may directly attack the dentine, possibly causing post-insertion sensitivity.

2.7.2. PROBLEMS WITH LABORATORY OBSERVATIONS

Studying the Sandwich Technique in vitro presents several problems which are less likely to occur in the mouth. Glass ionomer cements require humid conditions. They tend to dry out and crack or craze on the laboratory bench, and especially when placed under vacuum in the scanning electron microscope, unless the cement is fully mature, McLean et al. (1985). For this reason Fuss et al. (1990) stored their samples for at least 1 week before preparation for SEM examination. This is time consuming and may be impractical and, therefore alternatively, examination may be done by dissolving away the glass ionomer cement under the composite, using concentrated hydrochloric acid, to examine the interface between glass ionomer cement and resin composite. The composite surface can then be examined directly without replication. The last alternative is to examine a positive replica by taking an impression of the glass ionomer surface, Causton et al. (1987).

It is also difficult to compare various studies, because each study exposes the glass ionomer cements to different conditions i.e. powder:liquid ratio and thickness of cement sample, setting time before exposure to etch, etching time, and humidity of the environment.

2.7.3. SURFACE EFFECTS

Several studies have made SEM observations of the glass ionomer surface following acid etching, McLean et al. (1985), Garcia-Godoy and Malone (1986, 1987), Fuss et al. (1990), Smith (1988).

Unetched glass ionomer cement specimens are found to have varying degrees of surface roughness and porosity due to incorporation of air during mixing. This is particularly evident if the matrix-rich surface layer is removed. Unetched Ketac-Bond is rougher than the G.C. Cement surface, with striations and voids up to 50 μm . Hand-mixed materials are found to have more porosity than mechanically mixed materials.

Resin composite which has been in contact with glass ionomer cement protrudes into voids and invaginations on the cement surface, and this gives a mechanical interlock in the case of both etched and unetched glass ionomer cement. Acid etching produces a mechanically more retentive surface. However, at present it has not been definitely established whether acid etching is necessary.

Etching with phosphoric acid causes erosion of the surface. Initially the gel matrix is dissolved forming new voids and leaving clusters of glass particles standing proud. As etching time progresses, these glass particles appear cleaner with less residual matrix being present on their surface. Also, sharp features become rounded, including edges of air entrapment voids, and larger particles lose their definition. As more matrix is removed, some of the glass particles are lost and crack propagation begins to occur. Eventually the material is virtually destroyed.

2.7.4. ROLE OF WATER

Water has two roles in the setting of glass ionomer cements; as a medium for action transport, and to hydrate the matrix salts, Wilson and McLean (1988). If water is lost during setting the cement-forming reaction stops. Aluminium ion cross-linking is most important for the ultimate strength of the glass ionomer cement. Once aluminium ions become bound in the cement matrix, they are difficult to leach out. During the early stages of setting, ions are susceptible to diffusion from moisture contamination, and can be lost from the cement and are unable to cross-link with the polyacrylate chains, Mount (1984). As cement ages, the degree of hydration increases i.e. the ratio of tightly bound to loosely bound water increases. During the early stages of setting, the loosely bound water may be easily lost and cannot contribute to the final strength of the material.

Damage from early water uptake is likely to penetrate rapidly through a considerable depth of the cement, thus reducing its physical properties and translucency, Mount and Makinson (1982). Exposure to air and consequent dehydration in the early minutes is likely to cause cracks and crazing which will propagate through a considerable depth. Excess dehydration will rapidly remove water needed for setting and hydration, and therefore reduce the ultimate strength. Excess water will penetrate the weakened polysalt matrix and invade any craze areas.

Reinforced restorative cements (silver cermets), the lining cements and some of the luting cements achieve a degree of maturity where they are resistant to hydration within six minutes from the start of mix, Mount (1989d). During this time, the setting glass ionomer cement must be protected from both desiccation and fluid contact, by being maintained in an environment of approximately 80% relative humidity, Wilson and McLean (1988). A similar, fluid-free environment is necessary for composite placement.

Rubber dam usage varies. Wilson and McLean (1988) do not recommend its use for fear of cement dessication, but Garcia-Godoy (1986) and Mount (1989d) certainly recommend it to avoid saliva contamination. These operators have all reported excellent clinical results.

The fast setting glass ionomer cements are resistant to damage from water uptake soon after setting. However, they remain prone to damage from dehydration for possibly six months and, if teeth are isolated with rubber dam during this later period, exposed surfaces of glass ionomer cements should be protected by an application of an unfilled resin. Dentine bonding agents should not be used for this purpose because they tend to produce a non-protective porous film, Mount (1988a).

2.7.5. SETTING TIME

The rate of setting reaction is slow and varies greatly for different types and brands of cements. In the early stages of set, glass ionomer cements are particularly prone to moisture contamination because the matrix is comparatively weak. The higher the strength of the cement, the better is the clinical result. A slow setting Type II.1 restorative aesthetic glass ionomer cement will be considerably weakened if etched prematurely because excess water will remove calcium ions required for salt formation. Fast-setting cements that can be etched after two to five minutes require higher alumina content in the glass and are therefore more opaque. The more translucent materials, such as the Type II.1 restorative aesthetic cements, are slower setting due to the lower alumina/silica ratio and therefore require a setting period of at least eight minutes prior to acid etching. For these reasons the ideal glass ionomer cement for universal use in the Sandwich Technique is difficult to produce, Wilson and McLean (1988).

2.7.6. ETCHING TIME

Attachment of composites to a glass ionomer cement is best achieved when acid etching is restricted to the minimum period required to remove just enough matrix material to leave the unreacted glass particles proud on the surface. This provides a surface that is mechanically retentive while preserving the strength of the underlying cement.

Etching with a solution of 37% phosphoric acid for 10 to 30 seconds is generally considered as the optimum time to achieve good bonding, Quiroz and Lentz (1987), Smith and Soderholm (1987), Fuss et al. (1990), Kanca (1988). This is generally a sufficient period to achieve a good etch pattern on the enamel as well.

There are numerous glass ionomer cement brands available on the market and not all respond the same to etching, as was found by Fuss et al. (1990). Numerous brands were tested under identical conditions. For most, a 15-second etch period was adequate to remove an apparently satisfactory degree of matrix from around the glass particles, without penetrating too deeply or removing too much of the cement. Beyond 15 seconds, most materials lost an excessive amount of matrix and some glass particles. However, the remaining glass particles appeared cleaner and, it may be for this reason, that some workers and manufacturers have recommended longer etching periods. Fuss et al. (1988) and Smith (1988) both found that many glass particles were lost and the cement surface appeared nearly destroyed after acid-etching for 60 seconds. Ketac-Silver was more resistant to etching and showed a better etch pattern with a 30 second etch or greater. It was postulated that the fine, sintered silver particles may make the glass ionomer cement more resistant to etching, Fuss et al. (1990).

2.7.7. CEMENT THICKNESS

The thinner the cement lining the more likely damage will occur during acid etching. A thin lining may bond to the composite but stress at the interface may cause a cohesive failure at the dentine bond, Shortall and Wilson (1988), Wilson and McLean (1988). Penetration of acid through the cement and into dentine will not occur if the cement thickness is not less than 0.5 mm, Tjan and Glancy (1989). Glass ionomer cement should be used as a "dentine replacement" rather than as a thin wash, McLean et al. (1985). The cement will be stronger, provide a better surface for acid etching, and will not fail because of high stress from the shrinking composite. By increasing the bulk of glass ionomer cement and reducing the bulk of composite, it is more likely that a stable bond will be achieved. For these reasons it seems that cement thickness should be 0.5 mm or greater, Wilson and McLean (1988). If a thinner lining is used, it should not be etched, McLean (1988). Most of the recommendations are empirical and only a few are backed up by laboratory studies.

2.7.8. RADIOPACITY AND TRANSLUCENCY

Radiopacity in a lining cement is valuable for detection of subsequent microleakage and secondary caries under the restoration. Reinforced restorative glass ionomer cements such as Ketac-Silver, Chelon Silver (Espe GmbH) and Miracle Mix (G.C. Int.) are the most radiopaque followed by the lining cements which are moderately radiopaque, Prevost et al. (1990). Where aesthetics is important, the fast-setting lining cements can be used. Where strength is critical, the more translucent and stronger Type II .1 aesthetic restorative cements are preferred, even though there is an increased time factor in placement to be considered, Wilson and McLean (1988).

2.8. GLASS IONOMER CEMENT SUITABILITY FOR SANDWICH TECHNIQUE

2.8.1. GLASS IONOMER CEMENT BRAND SUITABILITY

The ideal glass ionomer cement for use with the Sandwich Technique is very difficult to produce, Wilson and McLean (1988). Fast-setting cements that can be etched after two to five minutes require higher alumina content in the glass and therefore are often more opaque.

Different glass ionomer cements have considerably different physical properties. They are greatly influenced by the powder:liquid ratio in the mix. The powder:liquid ratio prescribed by the manufacturer is generally regarded as optimal and should be carefully adhered to. It is desirable to have a high powder:liquid ratio to give the best compressive and tensile strengths and to decrease the setting time. Capsulated materials give a higher and more consistent powder:liquid ratio and produce less porosity i.e. the bubbles are smaller and more regular, Mount (1989d). However, variation in speed of vibration of the mechanical mixer can adversely affect working time, Bass and Wing (1988). A higher number of cycles per minute produced by one brand of high-speed mixer resulted in excessively short working times of capsulated Ketac Fil mixed for 15 seconds.

There are many cements available on the market which are advocated for use in the Sandwich Technique. However, it would appear that not all of these are entirely suitable. Three materials tested were found unsuitable for etching because they expanded and distorted on setting: Ionobond (Voco), Ceram Chem and Ceram Core B (PSP Dental). It was postulated, that this effect may have occurred because there were a number of porous particles, Fuss et al. (1990).

2.8.2. TYPES OF GLASS IONOMER CEMENTS

The aesthetic restorative materials are relatively slow setting, taking 24 hours to attain maximum physical properties, and many are radiolucent. Mount (1989d) concluded that, after four minutes from the start of mixing, they are too susceptible to water uptake to polish. Although the matrix can be removed, they must be protected from both water loss and uptake. Early water absorption will penetrate deeply and will adversely affect their physical properties. If etched prematurely, excess water will remove calcium ions required for salt formation. Dehydration will cause deep cracks. Despite their drawbacks, these materials have the best translucency of all glass ionomer cements and should be used where aesthetics is a major concern, and where space is limited.

Ketac-Fil, an aesthetic restorative capsulated material, is the strongest chemically-cured glass ionomer cement of those most commonly used in Australia. It has a tensile strength of approximately 7 MPa, Mount (1989b). Ideally, it should be left for 24 hours before veneering. However, 10-20 minutes from the start of mixing allows sufficient maturation for this cement to be etched without adversely affecting properties, apart from translucency. Four minutes from the start of mixing it should be protected by a resin bonding agent such as light-cured Visio-Bond, to seal the cement and prevent hydration and dehydration. This bonding agent is removed before etching, Wilson and McLean (1988), Mount (1989d).

It is suggested that Fuji II is slower setting and requires approximately 60 minutes from the start of mix to reach sufficient maturity to be etched. It may be etched sooner but, a reduction in strength of the bond may result, Mount (1989a).

The reinforced restorative materials (silver cermets), the lining cements and some of the luting cements are mature early enough to be resistant to water movement within 6 minutes and can be etched at this stage.

Some of these cement materials are radiopaque, which is an advantage, but they have poor colour which may be undesirable in areas where aesthetics is of prime concern. The fast setting lining materials may also be used provided they can be covered by at least 1 mm of composite in thin areas, Wilson and McLean (1988). Wilson and McLean (1988) state that more recently (in 1986), the poor colour of and tooth staining by Ketac-Silver has been improved and is now more acceptable. Therefore, these materials should be used where radiopacity or fast set is required. They show early resistance to water uptake, but will dehydrate if left exposed to air longer than 15 minutes from the start of mix.

Many glass ionomer cements have a low tensile strength because they are mixed by hand at a relatively low powder:liquid ratio. Also, hand dispensing can give a large variation in weight of powder and hence the powder:liquid ratio. Therefore, it is recommended that capsulated materials giving a consistent high powder:liquid ratio be used, Mount (1989d). More recently, a capsulated lining cement (Ketac-Bond) has also become available, as well as Fuji Cap II aesthetic restorative (radiopaque) cement.

2.8.3. FRACTURE TESTING

The tensile strength of glass ionomer cement is less than the strength of the bond between acid-etched glass ionomer cement and composite, and therefore the true bond strength at the interface cannot be measured until the tensile strength of glass ionomer cement is improved, Kahlife et al. (1988), Wexler and Beech (1988), Mount (1988b & 1989d).

The glass ionomer cement with highest tensile strength is the material of choice where strength is important.

McLean et al. (1985) used the three-point flexural test to assess the fracture strength between Visio-Dispers (Espe GmbH) composite bonded to Ketac (Espe GmbH) glass ionomer cement, using Visio-Bond liquid bonding resin. The range of fracture strength was 7.8-12.4 MPa for etched glass ionomer cement specimens, with a mean value of 10.25 +/- 1.61 MPa. Fracture usually was cohesive within the glass ionomer cement itself. This is not surprising since glass ionomer cement has a low tensile strength. For unetched glass ionomer cement specimens, the bond fracture strength was 6.5 +/- 3.10 MPa. Therefore, etching of glass ionomer cement gave greater tensile and shear bond strengths than for unetched specimens.

Tensile bond strength can vary widely from 0.3 - 14.7 MPa, depending on the combination of glass ionomer cement, composite and surface treatment used, Calamia et al. (1986), Hinoura et al. (1987b), Chin and Tyas (1988).

Ketac-Fil was found to have the highest inherent tensile strength. Ketac-Silver, a Type II.2 reinforced restorative, had the second highest inherent tensile strength and therefore, bond strength to dentine and composite, Hinoura et al. (1987b), Mount (1989a). The remainder all had similar low order tensile strengths of about 2-3 MPa and included: Ketac-Bond (lining hand-mixed), Fuji II (aesthetic restorative), G.C.

Lining (lining), Fuji II and Lumi Alloy (reinforced restorative), and Chemfil II (aesthetic restorative). Ketac-Bond has been found to produce a consistently higher shear bond strength to composite than G.C. Lining Cement, Hassan and Nathanson (1987), Garcia-Godoy et al. (1988a), Draheim et al. (1987).

2.8.4. ACIDITY OF BONDING RESIN

In general, acid etching of glass ionomer cement markedly improves composite bond strength, Hinoura et al. (1987b). Merely grinding the surface enhances bond strength, but not to the same degree as acid etching. However, several studies have found no statistical difference between etching, not etching or a simple wash with water only, Garcia-Godoy et al. (1988b), Sheth et al. (1988), Welbury et al. (1988). It is interesting to note that in one case Hinoura et al. (1987a) found acid etching to have no added effect, which led them to presume that a chemical bond occurred between certain composites and glass ionomer cements. Wilson and McLean (1988) state that a more likely explanation is that the bonding resin itself is acidic and therefore etches the surface. This was confirmed by a later experiment by Hinoura et al. (1989b) where bond strengths to unetched glass ionomer cements were tested. It was found that the bond strengths decreased as the time lapse between the end of mix and application of the bonding agent, increased. As the glass ionomer cements became more mature, they became more resistant to the etching effect of the acidic bonding agents.

2.9. BONDING COMPOSITE RESIN TO GLASS IONOMER CEMENT

2.9.1. LIMITATIONS

Glass ionomer cement and composite effectively form a mechanical bond to one another, but there are limitations to the system. The tensile strength of glass ionomer cement when properly placed, is generally the point of failure of the Sandwich Technique restoration.

The higher the tensile strength of the cement, the better the clinical result will be, providing a low-contact-angle bonding resin is used and the cement is completely wetted by the resin. Good penetration of the acid-etched surface of glass ionomer by the bonding resin is dependent upon wettability. The composite shrinks rapidly on setting and subsequent dimensional changes may occur as a result of thermal changes in the mouth.

2.9.2. DESIRABLE PROPERTIES OF BONDING AGENTS

Causton et al. (1987) observed that when intermediate resin was not used, very poor wetting by the composite occurred and the fracture was adhesive. Bonding agents gain mechanical interlock by filling voids left on the surface of the etched glass ionomer cement and surrounding exposed glass particles. Causton et al. (1987) suggest that the infiltration of resin may actually strengthen the cement in the immediate vicinity of the bond, since tensile fracture occurred 1 mm from the bond interface.

The best union is achieved by agents that have a low viscosity, and thus high wettability and low contact angle, Hinoura et al. (1987a). Mount (1987, 1989d) observed that, when using certain composite resins and their prescribed bonding resins, failure was adhesive in the union rather than cohesive in the cement. This

was attributed to the high viscosity of some of the bonding resins. Bonding agents, such as Scotchbond (3M Dental Divis.) which are two part systems requiring to be mixed, become more viscous with time and therefore should be mixed fresh for each restoration placed. In general, dentine bonding resins produce a non-protective porous film and are therefore not recommended, Mount (1988a). This may partly explain the result in a study conducted by Sheth et al. (1988), where the tensile bond strength of resin to etched and unetched glass ionomer cement surfaces was comparable when Scotchbond was used. The mode of fracture was not examined.

It is recommended that excess bonding agent be removed before curing, by air thinning to avoid pooling. Bonding agents which have to be freshly mixed have an evaporative vehicle which may fail to completely evaporate, resulting in porosity. Prevost et al. (1982) suggest that bonding agents in some studies do not show a complete seal. This may be due in part to the volatility of the bonding agent. Hinoura et al. (1986) postulated that bond strengths may be enhanced by chemical reaction between bonding agent and cement.

2.9.3. DIMENSIONAL CHANGE OF COMPOSITE AND GLASS IONOMER

Glass ionomer cements have minimal shrinkage providing they are in a humid environment, Wilson and McLean (1988). Goldman (1983) found that composite polymerisation shrinkage was in the range from 1.67 to 5.68 vol. per cent which can be severe enough to produce cusp distortion, bond failure, microleakage and post-operative sensitivity, Causton et al. (1985), McLean (1987). In the Sandwich Technique the volume of composite used is less because of the thick glass ionomer cement base, and therefore it has been postulated that the effect of composite shrinkage may be reduced. The adhesive bond of glass ionomer cement to dentine survives contraction stresses better than composite bonded directly to dentine, because of the more favourable flow characteristics of the cement, Feilzer et al. (1986). The overall shrinkage stress in glass ionomer cement reaches only approximately 40% of the value for composite used with dentine bonding agents.

Mount, (1989d) found that setting shrinkage places stress on the glass ionomer cement/composite bond. The amount of shrinkage on setting can be ideally kept to a minimum by selecting a composite with a high filler content. Lightly-filled microfil resins show greater curing shrinkage than heavily-filled hybrid materials or small particle size resins.

If the direction of cure in the composite is away from the gingival margin, then it is possible, in vitro, to break the marginal seal by physically lifting the glass ionomer cement away from the dentine. Curing from interproximal directions reduces gingival margin shrinkage and marginal gap formation. The use of a transparent plastic matrix and light transmitting wedges is also recommended, Ironside (1988).

Incremental build-up can reduce problems due to shrinkage of a large bulk of material. Composite can also be pulled away from the cavity if it sticks to the packing instrument. This may account for some post-insertion sensitivity. In a study

by Marshall et al. (1982) it was found that the glass ionomer cement could interfere with polymerisation of the composite and could plasticise the set resin. This resulted in a decreased hardness of the composite.

Dimensional change of the composite as a result of thermal stress can also place stress on the bond between resin and the cement, as well as on the enamel bond. The coefficient of thermal expansion for composites is relatively high. Thermal cycling in vitro will produce a range of expansion and contraction, and microleakage may result. More highly-filled resin systems have a reduced co-efficient of thermal expansion, Craig (1985).

2.9.4. RESIN COMPOSITE MATERIALS AND BONDING AGENTS

The unfilled bonding resins supplied by the manufacturer are generally described as low viscosity but their actual viscosity varies, Mount (1989a). If the resin fails to wet the cement surface adequately, then a weaker bond strength will result. Failure will then be adhesive and may explain the unexpected results seen in some studies. Welbury et al. (1988) showed no advantage in tensile strength when the glass ionomer cement was acid etched, compared to a one minute wash with water only.

In general, the microfilled composites will shrink more than the heavily filled hybrid or small particle-size resins, so that in the posterior region, the lower shrinkage materials should be used. In the anterior region the volume of the composite veneer is generally less, so that the more translucent and aesthetic microfilled composites can be used with safety, Mount (1989a).

Other limitations of composites include long-term hydrolytic breakdown at the filler-matrix or tooth interface, and surface wear may flatten contact areas. By contrast, amalgam alloy, because of its metallic nature, has a low coefficient of friction which produces a very slow rate of clinical wear and thus gives good occlusal stability. Composites are also technique-sensitive and more time consuming to place than amalgam alloy, Hendriks and Letzel (1986), McLean (1987),.

A. HYBRID MATERIALS

Visio-Fil (Espe GmbH) used with Visio-Bond as the bonding agent, gives good in vitro bonding results. It exhibits a marginal, but statistically insignificant, increase in the tensile strength of the sandwich restoration compared to the strength of glass ionomer cement on its own. Failure is still cohesive within the glass ionomer cement.

Two other hybrid composites Prisma-fil (L.D. Caulk) and Aurafill (Johnson and Johnson) are less suitable for use in the Sandwich Technique, probably due to the high viscosity of their bonding agents (Prisma-Bond and Aurabond). Since the agents have very high contact angles, they gave low bond strengths, and failure was found to be adhesive through this interface, unlike most other systems, Mount (1989a).

B. MICROFIL RESIN COMPOSITES

These were found to have low strengths, and are the only group of materials which exhibited cohesive failure within the resin itself, Mount (1989a). Due to their high curing shrinkage, they place a high stress on the bond and are therefore least desirable for use in the Sandwich Technique.

C. POSTERIOR RESIN COMPOSITES

The posterior composites exhibit a wide variation in the strength of the bond with glass ionomer cements. The standard deviation is quite large, due to the presence of many voids and difficulty in adapting the composite resin to the glass ionomer cement (even in "ideal" laboratory studies). The resin composite tends to stick to the packing instrument and is pulled away from the cement.

Visio-Molar and P-30 (3M Dental Divis.) are hybrid composites which give reasonably consistent bonding results, and adapt best to the cement surface when used with their respective bonding agents Visio-Bond and Scotchbond. Despite having a low viscosity bonding agent (Sinter-Bond), Sinterfil (Teledyne-Getz) exhibits a very wide range of bond strengths, ranging from results comparable to the best materials, to the weakest, Mount (1989a).

2.10. DESCRIPTION OF TECHNIQUE FOR OPTIMUM RESULTS

2.10.1. CAVITY PREPARATION

Garcia-Godoy (1986) and Mount (1989d) suggest that rubber dam should be used to prevent moisture contamination of the glass ionomer cement and etched surfaces. However, Wilson and McLean (1988) feel that rubber dam is unnecessary where adequate moisture control is possible, since the humid condition of the mouth is useful to prevent the dehydration of the cement.

A small tungsten carbide bur is used to prepare a small cavity just large enough to remove the carious lesion. No retentive elements need be placed in the cavity, Garcia-Godoy (1986). With Class V cervical erosion-abrasion lesions, the surface is just cleaned with pumice and water slurry and on a rubber cup.

If the cavity is very deep, leaving less than 0.5 mm of dentine covering the pulp, then a calcium hydroxide lining is placed over the region of the pulp, otherwise no lining is necessary. Covering large areas of dentine with calcium hydroxide should be avoided because it decreases the dentine surface area available for glass ionomer cement adhesion.

2.10.2. CONDITIONING

Fifteen per cent polyacrylic acid liquid is applied for 10 seconds, Garcia-Godoy (1986), Wilson and McLean (1988), and then rinsed thoroughly with air-water spray for 20-30 seconds, Garcia-Godoy (1986), and dried, but not excessively. In cases where extensive areas of dentine are involved Wilson and McLean (1988) prefer a 25% tannic acid solution applied for 30 seconds.

2.10.3. GLASS IONOMER CEMENT PLACEMENT

The glass ionomer lining is hand-mixed with as high a powder:liquid ratio as possible or, ideally, premeasured capsules are mechanically mixed.

At least 0.5 mm thickness of glass ionomer cement is placed over the entire dentine surface whenever possible to prevent destruction of the cement during acid-etching. When a cermet lining is placed in the posterior region, it may be extended 2 mm from the cervical aspect of a Class II proximal box if the gingival margin is in cementum, to provide a cariostatic seal and reduce the volume of composite applied approximately, Wilson and McLean (1988).

2.10.4. SETTING TIME

Wherever high stresses are involved, stronger cements are recommended such as the Type II.1 aesthetic restorative and Type II.2 reinforced restorative (cermet) cements. Where radiopacity is required, a silver cermet should be used for the posterior restorations and a radiopaque fast-setting lining cement for the anterior restorations. The cermets should be allowed to set for a minimum of five minutes prior to etching, and the fast setting lining cement for a minimum of three to four minutes. Regardless, however, the cement should be clinically hard to firm probing before etching, Wilson and McLean (1988).

Where optimum aesthetics is required and there is limited space for the composite veneer, a Type II.1 aesthetic restorative cement is used. A minimum setting period of eight minutes prior to a reduced etching period of ten to fifteen seconds is recommended, Wilson and McLean (1988). Alternatively, the cement may be allowed to set for 24 hours to develop maximum strength before etching, Mount (1989d). In any case the aesthetic restorative cements should be protected with a light-cured unfilled low viscosity resin bonding agent at approximately four minutes

after the start of mixing, Lim et al. (1987) demonstrated that the protection from water contamination using a varnish was superior to that using low viscosity resin.

2.10.5. ETCHING

Glass ionomer cements are allowed to set undisturbed prior to acid etching, Wilson and McLean (1988).

Mount (1989a) recommends gently trimming excess glass ionomer cement from the enamel margins with a fine diamond point under air/water spray, after it has set. The glass ionomer cement and enamel walls are etched with a 37% phosphoric acid gel or liquid for 15 seconds usually, but 30 seconds for Ketac-Silver. The tooth is rinsed with water for 30 seconds and then dried carefully to provide a high energy surface for wetting with the bonding resin.

2.10.6. RESIN SEALANT APPLICATION

A low-viscosity light-cured bonding resin is applied and cured immediately after drying the cement, to prevent contamination. Pooling is avoided by removing resin excess with a gentle stream of clean, dry compressed air. A visible-light-cured composite is placed and cured in increments over the etched glass ionomer cement lining and enamel. The occlusion is adjusted after removal of the rubber dam, if used.

2.11. CLINICAL APPLICATIONS

No dental restorative material is perfect, and now there is greater emphasis being placed on appearance. Attempts to replace amalgam alloys with more aesthetic tooth-coloured materials have not yet completely succeeded, although considerable progress have been made, McLean and Gasser (1985). Despite considerable progress in refining both resin and filler systems, bonding agents and placement techniques, certain problems still exist with the use of resin composite. Shortcomings are seen regarding dentine microleakage and hydrolytic instability. On the other hand, the main limitations of chemically-cured glass ionomer cements are relatively poor fracture and abrasion resistance, thus limiting their use in supporting occlusal loads, which may be a concern in Class I and II preparations, Mount (1989d). The cements are unsuitable for class IV preparations.

McLean (1987) thought that the properties of the current composites and glass ionomer cements were inadequate for replacing amalgam alloy in the Class II cavity design when a conventional cavity design was used. Modified cavity designs are being tested where greater reliance is placed on adhesion of the restoration to the remaining tooth structure, thus avoiding the need for excessive removal of tooth substance to gain mechanical retention, Mount (1989d). When new approaches are used, amalgam alloys can be replaced with the Sandwich Technique. Where the diagnosis of caries is made before enamel destruction is severe, minimal cavity preparation can ensure a low stress-bearing restoration, McLean (1987). Thus, the Sandwich Technique has numerous applications.

2.11.1. CLASS I

The preventive resin restoration (PRR) described by Simonsen and Stallard (1977) is now a well-established procedure and is considered an alternative to the more invasive approach of Class I amalgam preparations. Early carious lesions are restored with minimal removal of unrestored tooth structure. A conservative cavity is filled with resin composite and adjacent unrestored pits and fissures are protected from later carious attack with resin sealants. The use of glass ionomer cement in an analogous manner has been described by Garcia-Godoy (1986).

When using glass ionomer cement, a fissure filling approach may also be used, which involves cutting an occlusal cavity preparation only where carious dentine is present, and the remaining fissures are then merely widened with a very fine tapered diamond point. The glass ionomer cement is inserted under pressure and then excess material is trimmed back following the initial set.

2.11.2. CLASS II

The Sandwich Technique may be used in association with the tunnel preparation for restoration of the early interproximal lesion. The occlusal access channel may be widened but not to encroach upon the strong peripheral ring of enamel, thus leaving the marginal ridge intact (for further details refer Wilkie "Essay on The Tunnel Preparation" (1989)). Ketac-Silver is preferred for restoring the approximal area exposed to the mouth to avoid erosion and wear, and because the material is strongly radiopaque, McLean (1987). Bassiouny et al. (1989) suggest that a combination of Ketac-Silver which is veneered occlusally with composite produces the best seal of both the occlusal access cavity and the proximal enamel lesion in tunnel preparations.

Where the extent of the caries is such that the marginal ridge is lost, adhesive restorative techniques (including the Sandwich Technique), may increase the in vitro fracture resistance and restore the structural integrity of the tooth, McCulloch and Smith (1986). The presence of a glass ionomer cement base significantly increases resistance to in vitro cuspal fracture in large Class II cavity preparations, Halverson and Hamilton (1987). The marginal adaptation, wear resistance and sensitivity of the tooth with a Class II resin composite restoration may be influenced significantly by the physical properties of the underlying base material. An interesting result was reported following an in vitro investigation by Krejci et al. (1988), where better proximal marginal adaptation of MOD resin composite restorations occurred with an unetched as opposed to an acid-etched glass ionomer cement base. Also, a reduced amount of lingering stress in the restoration was noted using a thicker glass ionomer cement base, thus giving a reduced volume of composite, combined with a multi-step technique, Goetsch et al. (1989). This may not be relevant to the clinical situation.

2.11.3. CLASS III

The Sandwich Technique restoration is particularly useful for the very large Class III restoration. The glass ionomer cement is used to totally seal the dentine. The composite is useful to restore enamel aesthetics if required.

2.11.4. CLASS IV

Since glass ionomer cements are brittle materials, lacking high flexural strength, it is important that they are not placed in high tensile stress bearing areas. Resin composite should be used in these areas, gaining flexural strength from the enamel bond. Glass ionomer cement is used as a lining or dentine replacement and will withstand compressive forces only, Wilson and McLean (1988).

In the event of trauma to an incisal tooth edge, it is possible to protect exposed dentine with an aesthetic restorative glass ionomer cement as an emergency measure. At a later date, a composite may be used to build up the remainder of the tooth, Mount (1989c).

2.11.5. CLASS V

While the use of the acid-etch enamel has reduced the need for retentive cavity preparation for resin composite, a total dependence on the enamel bond is inadvisable in some situations, such as cervical abrasion or erosion lesions, where there is little or no enamel available for bonding at the gingival margin. Chemically-cured glass ionomer cements give good results when used in this situation, but may not give the aesthetics of composite, Shortall and Wilson (1988).

McLean et al. (1985) recommended the Sandwich Technique for restoration of Class V restorations. However, as mentioned earlier, a variable extent of microleakage is observed depending on the bonding resin and composite selected. When glass ionomer cement is used as the liner, any microleakage initiated at the gingival margin has been shown to progress no further than the resin/cement interface, Mathis et al. (1988), Leary et al. (1989). The stress developed by the composite polymerisation shrinkage may be capable of disrupting the cement/dentine bond. The design of this restoration, especially with respect to the quality of the gingival cavo-surface margin and glass ionomer cement extent, needs further study.

2.11.6. CROWN MARGIN REPAIR

Bertolotti (1987) reported the use of the Sandwich Technique to hide unaesthetic margins in cosmetic areas. Porcelain fused to metal crowns may exhibit metal margins or metal shining through the porcelain.

2.11.7. AMALGAM BOND TO GLASS IONOMER CEMENT

Glass ionomer cement is also used as a base under amalgam restorations. Its relatively high modulus of elasticity, low thermal co-efficiency properties and tooth bonding ability are major reasons. Amalgam alloy in Class II preparations may fail at the cervical margin due to leakage and further caries. The use of a glass ionomer cement lining significantly reduces leakage, Fisher et al. (1989). Ketac-Silver can be used to restore approximately 2 mm height of the proximal box from the cervical floor to provide a dentine seal and cariostatic action, McLean and Gasser (1985). However, no bond is established between the Ketac-Silver and amalgam, Scherer et al. (1989).

Glass ionomer cement, during its early reaction phase, has been shown to bond to many base metals especially tin and silver, Hotz et al. (1977), Negm et al. (1982). Such a bond can be exhibited between freshly-mixed glass ionomer cement and set amalgam, and has been used in veneering techniques, Pollack and Blitzer (1983).

A technique has been postulated whereby a thin coating (0.1 mm) of 40% polyacrylic acid solution is applied to the set glass ionomer cement base before amalgam placement. A 60-120 second application of polyacrylic acid solution, immediately followed by amalgam condensation, resulted in a shear bond strength between the materials as strong as the shear strength of glass ionomer cement itself. There is some evidence that the bond formed is mechanical and, despite current lack of evidence, the possibility of a chemical bond has also been suggested. Although the stability of this bond needs evaluation, the results may offer some promise in the clinical situation, Warren and Soderholm (1988). However, the technique is of doubtful clinical relevance.

2.11.8. LAMINATE VENEERS

Wilson and McLean (1988) discussed the increasing interest in porcelain or resin composite veneers, especially when used as labial facings. They felt that neither resin bonding agents nor glass ionomer cements could be regarded as ideal for long term adhesion, particularly where tensile or shear stresses prevail. Only long-term clinical studies will show the validity of this assumption.

Where possible, the laminate should be bonded to enamel only, since it has been shown that the bond strengths of composite to etched enamel can be quite high. Where dentine is exposed, a glass ionomer cement base may be contemplated. This base may be etched in a similar way to Sandwich Technique bases elsewhere.

Where cervical enamel is removed, or structureless, the margin will finish in dentine. A cervical restoration of glass ionomer cement should be placed and the laminate finished in the cement, Wilson and McLean (1988). Long term results of such a technique need to be evaluated.

2.12. CLINICAL EVALUATION

Laboratory bond strength measurements show the Sandwich Technique to have potential. However, clinical studies report relatively short-term results. As with any new technique it will be important to observe restorations for a longer period to decide if the technique is viable. Some early clinical results are promising, Woolford (1993).

Tyas et al. (1989) showed a failure rate of 10% over 2 years in the restoration of Class V abrasion cavities, when the enamel and glass ionomer cement were both etched. A comparison of restoration retention was made using either etched glass ionomer cement as a lining, or dentine bonding agents. It was found that after one year, the results were comparable, Tyas (1988), Tyas et al. (1989). It is concluded that a significant bond between etched glass ionomer cement and composite can be obtained. However, Tyas et al. (1989) suggest additional mechanical retention of the composite is necessary, so as not to rely solely on the bond between resin composite and glass ionomer cement.

2.13. SUMMARY

Increasing use is being made of glass ionomer cements as a lining material under resin composite restorations. A strong mechanical union is achieved between the cement and composite, and the composite is bonded with a low viscosity intermediate resin, when the cement is appropriately etched using 37% phosphoric acid solution, Mount (1989a).

When carefully selected, the Sandwich Technique can give good clinical results and overcome many of the limitations of either glass ionomer cements or composites used alone. The composite can give good aesthetics and an excellent surface texture. However, its major drawback is uncertain long-term dentine bonding, resulting in microleakage and subsequent secondary caries. An adequately thick, strong glass ionomer cement base overcomes this problem, due to its excellent long-term chemical adhesion to dentine with fluoride release, and hence secondary caries is less likely.

The tensile bond strength between etched glass ionomer cements and resin composite can be considered excellent, since it is greater than the inherent tensile strength of glass ionomer cement itself. Etching of glass ionomer cements produces a mechanically more retentive surface for composite bonding.

There are no long-term clinical results, and therefore most recommendations are based on laboratory studies with attempts to transfer this information to the clinical situation. These suggestions may yet prove to be incorrect, Woolford (1993).

In essence, information gained from clinical trials of glass ionomer cements may be useful. It has been found that microleakage with secondary caries under carefully placed glass ionomer cement restorations is very rare, and even if microleakage

occurs under the composite, the fluoride release from the cement may prevent caries progression into dentine, provided all the dentine has been protected by cement.

The following factors will affect the strength of the composite bond to glass ionomer cements.

1. The tensile strength of the glass ionomer cement can be enhanced:
 - (a) Use a high powder:liquid ratio. This can be difficult to achieve when hand-mixing and therefore capsulated materials are recommended.
 - (b) Choose a high strength cement.
 - (c) Place a thick lining - minimum 0.5 mm.
 - (d) Allow adequate time after mixing for the cement to develop strength, and in cases where time is a concern, choose a material with a rapid rate of set. The surface should be hard to probing.
 - (e) Avoid dehydration and cracking. Excess drying will cause loss of water which is essential for ion transport and hydration of the gel matrix, and thus a weaker cement will result.
 - (f) Use rubber dam to prevent moisture contamination.

2. The effect of etching of the cement surface should give a mechanical interlock for the bonding resin, but the etchant should not affect the properties of the cement. For most materials a 15 second application with 37% phosphoric acid solution is adequate to remove just enough matrix material to leave clean, unreacted glass particles proud on the surface. Etching produces a high surface energy which allows the surface to be more easily wet by the bonding resin.

3. The bonding agent should have a low viscosity and thus high wettability and low contact angle to give intimate contact over the entire cement surface,

thereby gaining mechanical interlock by filling voids left on the surface of the etched glass ionomer cement. Some bonding agents have a high viscosity, and result in a poor bond. Bonding agents containing an evaporative vehicle result in porosity and thus poorer strength. It has been suggested that the bond between unfilled resin and cement may be chemical to a degree.

4. The composite should have the ability to be closely adapted to the cement surface without voids. Some posterior composites exhibit variable tensile bond strength due to the tendency of the composite to stick to the packing instrument and be pulled away from the cement. Some have a high viscosity making it difficult to adapt them closely. Voids between the composite and cement may allow for microleakage.
 5. Polymerisation shrinkage of composite should be kept to a minimum to avoid placement of excess stress on the bond and the underlying cement. The volume of composite and hence shrinkage is less when a thicker cement base is placed. The amount of shrinkage ideally can be kept to a minimum by selecting a composite with a high filler content and placing it incrementally. Lightly-filled microfil composites exhibit greater curing shrinkage than heavily-filled hybrid or small particle size resins. An incremental build up technique can also help to reduce shrinkage.
-

2.14. CONCLUSION

The resin composites have been developed as a restorative material over many years and are now being used extensively. Their main drawback is their hydrolytic instability and lack of long-term prevention of microleakage, especially along dentine margins or walls. Chemical adhesion between glass ionomer cement and dentine is long-term. This has led to the development of the "Sandwich Technique" where the cement is placed as a lining or base under composite restorations, especially where the margin finishes in dentine. The literature reviewed in this essay indicated that a mechanical union between the cement and composite is reasonably strong when placed under proper clinical conditions. Etching of the glass ionomer cement produces a bond between cement and composite which exceeds the inherent tensile strength of chemically-cured cements. Since the tensile strength of the glass ionomer cement is the limiting factor, the strength of the bond can only be improved if the tensile strength of the cement is improved. When placed correctly, the integrity of the glass ionomer cement is not disturbed and hence, tensile strength and other properties are maintained.

3. OBJECTIVES

The research project is divided into several sections. The first sections examined various aspects of the "Sandwich Technique" in vitro, to provide background information for the last section which was designed to assess the restorations in vivo.

The objectives were:

1. To establish if a methylene blue dye test could be used to determine the thickness of glass ionomer cement lining required to resist crazing and cracking during the acid etch procedure,
2. To determine the effect that variations in the thickness of the lining cement and resin composite may have in reducing the resistance to displacement under a load, of the overlying composite resin,
3. To observe the quality of restorations placed in vitro under simulated clinical conditions, especially regarding marginal integrity, porosity, filling defects, placement problems, finishing and radiopacity, and
4. To assess Sandwich Technique restorations, amalgam restorations and Ketac-Silver restorations in vivo.

Observations of cracking and crazing were limited to two brands of glass ionomer cement dispensed in various forms. Each sample was allowed to set sufficiently hard to resist indentation by a sharp probe prior to acid etching with 37% phosphoric acid gel. The samples were acid etched for 15 seconds prior to rinsing and then placed in dye to observe cracks and crazing. Observations were made of the degree to which acid etching for various time periods affected each brand, and of the possibility that

the handling and setting conditions may affect the degree of cracking. It was beyond the scope of the experiment to test all materials on the market.

The loading experiment compared the support offered by varying the thickness of a glass ionomer cement base under the composite. It was designed to confirm or allay fears that the strength of the cement is inadequate to prevent fracture of the overlying composite at usual occlusal loads.

The purpose of placing Sandwich Technique restorations in vitro in hydrated extracted teeth was to determine problems in their handling characteristics and physical behaviour, and to suggest means by which the technique may be improved.

The in vivo clinical study was mainly conducted to observe what effect placement of the glass ionomer cement base has on the overlying composite restoration, by assessing the modes of deterioration and failure of the Sandwich Technique. The purpose of the clinical study was to assess the handling and finishing properties, the deterioration of several clinical characteristics or factors, and the longevity of:

Class I

- (a) the newer resin composite/glass ionomer cement Sandwich Technique as compared with,
- (b) the traditional amalgam alloy restoration, and
- (c) the silver cermet restoration, for restoring minimal pit and fissure caries in the occlusal surfaces of the permanent posterior teeth of patients of different ages.

The hypothesis is that the resin composite/glass ionomer cement combination restoration is a viable, less destructive mode of treatment than is the use of amalgam for restoring occlusal caries in young adults.

The study also assessed the same clinical properties for:

Class II

- (a) the resin composite/glass ionomer cement Sandwich Technique as compared with ,
- (b) the traditional amalgam alloy restoration, for restoring small interproximal caries lesions in the permanent posterior teeth of patients of different ages.

The potential significance of the study is:

1. Less cutting of teeth is in line with the recent trends of Minimal Intervention Dentistry which leaves a much stronger, more intact tooth. Thus, the extent of cavity preparation is mainly dependent on the extent of caries involvement, rather than on empirical cavity designs demanding removal of tooth structure to gain mechanical retention form of the cavity,
 2. The Sandwich Technique may be potentially applicable as a technique for replacement of moderate sized amalgam restorations, and
 3. The combination Sandwich restoration requiring the use of glass ionomer cements as a base, provides a bland base for the dental pulp and fluoride transfer to the tooth to decrease secondary dental caries, as well as reducing microleakage at the margins finished on dentine.
-

4. CRACKING AND CRAZING WITHIN GLASS IONOMER CEMENT DUE TO ACID ETCHING - PILOT STUDY

4.1 INTRODUCTION

Numerous studies have shown that surface degradation of glass ionomer cements occurs upon acid etching, McLean et al. (1985), Garcia-Godoy and Malone (1986, 1987), Fuss et al. (1990), Smith (1988). Some authors have also suggested that cracking and crazing, if present, may penetrate to a considerable depth quite rapidly. The aim of the present experiment was to determine the preparation protocol required to resist damage to glass ionomer cement from acid etching.

4.1.1. ASSUMPTIONS AND EXPECTATIONS

In several of the above-mentioned Scanning Electron Microscope (S.E.M.) studies some degree of surface cracking and crazing of glass ionomer cement specimens was seen, supposedly as a result of exposure to 37% phosphoric acid gel. In the present study, it was assumed that immersion of the etched cements in a 0.03% methylene blue dye would cause penetration of the small dye molecules along these cracks, giving an intense stain. Retained dye would give a visual indication for the numbers of cracks and their depth of penetration. Based on S.E.M. study results, it was assumed that the depths of the cracks would be in the order of 0.5 mm, Smith (1988).

Finally, it was assumed that any intact surfaces would take up less dye than the cracked areas. The amount of dye retention in these areas would be directly related to the amount of surface degradation from acid etching, by providing mechanical niches for dye molecules to be retained.

It was expected that the amount of dye retention may also give an indication for potential composite bonding strengths, since the bonding of composite relies on a mechanical interlock from irregularities on the glass ionomer cement surface.

4.2 MATERIALS AND METHODS

Two different brands of glass ionomer cement materials were tested. The two cements investigated were:

1. capsulated Ketac-Bond (Espe GmbH), and
2. 3M glass ionomer lining cement (3M Dental Divis.).

4.2.1. PREPARATION OF SAMPLES

The glass ionomer cement specimens were placed within Perspex wells. The wells were formed by drilling a series of four holes each 5 mm in diameter in Perspex sheets of 1.2 mm thickness. This resulted in sets of Perspex strips, each with a series of four glass ionomer cement samples which could be easily identified, handled and observed.

4.2.2. CONDITIONS OF PLACEMENT

The Perspex strip was placed on a glass slab with a Mylar matrix strip between the Perspex and the glass to prevent direct contact of the glass ionomer cement with the glass slab. The glass ionomer cement was mixed according to manufacturer's instructions and placed into the well and allowed to dry.

There were several variables. Half the samples were filled approximately level with the top of the wells and allowed to set. The other half of the samples were slightly overfilled by about 1 mm and allowed to set. Once set, these were trimmed back with a pear-shaped 12-fluted tungsten carbide Komet high speed finishing bur under copious air-water spray till they were level with the top of the well. This resulted in a set of three different types of surface treatments.

A. "Air-dried"

The surfaces were placed at the correct level and allowed to set exposed to air. These were called the "air-dried" samples.

B. "Matrix band"

The reverse side of sample A was tested. At this surface the glass ionomer cement was allowed to set against the Mylar matrix band strip. These were called the "matrix band" samples.

C. "Cut-back"

The final set of samples were overfilled, allowed to set, and cut-back with a tungsten carbide bur. These were called the "cut-back" samples. The reverse side of these samples were not tested since they were essentially the same as sample B.

4.2.3. METHOD OF PLACEMENT

The method of placement varied. After mixing for 8 seconds in a Silamat amalgamator, the capsulated Ketac-Bond was injected directly from the manufacturer's syringe and capsule (Aplicap) in two increments and tamped into place with a 3M foam sponge held in tweezers. The 3M glass ionomer cement was transferred from the mixing pad to the well using a metal plastic instrument and did not require tamping because of its low viscosity. The time of set was determined by scratch test with a probe or when the Mylar strip could be easily lifted away. This time was noted and varied according to the ambient conditions on the day, but was usually approximately 10 minutes for 3M glass ionomer cement and 4 minutes for capsulated Ketac-Bond. To obtain a temperature, similar to the mouth, the glass slab was pre-warmed in lukewarm tap water (approximately 38°C), than carefully dried.

After setting, the cement surfaces were acid-etched. Each strip was subject to a uniform etching test which involved the following.

The first sample in each strip was unetched. The second sample was etched for 15 seconds, the third for 30 seconds and the fourth for 60 seconds. At the end of etching time the entire strip of four samples was rinsed under running tap water for 20 seconds to remove etchant and debris.

Specimens were handled taking particular care to prevent dehydration. While specimens were not being photographed or observed under the light microscope, they were stored in water.

During the initial pilot study with capsulated Ketac-Bond it was noted that severe physical changes such as cracking were only observed if the samples were allowed to dehydrate excessively in air for prolonged periods, in the order of 10-20 minutes after the observations and recording were complete. When placed in dye again, many samples which had not originally taken up dye, now did. It was decided that this procedure would be incorporated into the test and therefore, after initial observations and record taking, the samples were allowed to dehydrate for a further 5 minutes and then retested in dye as before.

4.2.4. RECORDS

The specimens were photographed with an Elicar hand-held camera using Ektachrome 100 ASA 35 mm colour transparency film at a magnification of 2:1, and were also examined under a binocular light microscope. Some specimens which were considered typical representative examples were broken in half and examined. Photographs of the fractured surfaces were taken to show the depth of dye uptake. To minimise exposure time to air, specimens were assessed individually and examined fairly quickly.

4.2.5. EVALUATION

It was originally envisaged that the specimens would be rated according to the presence or absence of dye uptake, indicating the amount of cracking.

4.3 RESULTS

4.3.1. SELECTION OF RATING CRITERIA

The original assumption was that acid etching would cause cracking or crazing of glass ionomer cement. However, this did not occur under the conditions tested. The results showed that dye uptake following acid etching may occur, but the results were so varied that trends or causative factors were difficult to isolate. Dye uptake was diffuse and did not appear in the form of isolated lines representing cracks as had been expected.

Initially, it was thought that a linear rating scale of dye uptake may give a rational approach to analysis, but the appearance of individual specimens was so varied that the scale was not practicable.

A rating scale of dye uptake varying from 1 to 6 was considered (i.e. 1 = dark, 6 = very pale). However, uniformity of colour was inconsistent since many individual samples had areas of extreme colour next to areas of pale colour (Figs. 1-7). The patchy appearance could not be given a single rating. Therefore, this scale was also discarded.

It is interesting to note that, whenever light and dark patches resulted for any specimen, their development during the course of the experiment was similar. On removal from the dye bath most specimens appeared totally dark blue. When rinsed under tap water an initial large amount of dye was cleaned away within the first instant. Then, with further rinsing, patchy clumps of intensely-stained material were dislodged from the surface. These clumps appeared to have lost their ability to remain adherent to the bulk of the specimen. Their dislodgement revealed a subsurface layer to which minimal or no dye had penetrated. The reason why certain

clumps appeared to lose their adherence to the remaining bulk can only be speculated on.

Another rating method considered, was to take several samples as being representative of a certain subgroup (e.g. pale background with very dark patch covering approximately half of the specimen area etc.). Once again, this was not objective enough and would have allowed a great deal of variation, dependent on the observer's personal perception in each case. It was felt that the information gained from such an exercise would have been difficult to analyse and therefore this rating scale was also discarded.

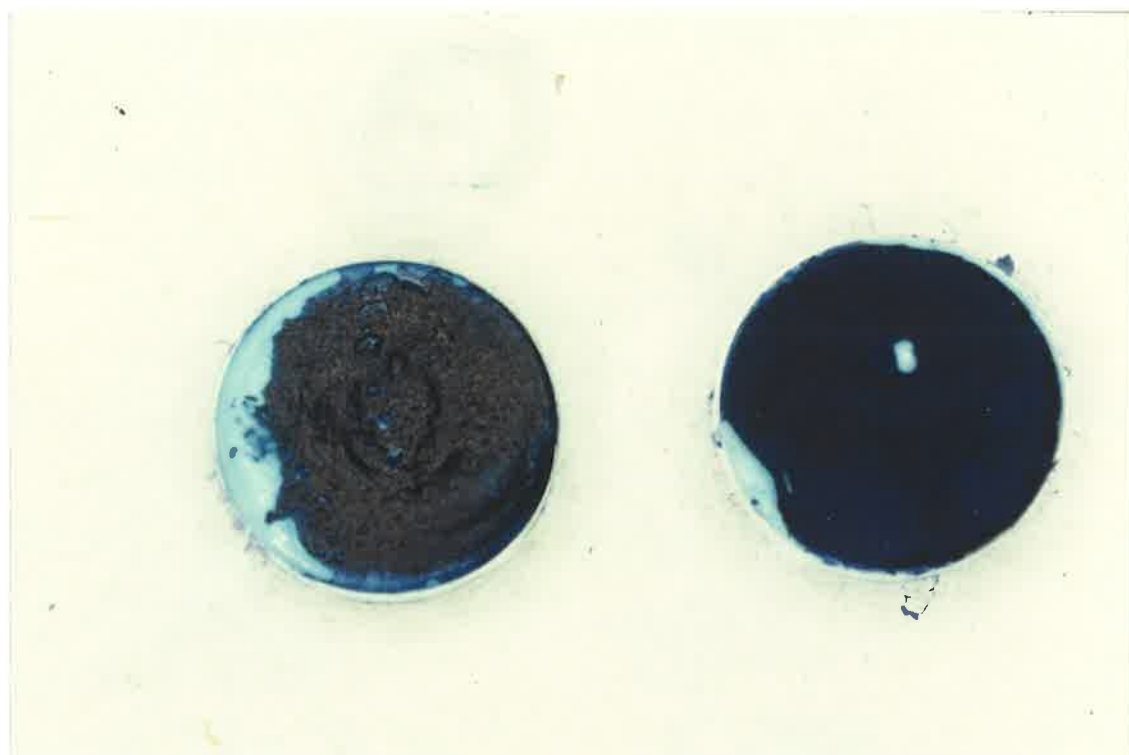
Finally, it was decided merely to describe what was observed for all surface areas of each material, and to propose any trends that may be noted with a summary of the observations.

4.3.2. OBSERVATIONS AND DATA

A. CAPSULATED KETAC-BOND:

Almost all the capsulated Ketac-Bond samples produced a fairly intense level of dye uptake.

Figure 1 - Ketac-Bond Air-Dried (Etch 0 and 15 seconds)

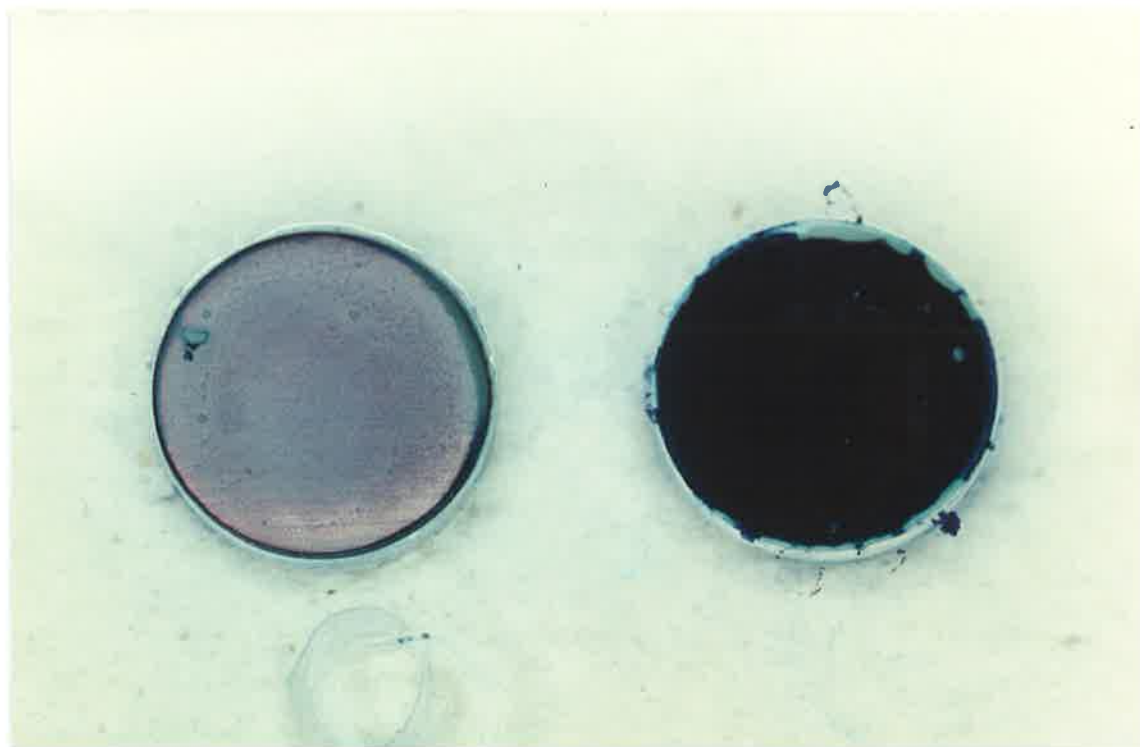


No etch

15 second etch

- A. The air-dried samples all took up dye, but also had areas where virtually no dye was present at all. Etching the samples for zero, 15, 30 or 60 seconds did not vary the surface appearance i.e. the samples which were not etched took up virtually as much dye as the samples which were etched for 60 seconds (Fig. 1).

Figure 2 - Ketac-Bond set against Matrix Band (Etch 0 and 15 seconds)

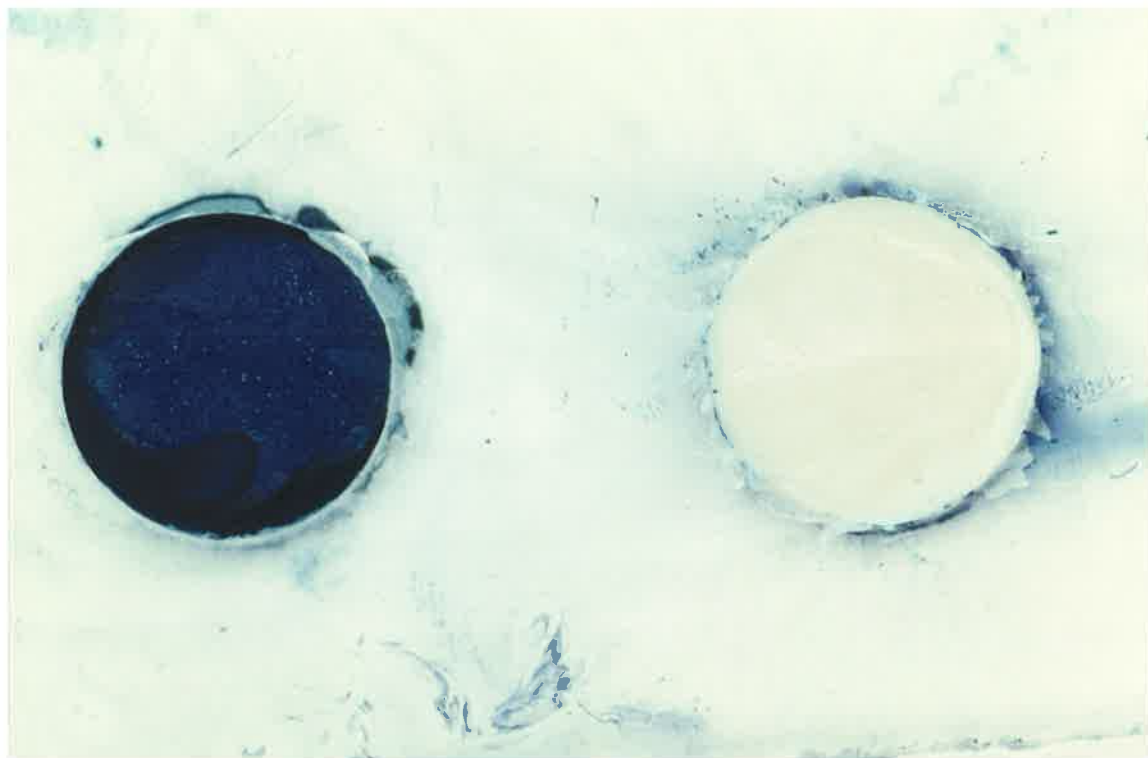


No etch

15 second etch

- B. The samples which set against the Mylar strip all exhibited a fairly high degree of dye uptake. Etching for 15, 30 or 60 seconds produced a dark blue colour with some slight peripheral very pale blue or white areas where no dye was taken up. However, the unetched samples gave a moderate degree of uniform blue colour which appeared distinctly as a surface gloss with no areas where dye was not taken up (Fig. 2).

Figure 3 - Ketac-Bond Cut Back (Etch 0 and 15 seconds)



No etch

15 second etch

- C. The capsulated Ketac-Bond samples which were overfilled and then cut back with a tungsten carbide bur showed the greater contrast. All the unetched samples produced a uniformly intense blue colour with no areas of paler colour. Etching for either 15, 30 or 60 seconds produced the most colour free samples of the series. All etched samples were free of dye uptake (Fig. 3).

Subsequent, additional air-drying of all capsulated Ketac-Bond samples A, B and C, followed by a second dye treatment, caused all samples to take up a moderate further amount of dye. Any originally pale areas on the samples took up dye and became darker.

Figure 4 - Sectioned Ketac-Bond sample

Top surface - Air Dried (Etch 60 seconds)

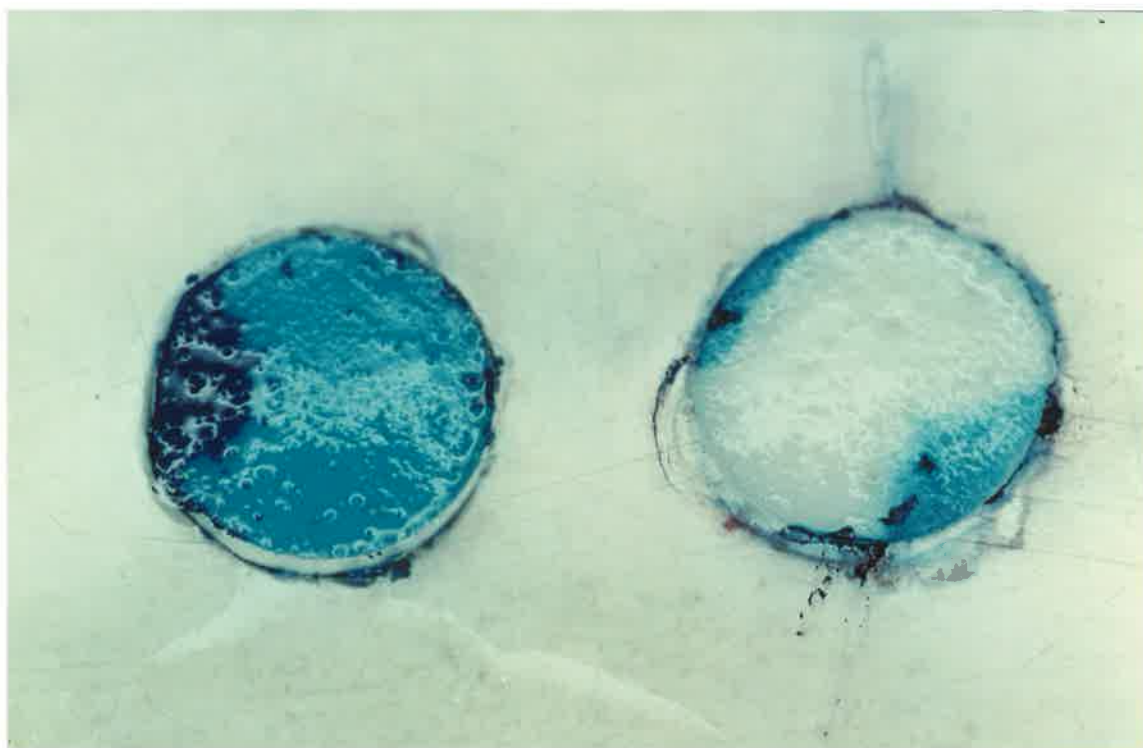


When selected samples were broken in half it was found that the dye did not penetrate to any great depth. Depth of penetration appeared uniform and typically only less than around 0.1 mm (Fig. 4). The method of visually assessing the depth of dye penetration was too coarse to show any trends.

B. 3M GLASS IONOMER CEMENT:

The uniformity and intensity of the dye uptake showed variation. Dye uptake often gave a patchy surface appearance. More definite trends were seen with the 3M material.

Figure 5 - 3M Glass Ionomer Cement Air-Dried (Etch - 30 and 60 seconds)

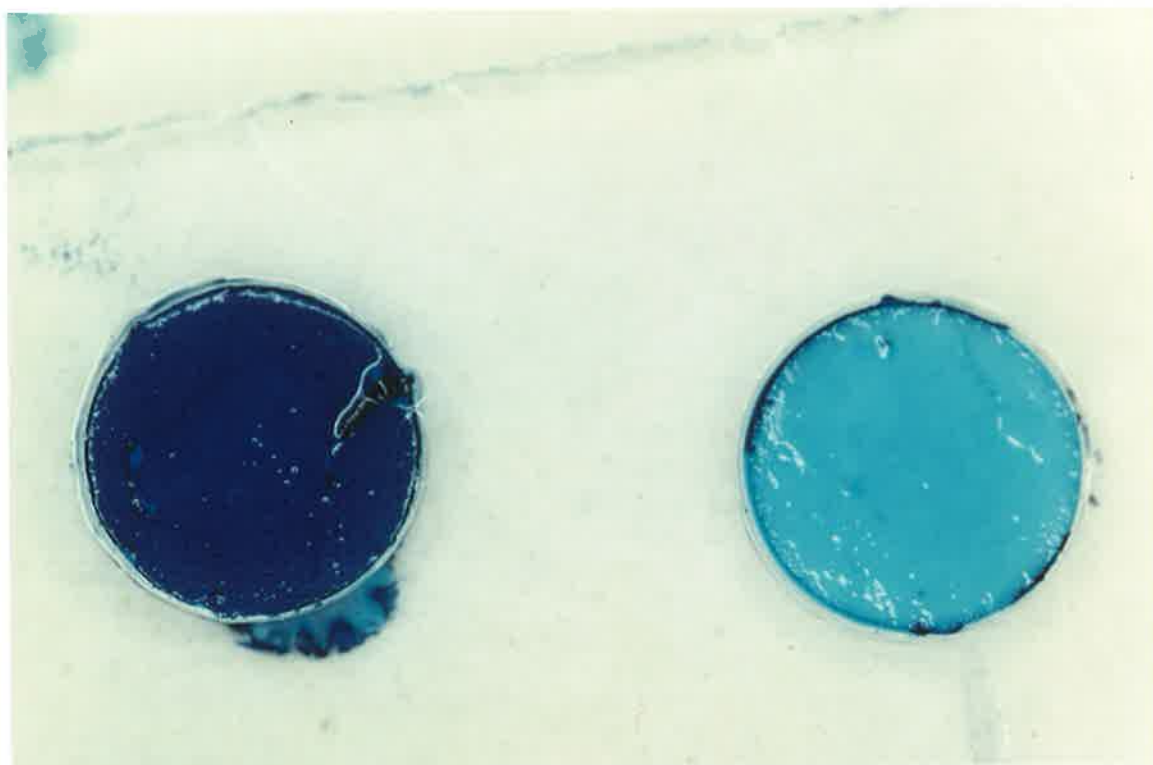


30 second etch

60 second etch

- A. In contrast to the air-dried capsulated Ketac-Bond samples, where etching had no effect on dye uptake, it was found that longer etching times of the air-dried 3M glass ionomer cement produced a generally larger area of pale blue or white surface appearance (Fig. 5). With no etching, a fairly intense blue colour resulted. With 15 or 30 seconds of etching some of the samples started to have varying degrees of pale and dark areas. Eventually, following 60 seconds of etching, virtually no intense blue areas remained and the whole surface appeared white.

Figure 6 - 3M Glass Ionomer Cement Set against Matrix Band
(Etch - 30 and 60 seconds)

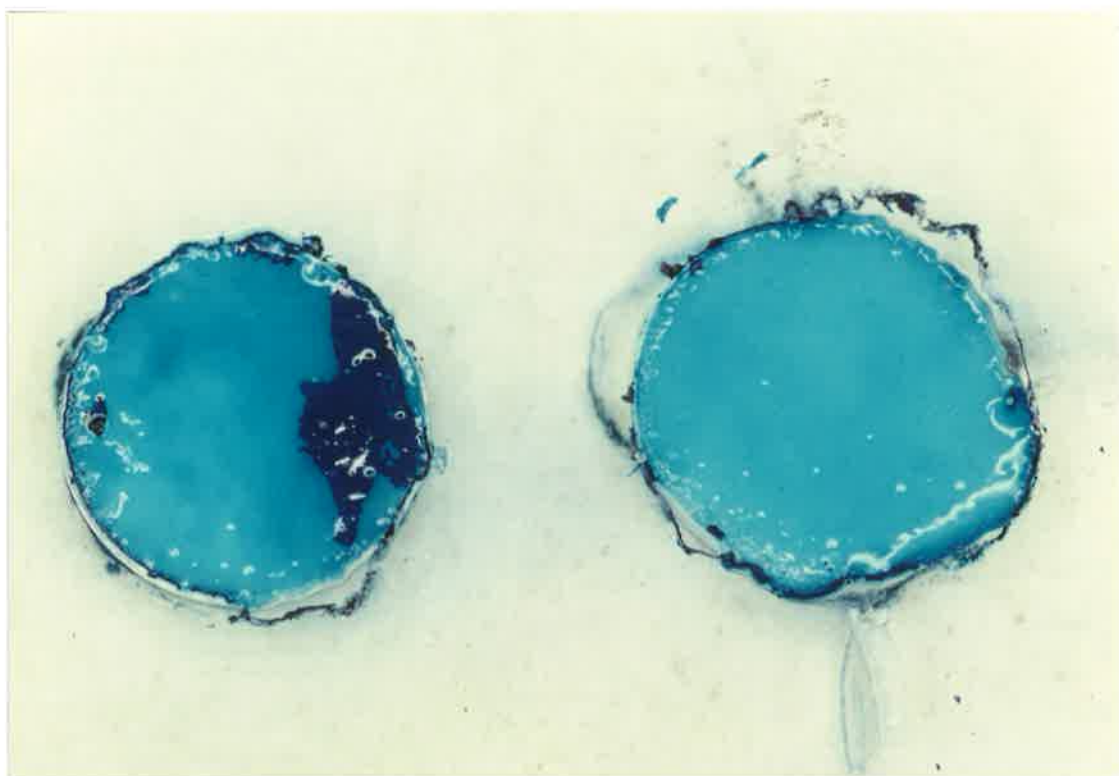


30 second etch

60 second etch

- B. The samples which set against the Mylar strip also showed a generally larger pale area with longer etching times (Fig. 6). The unetched samples produced a light blue glossy surface. On etching for 15 seconds an intense dark blue surface was produced. Thirty seconds of etch produced various degrees of light blue and dark blue. Finally, with 60 seconds of etch, a uniform very light blue colour was produced over the entire surface.

Figure 7 - 3M Glass Ionomer Cement Cut-Back (Etch - 30 and 60 seconds)



30 second etch

60 second etch

- C. The cut-back 3M samples were similar to the Mylar strip samples except that the unetched samples uniform intense blue colour (Fig. 7). On etching for 15 seconds, the intense blue colour was still present with small peripheral patches of light blue. By 30 seconds of etch, virtually the entire surface was pale blue with only one or two patches of dark blue remaining. With 60 seconds of etch, all samples were almost purely light blue with even less area of dark blue remaining.

Subsequent, additional air-drying of all 3M samples A, B and C, followed by further dye treatment, caused all samples to take up a moderate further amount of dye, as was apparent with the capsulated Ketac-Bond samples. Pale blue areas took up dye and became darker, and very dark areas remained dark. No areas became paler.

Also, as was apparent with the capsulated Ketac-Bond samples, the 3M samples exhibited a very shallow uniform depth of dye penetration when broken in half and examined. Once again this seemed to be less than around 0.1 mm as estimated visually.

4.4 DISCUSSION

4.4.1. CHOICE OF SURFACE TREATMENT

The three sub-classes of conditions (A, B and C) of glass ionomer cement placement seek to reproduce all conditions to which the glass ionomer cement may be exposed in placement of a clinical Sandwich Technique restoration. Class A, where the glass ionomer cement was placed to the correct level and allowed to dry in air, simulates the situation which may occur when the clinician places the cement accurately with no excess to be removed after setting. Class B, where the glass ionomer cement set against a Mylar strip, simulates the situation that may occur in the proximal box of a Class II cavity where a clear matrix polyester band is used to contain the cement within the box, and where the cement forms part of the external surface of the restoration. Finally, Class C, where excess glass ionomer cement is placed, allowed to set and is then cut back with a tungsten carbide bur under an air-water spray, simulates the situation that may occur when the clinician places excess cement and then cuts the surface back after setting. This approach is used by some clinicians, reportedly to remove the matrix-rich dehydrated surface layer prior to acid-etching, Mount (1989c).

The results show that acid etching has a different effect on each one of these sub-classes, and also varies slightly according to the brand of glass ionomer cement material used.

A. CAPSULATED KETAC-BOND:

A. The air-dried capsulated Ketac-Bond specimens all took up dye intensely, regardless of the etching regime. The ability of the surface to take up dye so intensely appears to be a function of the material having set in air and is

unaltered by any etching regime. Setting in air renders the surface very prone to dye uptake and this is unaltered when exposed to etching.

A recent study by Um and Oilo (1992) also found a similar surface uptake of methylene blue dye at the exposed margins of four glass-ionomer luting cements setting in air between glass plates. The longer the setting time before placement of the samples in dye, the less the dye uptake. The degree of dye uptake paralleled the amount of material lost from the surfaces of the cements.

The reasons which determine whether methylene blue dye is taken up or not are not clear to the author. Clarification would help to explain whether dye uptake occurs as a result of surface irregularities and porosities giving a mechanical niche, or whether it is a simple matter of uptake due to rehydration of damaged glass ionomer cement or due to chemical reactions. Um and Oilo (1992) state that contact with water at an early stage during setting washes out cement-forming cations, preventing the setting reaction, allowing the larger dye molecules to penetrate the cement. The translucency of the underlying cements is also reduced.

The author can only speculate that air-drying causes the surface to be damaged permanently in such a way that dye is taken up easily. This damage is not so extensive that all the damaged surface loses adherence during normal rinsing, but more is dislodged if subjected to ultrasonic vibration, Um and Oilo (1992).

B. The samples set against a Mylar strip, when unetched, gave a glossy moderate blue surface with no surface dye penetration. This may be the appearance of a matrix-rich surface layer which has only a moderate affinity for dye uptake. A matrix-rich surface layer generally occurs when glass

ionomer cement sets against a Mylar strip, Mount (1989c). Acid etching for 15, 30 or 60 seconds renders most of the surface very prone to intense dye uptake. Prolonged 60 seconds etching appeared to leave some areas denuded of intense blue dye.

- C. The cut-back samples demonstrated the most marked effects. Initially, without etching, the surface took up stain intensely. Etching, for 15, 30 or 60 seconds, altered the surface enough to cause the intensely-stained surface to lose all adherence and be totally rinsed away. It can be speculated that the material being stained was surface debris that forms as a result of bur-cutting action, and was equivalent to the smear layer remaining on the walls of a cavity after cavity preparation. This debris takes up stain readily due to its broken-down nature. Simple rinsing under running tap water is not enough to dislodge this surface debris. However, the debris is fragile enough that any acid-etching rapidly causes it to lose all its adherence ability and be washed away by running water.

No matter what surface remained for samples A, B and C, subsequent air-drying and additional dye testing caused further dye uptake and did not cause any areas to become paler. This may have occurred for two reasons. Firstly, an additive effect occurred by the prolonged exposure time to dye i.e. one minute plus one minute gave two minutes total exposure. Secondly, further air-drying caused dehydration of the surface, thus rendering the surface liable to imbibe water at a subsequent stage very rapidly, regardless of whether the solution contained dye or not.

B. 3M GLASS IONOMER CEMENT:

-
- A. The unetched air-dried 3M glass ionomer cement samples took up dye intensely as was the case with capsulated Ketac-Bond in the same situation. Therefore, it can be concluded that, regardless of brand used, glass ionomer

cement set in air has a surface very prone to dye uptake and retention. The capsulated Ketac-Bond surface dye retention ability was apparently unaltered on acid-etching. Acid etching of 3M glass ionomer cement for 15-30 seconds caused some of the areas containing dye to lose adherence and be rinsed away, revealing a subsurface not entirely free of dye uptake. Prolonged etching for 60 seconds caused loss of adherence of virtually all dye-containing material revealing a subsurface free of dye uptake.

- B. As was the case for capsulated Ketac-Bond, unetched 3M glass ionomer cement set against a Mylar matrix band produced a light-blue glossy surface with no surface dye penetration. Etching for 15 seconds altered the cement surface sufficiently to cause a high dye uptake. Thirty seconds of etching gave a partial loss of adherence of some areas of dye uptake, while 60 seconds of etching caused a uniform loss of the dye-containing material, revealing a subsurface level with only a minimal amount of dye present. It would be interesting to speculate if a prolonged exposure of, for instance, two minutes acid etching, would have caused total loss of adherence of all dye-containing material, revealing a dye-free sub-surface.
- C. As was the case for capsulated Ketac-Bond, for 3M glass ionomer cement the intensely-stained unetched surface present after cut-back of the 3M cement, probably also represents debris resulting from bur-cutting action. However, this blue-stained material was not lost as easily after acid etching as was the case for capsulated Ketac-Bond.

Subsequent air-drying and additional dye testing of 3M glass ionomer cement had a similar effect to capsulated Ketac-Bond causing further uptake.

4.4.2. CRACKING FREQUENCY

Following the results of Smith (1988) it was expected that acid-etching would cause cracking in the order of 0.5 mm in depth. No cracks of this size were observed in any sample. This may be due to several reasons.

It is well known that, following early dehydration of incompletely set or immature glass ionomer cement, cracking will occur. This effect was confirmed by the author in a simple experiment where samples were placed in a similar fashion to group A in Perspex wells, and allowed to set in air. These samples were not tested at the point of initial set, but were left in air for a prolonged period and observed under the binocular light microscope. No protection against water loss was provided and observations were made as dehydration progressed. Initially, the surface began to appear more and more chalky and opaque with areas of small cracks appearing. The surface then become rougher and more opaque, with very obvious deep cracks opening up within five minutes from the initial set. This finding was particularly apparent with the capsulated Ketac-Bond material and did not occur with the 3M material. Evidence of obvious damage to immature glass ionomer cement due to early dehydration was extreme.

It was for this reason that great care was taken during the present study to ensure that possible dehydration conditions were avoided. The only time samples were exposed to air was during the initial set and during short periods of observation and recording. During the remaining time they were kept in water or an aqueous environment such as the dye bath. This particular attention to water balance may help to explain why no cracks appeared in the glass ionomer cements. In the preparation of samples for S.E.M. observation dehydration occurs which causes damage to the glass ionomer cement surface. Unless particular care is taken with the water balance in any experiment, regardless of whether S.E.M. observation is involved, there is a danger that cracks will appear in the glass ionomer cement.

These cracks should not necessarily be attributed to factors being tested in the experiment, such as acid etching.

A second factor to be considered in explaining the presence of deep cracks reported by other authors, is the stage of maturity of the glass ionomer cement when the acid-etch was applied. In the current experiment, etch was applied at the time of initial set, as determined by probe test and when the Mylar strip easily lifted away. At this time, penetration of acid-etch itself did not occur to any great depth. However, if samples were allowed to set longer and dehydrate further, the ensuing dehydrated surface may allow acid-etchant to penetrate to a far greater degree due to a greater affinity for the etchant. This would cause the etchant to have an effect at a deeper level. Therefore, in the present experiment, it is possible that, due to the stage of maturity of the glass ionomer cement, it simply did not have as great an affinity for the etchant as was present in other studies.

4.4.3. SIGNIFICANCE OF CRACKING

The clinical significance of surface cracking can be several-fold. Where the glass ionomer cement liner is thin the cracks may penetrate the entire thickness of the lining giving direct access from cement surface to underlying dentine. If such a full depth crack were to appear prior to etching it would allow acid etchant to act directly on dentine, opening up the tubules and allowing acid penetration, Powis et al. (1982). Acid etching of dentine is controversial, currently topical, and will not be discussed further.

If a full-depth crack were to appear after acid etching, it would allow penetration of the unfilled bonding resin directly to dentine. The effect of this may vary. If a conventional enamel bonding agent was used it would bond poorly to the dentine and could allow a potential path for microleakage under the glass ionomer cement, and later secondary caries. If a dentine bonding agent was used it may bond either

chemically or micro-mechanically to dentine, but the long-term stability of the newer dentine bonding agents has yet to be established.

Surface degradation of the cement, with no cracking due to etching, may uniformly and slightly reduce the overall thickness of the cement but, as long as an adequate thickness of lining remains, a barrier to microleakage will be present. The main concern would be the question whether this layer of glass ionomer cement can form an adequately-strong mechanical union with the overlying composite resin.

In the current experiment, the relationship of the appearance of various surfaces to potential composite resin bonding strength is unknown. An intensely-stained surface may have the potential to form a stronger or weaker bond to composite resin than does a pale surface resulting after the intensely-stained dye material has totally lost its adherence and has been washed away. Originally, it was thought that the amount of dye uptake would be directly related to the amount of surface degradation due to acid etching. The degraded surface was thought to produce a greater potential for mechanical interlock of the bonding resin and thus potentially give a greater bond strength. Since dye retention in the current experiment was not directly related to the duration of acid etching, no relationship between the amount of dye penetration and potential composite resin bond strength can be drawn.

4.5. CONCLUSION

It is difficult to draw conclusions from the experiment because there are so many factors that could not be, or were not, measured and many mechanisms such as dye retention are not understood. The sample size was also small.

The initial assumption that cracking and crazing were a result of acid etching of the glass ionomer cement surface was not supported. Either dye penetration did not occur along any of the cracks, which was considered unlikely or cracks, if they occurred, were so small that they couldn't be observed with the experimental method used. Cracks of the magnitude of 0.5 mm as seen by Smith (1988) were not observed.

Surface degradation or alteration did occur. On immediate removal from the dye bath all surfaces were covered in intense blue dye, which stained a very superficial layer only. Depth of damage was not in the order of 0.5 mm as suggested by Smith (1988), but was less than about 0.1 mm which also agrees more with the findings of Um and Oilo (1992). Samples thinner than 1.2 mm were not tested because of the difficulties of handling such thin sections. However, based on the present observations and assuming that alteration in the thickness of the material used would have no effect on its structure, strength or water balance, it can be suggested that thin linings may be adequate to resist any damage due to acid etching for a duration as long as 60 seconds.

Maintenance of water balance appears important, and may be one of the key factors why gross depth of damage did not occur in this experiment. In the binocular light-microscope study of glass ionomer cement setting in air, the considerable damage caused by excess dehydration was obvious. It must be emphasised that, when working with traditional chemical-cured glass ionomer cement, attention must be paid to water balance. All specimens in this experiment were placed in an aqueous

environment very soon after they had reached the initial set, to allow the cement to reach its maximal potential strength.

In comparing 3M glass ionomer cement to capsulated Ketac-Bond, it would appear that the 3M glass ionomer cement on acid-etching was more prone to having this surface layer lose adherence than the Ketac-Bond. However, this presupposed that the mechanism and depth of surface dye uptake is similar for both materials. Given the limits of the experimental conditions and poor ability to measure depth of dye uptake accurately, this effect cannot be assumed and must be given as an area requiring further, more detailed observation in the future.

Differences between the two brands may be due to their composition, powder: liquid ratios, rates of setting and resistance to dehydration and etching.

Conclusions regarding differences between the two brands tested are not possible. Since the mechanism of dye uptake and retention in the two materials is not fully known and the significance of various surface appearances is uncertain, no conclusions can be drawn. If further data were available, such as resin composite bond strength to the materials under the various conditions tested, then some correlations may be found.

Regarding the effect of the time of acid etching on surface appearance, it can be concluded that acid etching for 60 seconds compared to 30 seconds or 15 seconds caused less dye to be retained in most cases. The exception was for air-dried and cut-back capsulated Ketac-Bond samples, where no differences were seen with changes in etching times. However, in the cases where less dye was retained with increased etching time, the mechanism for this process is unknown.

4.6. SUMMARY OF FINDINGS

Previous S.E.M. studies have shown that acid-etching of the glass ionomer cement causes alteration to the surface giving an apparently, more retentive surface. In the present pilot study, the original expectation was that this altered surface would take up more methylene blue dye than the original unetched surface. This was not reflected in the results.

Acid etching of glass ionomer cement, under the parameters tested, did not increase the penetration or retention of methylene blue dye.

5. THICKNESS OF GLASS IONOMER CEMENT REQUIRED TO SUPPORT RESIN COMPOSITE UNDER LOAD - PILOT STUDY

5.1. INTRODUCTION

The aim of the experiment was to determine the optimal thickness of the glass ionomer cement base required to support variable thicknesses of resin composite under load. It has been postulated that the relatively low compressive strength of glass ionomer cement may allow the overlying composite to flex, possibly causing fracture. Clinical studies of Class II posterior resin composite restorations have shown failures because of fracture. It is important to note that amalgam restorations may fail when supported by relatively thick zinc-oxide-eugenol or calcium hydroxide bases. There are several reasons why amalgam restorations may have failed in this situation, including possible dissolution of these bases, Pereira et al. (1990). The presence of the bases may also have provided inadequate long-term support for the amalgam restorations to withstand constant loading, thus causing the amalgam alloy to fracture at lower loads than if amalgam was supported by dentine alone.

In any loading test the physical nature of the base underlying the material being tested is important. If the lining material has a high modulus of elasticity and high compressive strength the overlying material may be tested using a conventional single-point compressive load test. However, if the underlying material has a low modulus of elasticity then the situation changes and complicates the tests.

If the underlying material is more flexible and weaker then it is likely that the overlying material will be supported less, will flex more, and will therefore fracture at a lower load. Resin composite is relatively flexible and requires support from either the underlying glass ionomer cement base or dentine. The test design used in the current experiment may give a type of slow-impact hardness indentation test. The

test was designed to simulate the clinical situation of a large Class I Sandwich Technique restoration being loaded axially by an opposing cusp tip.

5.2. MATERIALS AND METHODS

5.2.1. PREPARATION OF SAMPLES:

Sandwich Technique samples were placed into Perspex wells to simulate Class I cavity preparations and were subjected to a loading test. The wells were prepared by drilling into 6 mm thick Perspex blocks to a depth of 3 mm with a 6.35 mm (1/4") diameter square end-cutting drill. This resulted in wells with a flat base. The materials used were:

1. capsulated Ketac-Bond glass ionomer cement as a base,
2. Visio-Bond unfilled resin enamel bond as the adhesive, and
3. Visio-Molar RO (radiopaque) resin composite.

Combinations of glass ionomer cement and composite Sandwich samples and their controls were tested. The thickness of glass ionomer cement and composite components were varied.

THICKNESS OF MATERIALS TESTED:

Sample No.	Thickness of Material (mm)			
I (Control)	3.0 mm	Composite Resin;	0.0 mm	Glass Ionomer Cement
II	2.5 mm	Composite Resin;	0.5 mm	Glass Ionomer Cement
III	0.5 mm	Composite Resin;	2.5 mm	Glass Ionomer Cement
IV (Control)	0.0 mm	Composite Resin;	3.0 mm	Glass Ionomer Cement

Ten samples of each variable I-IV were tested. Samples II and III represented variations in the Sandwich Technique thickness combinations while Samples I and IV acted as controls for each material.

The capsulated Ketac-Bond was mixed on a Silamat amalgamator for 8 seconds and then injected directly into the well using the manufacturer's syringe and capsule (Aplicap) delivery system. One to two increments were placed and the material was levelled slightly using gentle tamping with a 3M plastic sponge held in tweezers. The material was allowed to set exposed to air. Time of set was determined by scratch test with a probe. The thickness of glass ionomer cement was estimated visually. The glass ionomer cement in samples II and III was acid etched for 15 seconds with 37% phosphoric acid gel, rinsed with tap water for 20 seconds, and the surface then gently dried with an air blast of oil-free dry air for 20 seconds, being careful not to excessively dehydrate the surface. Visio-Bond was applied, thinned by blowing with dry air, and light cured for 10 seconds using a visible-light-curing unit (3M - Visilux 2). Visio-Molar RO was placed in no greater than 2 mm thick increments, using a small stainless steel plastic hand instrument until level with the rim of the well. The composite was covered with a Mylar strip and then a glass slab placed over the samples to produce a flat surface level with the top of the well. After removing the glass slab the material was light cured from the top surface for 40 seconds. No further finishing of the samples occurred. For sample IV only, the capsulated Ketac-Bond was injected in one increment to the correct level and then a glass slab with interspersed Mylar strip was held in place during setting to give a level surface. After setting, the surface was protected from dehydration by a coat of Visio-Bond which was then cured.

5.2.2. LOADING

The samples were stored in water for 3 weeks to allow the materials to mature. They were then loaded to failure on an Instron testing machine, using a stainless steel hemisphere of diameter 5 mm. A 5 mm diameter was used to simulate a cusp tip giving a small contact area. The machine was calibrated using a 20 kg weight, and samples were loaded with a cross-head speed of 1.0 mm per minute. The recording chart-speed was set at 5 mm per minute to show load versus time. Fracture load could be calculated by observing any deviation from a straight line on the plot.

Failure mode was determined by observation of all samples under a stereomicroscope.

5.3. RESULTS AND DISCUSSION

5.3.1. DATA AND OBSERVATIONS

COMPRESSIVE TEST - FRACTURE LOAD

Sample Type	Sample Size (N)	Thickness of Material (mm)	Mean +/- SEr (kg)
I (Control)	10	Composite Resin 3.0	199 ± 17.95
		Glass Ionomer Cement 0.0	
II	10	Composite Resin 2.5	110 ± 9.34
		Glass Ionomer Cement 0.5	
III	10	Composite Resin 0.5	33.4 ± 1.76
		Glass Ionomer Cement 2.5	
IV (Control)	10	Composite Resin 0.0	35.4 ± 2.52
		Glass Ionomer Cement 3.0	

Independent t-tests

III and IV, $t=0.6482$, $df=18$, $p>0.10$ (not sig.)

I and II, $t=4.3592$, $df=18$, $p<0.001$ (sig.)

It was anticipated that failure would be seen as both an obvious visual disturbance of the sample surface and a large deviation on the plot. Neither occurred unless the material was loaded to such a great degree that the ball indenter penetrated the surface by some 1 to 2 mm causing peripheral cracks to appear and sometimes causing some material to visually break away.

Usually, failure was indicated as a slight deviation on the recording plot. To determine the precise point a straight ruler was held against the plotted line for each test, and the first point where some obvious deviation from a straight line occurred was taken as the failure point.

5.3.2. RESULTS

The highest load at failure occurred with Sample I. The mean values for Sample I were approximately double those for Sample II ($p < 0.001$). In turn, Sample II mean values were about triple those for either Sample III or Sample IV. There was no significant difference between Sample III and Sample IV mean values ($p > 0.25$).

5.3.3. DISCUSSION

There may be several reasons why failure wasn't a single obvious catastrophic event. Since the load was applied with a ball-shaped instrument rather than a fine needle point the failure modes are different. With a needle point, when the material fails, a crack forms and material is displaced to either side of the crack resulting in the pin being able to continue its travel with less resistance opposing the load. In the case of a hemisphere or ball there is a contact area rather than a point. As the hemisphere indents the surface of the material the surface area of load application increases due to flexure of the material and thus more load is required before failure occurs. Also, as failure occurs in the area of initial contact, the material which fails will be displaced but the indenter will move relatively deeper into the test material, thus allowing for an increased surface area of remaining intact material to be contacted. Therefore, in essence, despite initial failure of the primary surface area, the support to the indenter is maintained at the same or greater level due to the increased surface area of the indenter which contacts the test material. This results in even greater loads being generated after the first detectable failure point. Since this period of transition from first surface area loading to second increased surface area loading is essentially continuous, minimal deviation of the chart plot was detected at initial failure. It must also be appreciated that a certain amount of recoil or rebound was present in the system. The initial distance between the indenter and the rigid stainless steel base was 6 mm, comprised of 3 mm of test material or materials plus 3 mm of Perspex below the base of the test well. All of these undergo some degree of elastic compression during loading, which may have the ability to return or rebound. At the initial failure this rebound effect occurs rapidly and thus minimal deviation occurs on the plot.

Despite the small sample sizes there were obvious, statistically significant differences between groups. Sample 1 fracture load values were well above maximum usual biting forces on posterior molar teeth of 40-90kg, Phillips (1991). In samples with

glass ionomer cement present (i.e. Samples II, III, and IV) the fracture load values were significantly reduced but were still above average physiological chewing loads of 0.2-2.0kg Bates et al. (1976), Reeh et al. (1989). In this present study glass ionomer cement exhibited a lower fracture load than composite. It was unknown what the exact effect would be of introducing glass ionomer cement to the system. On later examination under the binocular microscope, it was found that in all Sandwich Technique samples the overlying composite failed and the underlying glass ionomer cement appeared intact, when viewed through the Perspex base. The only cases where the glass ionomer cement was damaged was if the test was extended beyond initial failure and extremely high loads used, whereby the indenter passed a considerable distance through the sample. In vitro testing of Ketac-Bond has shown good values for compressive, tensile and flexural strengths, and modulus of elasticity, Tam et al. (1989).

5.4. SIGNIFICANCE

The aim of the experiment was to see what effect the introduction of a glass ionomer cement base would have on the strength of the overlying composite resin in the Sandwich Technique system.

The significance of the experiment is whether the Sandwich Technique restoration is able to withstand normal, functional occlusal loads. The Perspex enclosed samples are considered a reasonable simplified model of a tooth enclosed restoration (i.e. Class I restoration). In the loading strength tests all Sample I type examples were found to fail at loads far in excess of those normally expected to occur in the mouth. Most Sample II loads were slightly greater than those which may be exerted in the mouth. All Sample III and IV loads were less than maximum usual biting occlusal loads. Therefore, it must be considered that the Class I "Sandwich Technique" restoration when used with a thick glass ionomer base and thin composite veneer with the materials tested, may be of inadequate strength to resist maximum usual occlusal loads. However, this situation is slightly different to that found in restored teeth where the composite may gain additional support from the surrounding tooth structure to which it is bonded.

In a Class II type restoration the situation is also different. The restoration is not fully enclosed and therefore failure may occur via a different mode such as the material being extruded from the proximal box. This situation is further complicated where the glass ionomer cement forms part of the external surface in the proximal box. (A suitable model for this situation is harder to design, adding many more variables, and was considered beyond the scope of this pilot study). An in vitro study of Class II preparations restored with amalgam over various bases, found a lower fracture resistance when using a glass ionomer cement base than when using several other materials, including a posterior composite, Reel et al. (1987).

5.5. CONCLUSION

The results of this experiment, using a simulated Class I preparation, seem to indicate that a thick (2.5 mm) base of glass ionomer cement with a thin (0.5mm) veneer of resin composite offers a similar somewhat low resistance to occlusal loads as does glass ionomer cement used on its own. A thin (0.5 mm) lining of glass ionomer cement also reduces the strength of the overlying composite, but to a significantly less extent. Therefore, under simulated occlusal loading, Sandwich Technique restorations should have thin glass ionomer cement components, but the thickness of the resin composite is the deciding factor.

5.A.4. DISCUSSION

In contrast to the previous test, the free-standing sample failure was sharply-defined on the plot and obvious visually. In all cases a large piece of material was seen to fall away and correspondingly, on the plot, there was a sharp reduction in load produced.

The failure loads for the composite and glass ionomer cement free-standing samples were of the same order as for the Perspex enclosed samples. Therefore, the Perspex did not seem to significantly increase the size of the failure loads for either material when used alone.

5.A.5. CONCLUSION

The Perspex well enclosures offered very little or no additional support for the samples tested, when compared to conducting the tests in a free-standing situation.

6. EVALUATION OF CLINICAL TECHNIQUES IN VITRO

6.1. INTRODUCTION

There is wide variation in the recommended techniques for placement of the Sandwich Technique restoration. Quality of results can be related to technique and is operator skill-dependent. As was seen in the earlier tests, abuse of the glass ionomer cement at an early stage causes gross damage. In the present study, restorations were placed in hydrated extracted teeth in a manner designed to simulate, as near as possible, techniques used in the clinical situation. The aim of this experiment was to observe;

1. Marginal leakage along occlusal and proximal margins as well as leakage between the glass ionomer cement base and composite,
2. Porosity within the material and filling defects, and
3. Assessments were made of any placement problems, the finishing of the restorations, and the radiopacity of the materials.

Variable results have been recorded for Sandwich Technique restorations subjected to microleakage testing. Most previous studies examined Class II cavity restorations not extending beyond the cemento-enamel junction (C.E.J.), or Class V cavity restorations. Class II composite restorations placed beyond the C.E.J. are more difficult to place and produce a unique problem of gaining a microleakage-free bond due to the polymerisation shrinkage away from the gingival margin. The aim was to see if careful attention to water balance to prevent dehydration, could improve microleakage results.

6.2. MATERIALS AND METHODS

Ten extracted, hydrated molar teeth were prepared for Class II cavity Sandwich Technique restorations (either MO or DO restorations). Photographs were taken at each stage of tooth preparation and restoration placement, and radiographs were taken of the final restorations following placement. The teeth were immersed in methylene blue dye, then sectioned and photographed under magnification to investigate the quality of each margin and interface, and presence of voids and filling defects.

6.2.1. PREPARATION OF SAMPLES

Ten hydrated intact permanent teeth extracted in the Oral Surgery Clinic of the Adelaide Dental Hospital were mounted in individually-numbered plaster blocks covering the roots but keeping well clear of the C.E.J. The small plaster block mounting method allowed easy handling and clear vision of the proximal region. A sickle-shaped scaler was used to remove any remnants of calculus or periodontal tissues, leaving a clean root surface. Class II type cavity preparations with occlusal extensions were cut using a rounded-end coarse flat-fissure diamond point in a ultra high-speed air turbine under air/water spray. All restorations were finished in dentine 2-3 mm beyond the C.E.J., and final cavity finishing was performed using a flat-fissure tungsten carbide bur at high speed with air/water spray.

6.2.2. PLACEMENT TECHNIQUES

Two different placement methods of Class II Sandwich Technique restorations were used resulting in five samples of each method.

Method 1 ("Closed" Sandwich Technique. A 1 mm thickness of glass ionomer cement covered the axial wall and pulpal floor but the gingival margin was left free of

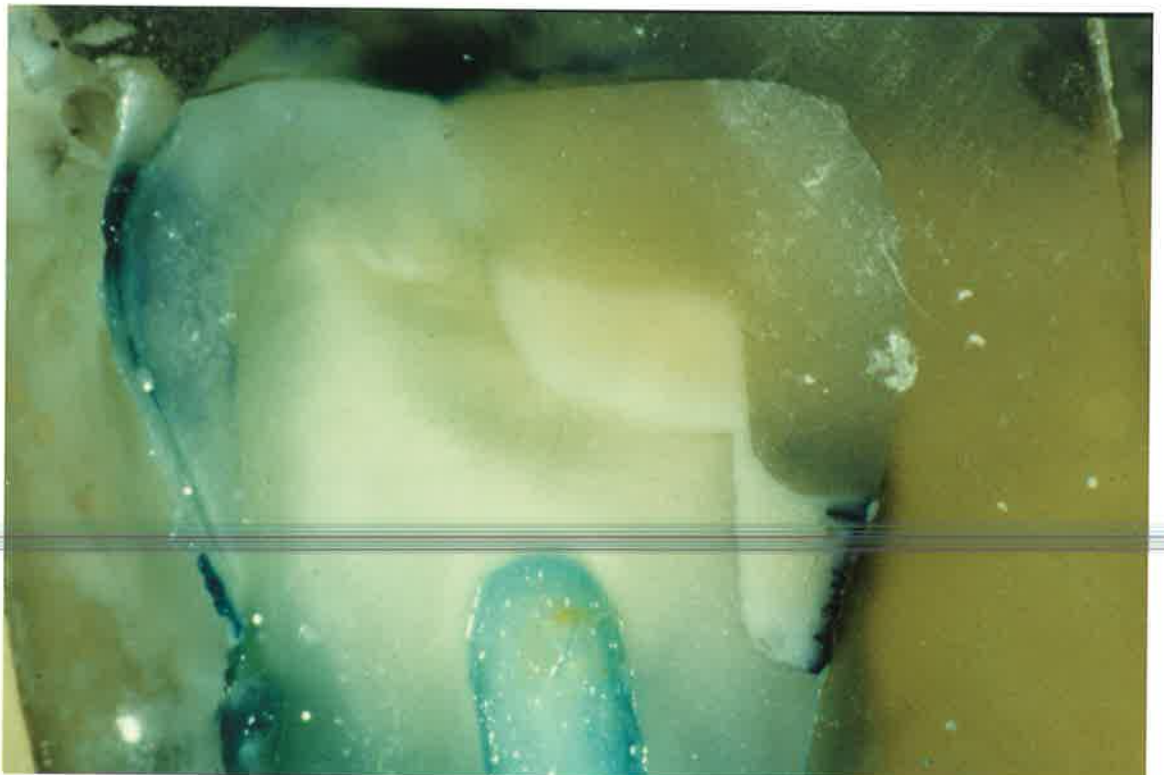
cement (Fig. 8). Following the use of bonding resin, the composite was placed over the cement and had margins to enamel and dentine. Thus, the quality of the margin at the gingival floor of the proximal box was dependent on the ability of the resin to bond to dentine.

Method 2 ("Open" Sandwich Technique). Glass ionomer cement covered the gingival floor of the proximal box and formed approximately 3-5 mm in height of the external surface, at least to the height of the cervical enamel (Fig. 9). Thus, the margin of the composite was finished in part on enamel, and in part on glass ionomer cement. A thin stainless steel matrix band (Toffelmire No. 1) contained the glass ionomer cement during its placement, (rather than a Mylar matrix), and during the subsequent placement of resin composite, as is widely used in clinical practice.

Figure 8 - "Closed" Sandwich Technique



Figure 9 - "Open" Sandwich Technique



The prepared cavities were conditioned for 10 seconds using a 25% polyacrylic acid liquid (Ketac-Conditioner). They were then rinsed thoroughly with a water syringe for 20 seconds and dried by blowing with clean dry air for 10 seconds. Capsulated Ketac-Bond was mixed using a Silamat machine for 8 seconds and, for Method 1, was injected in one increment into the proximal box over the axial and then the pulpal walls only, avoiding the gingival floor and buccal and lingual walls, then tamped into place using a 3M foam sponge. In Method 2, the glass ionomer cement was built up in several increments starting with the proximal box. Each increment was tamped into place using a 3M foam sponge, eventually covering all exposed dentine surfaces. The proximal box, from the gingival floor to several mm above the C.E.J. was filled entirely with glass ionomer cement.

The cement was allowed to set until hard to firm pressure with a dental probe. Using a dental probe or a flat fissure diamond point at intermediate speed under air/water spray, excess cement was then removed from the enamel margins, and gingival margins where appropriate. The enamel wall and cement base were then etched with 37% phosphoric acid gel for 15 seconds, washed with copious water for 20 seconds and dried with clean air for approximately 10 seconds, with care being taken not to dehydrate the cement excessively and thus risk damage. Unfilled bonding resin (Visio-Bond) was applied, thinned out using a gentle dry air blast, and then cured for 10 seconds using a visible light source (3M Visilux). The resin composite, Visio-Molar RO, was placed with an unlubricated small stainless steel plastic instrument using an incremental layer technique. Each layer, of no more than 2 mm, was cured using the visible light source for 20 seconds and the final layer for 40 seconds. The technique of composite placement varied for each method. In Method 1 the first increment was placed against the gingival floor of the proximal box, followed by a buccal or lingual increment where the flat metal instrument was wiped against the side of the proximal box. Then, after curing, another increment was placed against the opposing lingual or buccal wall with a similar wiping action and, finally, an occlusal increment was placed to complete filling of the occlusal and

proximal regions. Method 2 was similar to Method 1, but since the gingival floor of the box was already partially filled with glass ionomer cement the first gingival increment could be eliminated.

The restoration was trimmed and polished using a 12-fluted tungsten carbide pear shaped finishing bur (Komet) in an intermediate speed handpiece with copious water spray. Final polishing was done with a "Brownie" (Shofu) rubber point in a slow speed handpiece under copious water spray. The teeth were then carefully broken out of the plaster block and placed into a 0.03% methylene blue dye solution overnight, removed the next day and rinsed with tap water for 1 minute. The teeth were then embedded in Biopot (Bond Plastics Thebarton, Adelaide, South Australia) for easier manipulation during sectioning.

6.2.3. MINI-MICROLEAKAGE TEST

The appropriate immersion time in the 0.03% methylene blue bath was unknown, so a short experiment was set up aimed to determine optimal immersion time. Six Sandwich Technique samples were prepared in 1.2 mm thick Perspex strip wells of 5 mm diameter. Three Capsulated Ketac-Bond samples and three 3M glass ionomer cement samples were placed level with the top of the well and allowed to set in air in a manner similar to that described in the earlier acid-etching experiment. On setting, the glass ionomer cement surface was acid-etched, rinsed, and dried, then had Visio-Bond applied in the manner described earlier in this present experiment. A button of Visio-Molar RO was placed onto the glass ionomer cement, extending slightly over onto the Perspex, then light cured (Fig. 10). The resulting three samples of each cement were placed into the methylene blue dye bath for either;

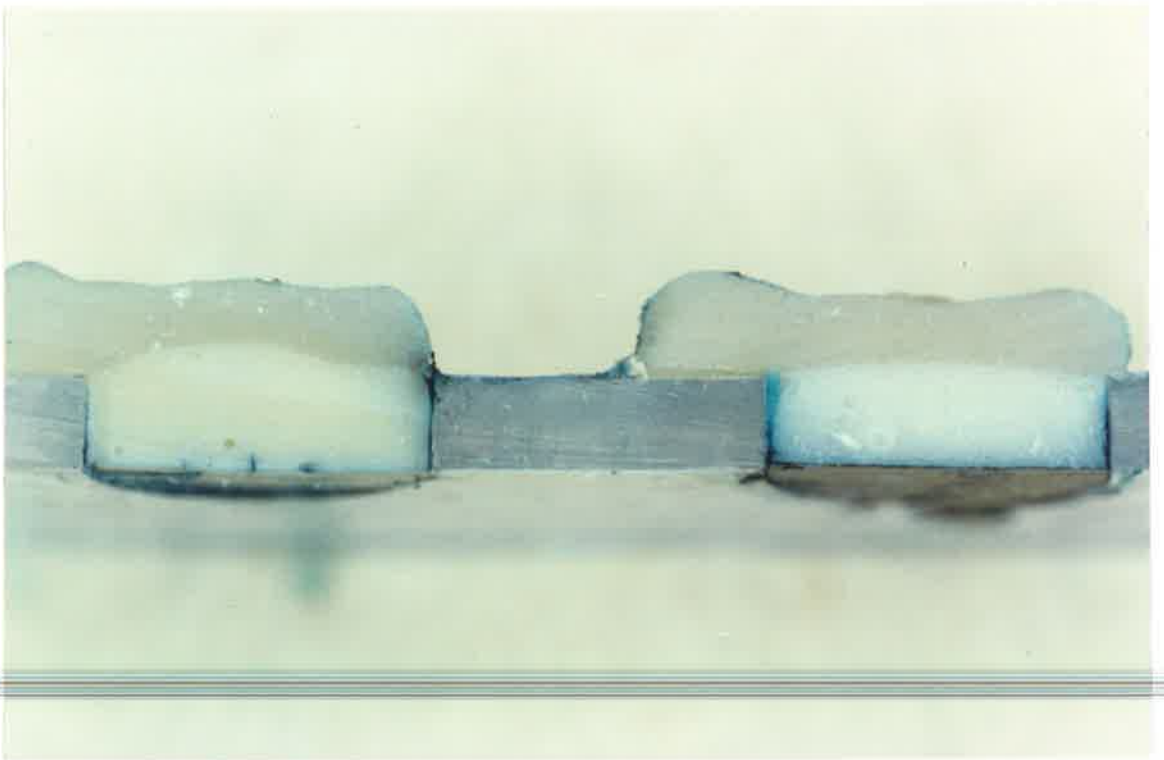
1. 1 minute,
2. 1 hour, or
3. overnight.

On removal, the samples were rinsed, sectioned and photographed. Results indicated that regardless of time of immersion, dye did not detectably penetrate the composite - glass ionomer cement interface. It was decided that since no greater degree of staining was seen overnight than after 1 minute, that the overnight period would be used to allow the dye every possible chance to detect microleakage.

Figure 10 - Sandwich Technique samples in Perspex
Overnight in methylene blue dye bath.

Ketac-Bond

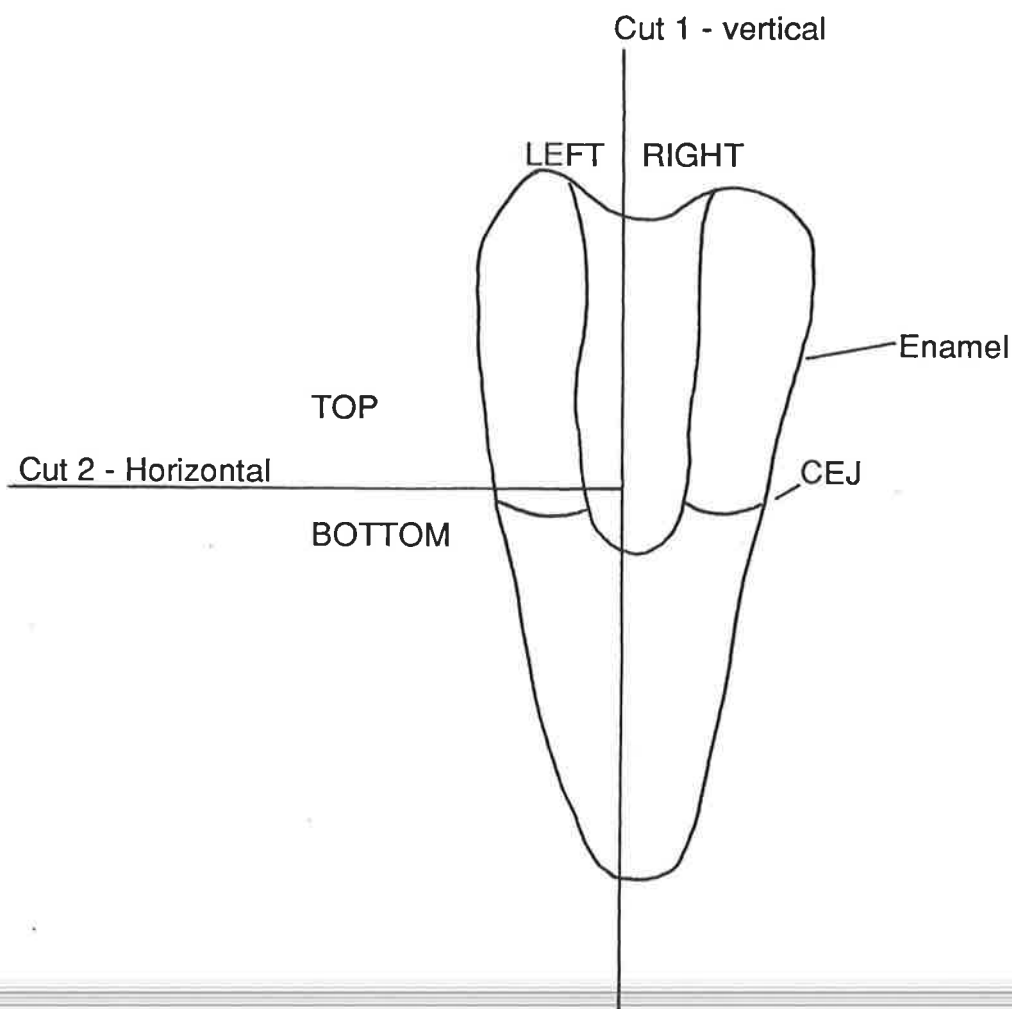
3M GIC



6.2.4. SECTIONING

The teeth were sectioned using two cuts with a high speed water cooled rotary diamond saw. The first cut was mesio-distally along the long axis of the tooth, passing vertically through the middle of both the proximal box and the occlusal surfaces, resulting in left and right section halves. The left half was then sectioned further with a horizontal cut at a level slightly occlusal to the C.E.J., giving a top and bottom section (Fig. 11).

Figure 11 - Placement of saw cuts for sectioning teeth



6.2.5. RECORDS

Radiographs were taken of the prepared cavity and final restored tooth. Photographs were taken at 2:1 times magnification using a hand-held Elicar camera with Ektachrome 100 ASA 35 mm colour transparency film at ;

- (1) completion of cavity preparation,
- (2) placement of restoration (prior to polishing), and
- (3) final (after polishing).

The sectioned teeth were stored in an environment of 100% humidity to prevent dehydration, but not in water, since storage in water was found to cause continued spread of dye across the freshly-cut surfaces. Photomicrographs of the sectioned teeth were taken using a Wild Leitz 'Photomakroskop' (photomicroscope), (GmbH, Wetzlar, Germany), M400 with camera body attachment, at 3x magnification.

Kodak Tungsten 125ASA rating type film was used. The tungsten light source produced very low heat, thus giving little risk of dehydrating the specimens. A magnification of 3x was used first, to give a standard view of all specimens. Subsequently, higher-power views were taken of the right axial sections to give a detailed study of the gingival floor of the proximal box. The magnification selected was different for each specimen, and was chosen to represent best fit within the film frame of all interfaces, including dentine, glass ionomer cement, and resin composite. This gave a magnification factor ranging from 9x to 22x. The horizontal sections were prepared after vertical section photographs were complete.

6.2.6. OBSERVATION AND RECORDING METHODS

A. MICROLEAKAGE

After processing, the colour transparencies were projected onto a screen and viewed by two examiners (AL and GJM). Both examiners viewed the transparencies individually and then discussed any points of disagreement until uniform agreement was reached.

Numerous rating scales for microleakage have been proposed in the literature and, since the present study had two methods of restoration placement, it was decided that a microleakage assessment rating would be designed appropriate for each method of restoration placement. A quantitative linear scale which measured microleakage in millimetres was considered inappropriate since its relationship to each interface and ultimate clinical significance could not be related. It was more appropriate to measure microleakage qualitatively, since the presence of microleakage at certain interfaces could indicate a less satisfactory clinical situation.

ASSESSMENT

The rating scale proposed was a modification of the one used by Gordon et al. (1985). The sequence of slide assessment for each restoration was as follows;

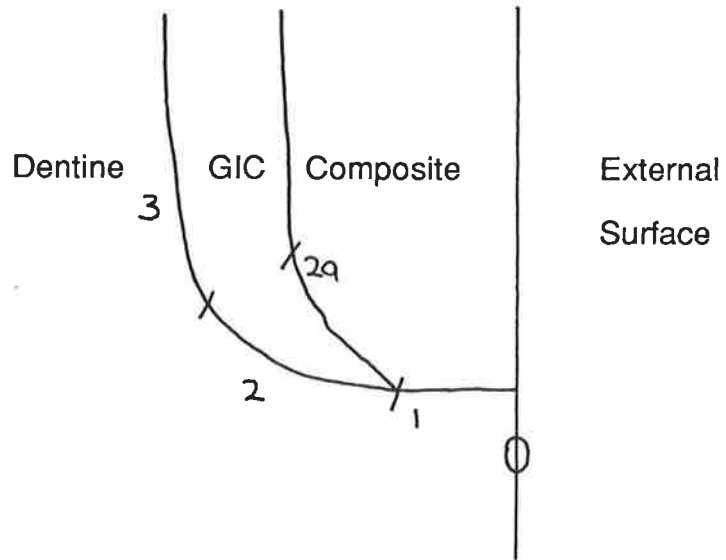
1. vertical section - left half (standard magnification 3x),
2. vertical section - right half (standard magnification 3x),
3. vertical section - right half (extra high magnification),
4. horizontal sections of left side
 - top section (standard magnification 3x)
 - bottom section (standard magnification 3x).

Each section had its individual rating scale as described (Fig. 12). The vertical sections were first assessed for the presence of dye at the occlusal enamel margin and then at the proximal region. The proximal assessment varied for Method 1 and 2 restorations because of the extra external interface, as shown. The assessment method for the horizontal sections also varied for Method 1 and 2 restorations because with Method 2, sectioning slightly occlusal to the C.E.J. revealed only glass ionomer cement at this level of the proximal box. The obvious presence of dye along the interface was taken as indicating the presence of microleakage. To delineate between microleakage along the composite - glass ionomer cement interface, and along the glass ionomer cement - tooth interface, any microleakage which occurred beyond the glass ionomer cement lining between the glass ionomer cement and the composite was given the suffix 'a'. Initially, all ratings were made using the 3x magnification slides but, final validation for the gingival region was done using the extra-high power magnification transparencies.

Figure 12. Microleakage Rating Scales

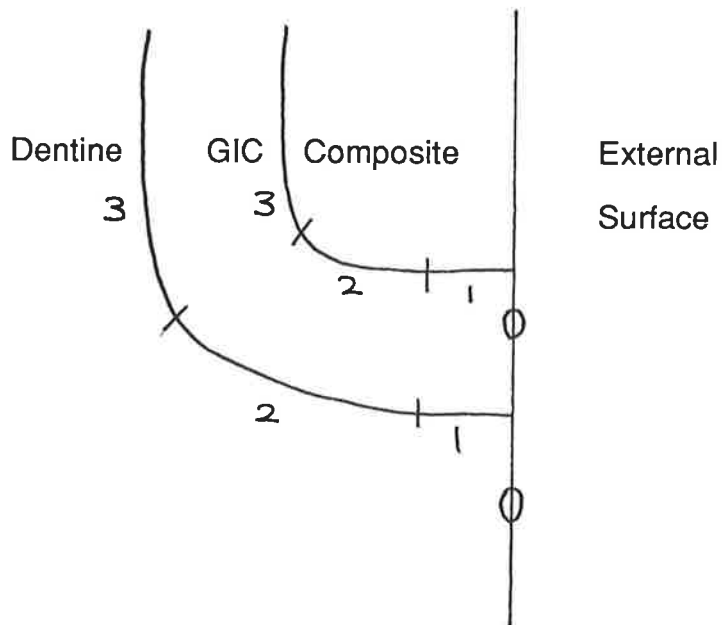
A. Vertical Section - Method 1 (Closed Sandwich Technique)

Proximal Region

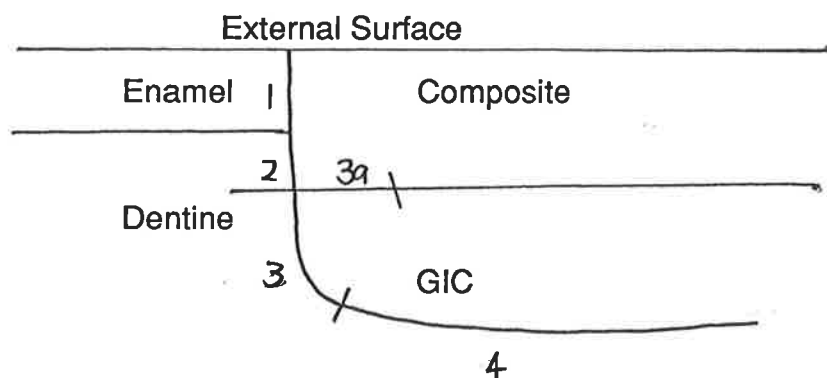


B. Vertical Section - Method 2 (Open Sandwich Technique)

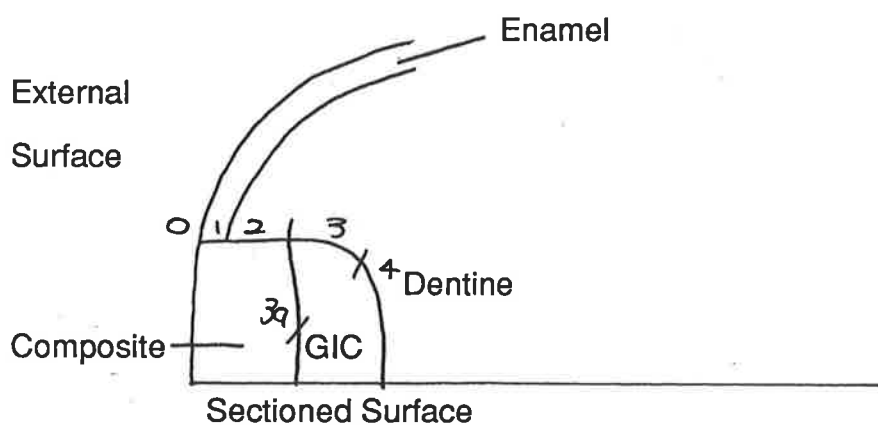
Proximal Region



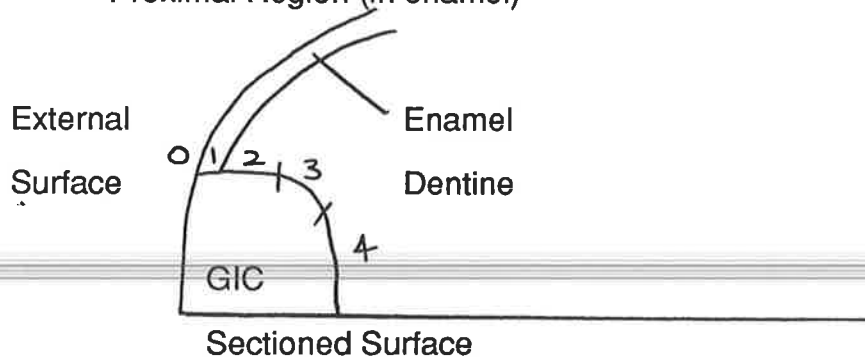
C. Vertical Section - Methods 1 and 2
Occlusal Region



D. Horizontal Section - Method 1 (Closed Sandwich Technique)
Proximal Region (in enamel)



E. Horizontal Section - Method 2 (Open Sandwich Technique)
Proximal Region (in enamel)



B. POROSITY

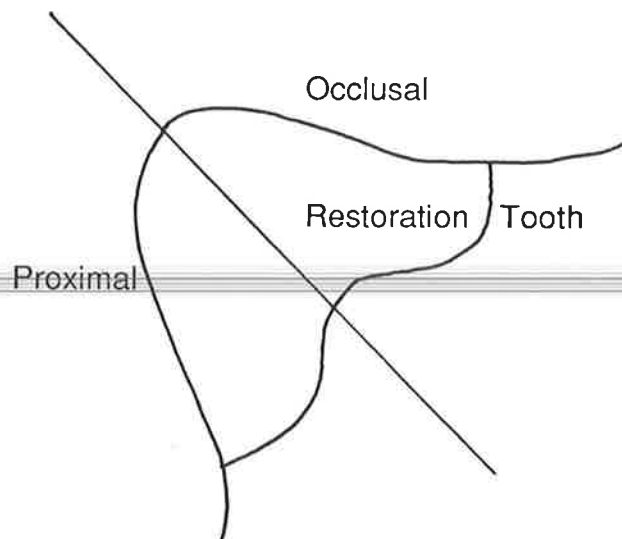
Porosity is defined for the purposes of this study as the presence of voids or air bubbles within the body of a material but not extending to the external surface or to any interface. Porosity is to be distinguished from filling defects which are defined as any voids or air bubbles present at any interface.

The resolution power of the method used, allowed only relatively-large defects to be detected and, therefore, only obvious and easily-distinguishable voids were noted. A very coarse sizing grade was given to each void as well as a description of its location within each material. The size was graded approximately according to diameter as either;

1. small,
2. medium, or
3. large.

The porosity rating was limited to the left vertical section at standard magnification (3x). The restoration region was delineated by separating the proximal and occlusal sections by an imaginary diagonal line from the marginal ridge to the pulpal-axial line angle (Fig. 13).

Figure 13. Porosity Location Scale (Vertical Section)

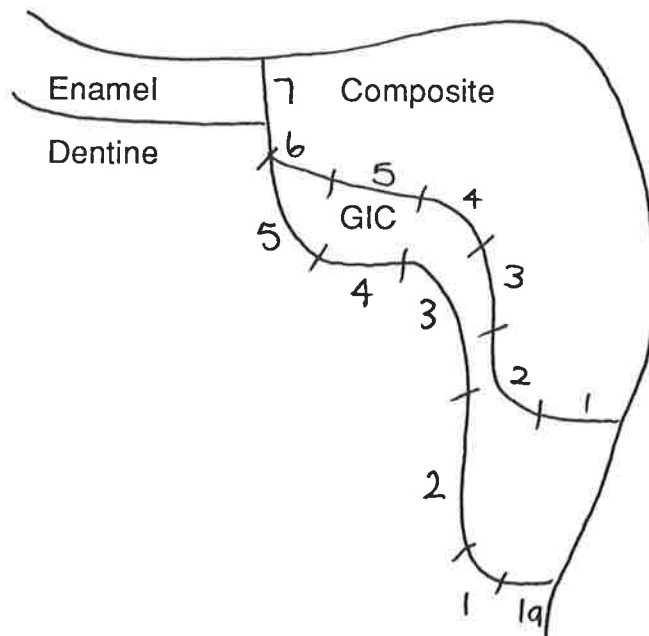


C. FILLING DEFECTS

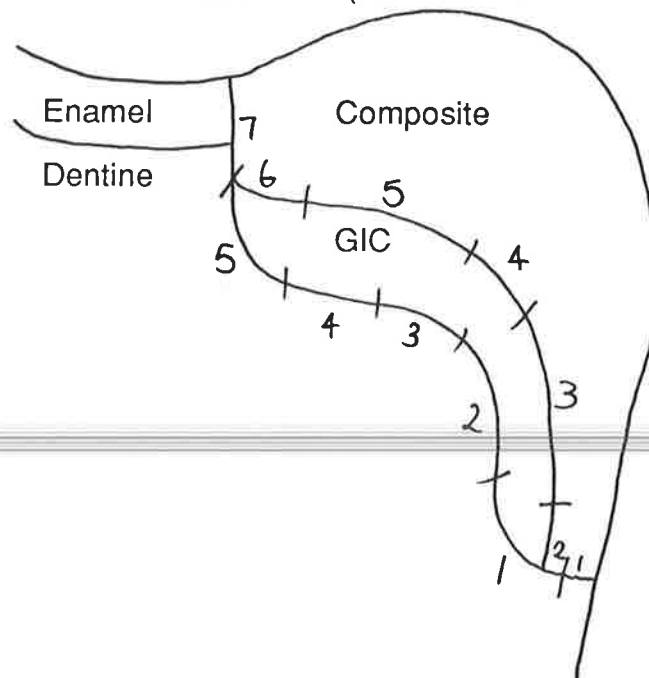
Filling defect assessments used a more detailed scale, allowing a description of location along all interfaces. Method 1 and 2 each had their own scale (Fig. 14). The same size scale was used as above : small, medium and large. The filling defect observation was also limited to the left vertical section at standard magnification (3x).

Figure 14. Filling Defects Location Scales

A. Vertical Section - Method 1 (Open Sandwich Technique)



B. Vertical Section - Method 2 (Closed Sandwich Technique)



D. SURFACE DYE PENETRATION AND DEPTH OF CRACKS (GLASS IONOMER CEMENT ONLY)

Finally, for Method 2, observation was made of the exposed glass ionomer cement in the proximal region where it formed part of the external surface. The left vertical section was analysed for depth of dye penetration and the presence of stained cracks penetrating below the surface. The deeper or worse score was taken where any doubt arose. The scoring criteria were as follows, using a modification of those proposed by Phair and Fuller (1985);

- 0 = No dye penetration
 - 1 = less than 1/4 of glass ionomer cement thickness penetrated
 - 2 = greater than 1/4 and less than or equal to 1/2
 - 3 = greater than 1/2 but less than to axial wall
 - 4 = penetration to axial wall.
-

6.3. RESULTS AND DISCUSSION

6.3.1. DIRECT VISUAL AND RADIOGRAPHIC OBSERVATIONS

It was noted during the pilot study that in Method 2 (Open Sandwich Technique), despite the initial appearance of fairly clean buccal and lingual enamel walls after trimming back the glass ionomer cement in the proximal box, the glass ionomer cement was found at the external surface partly covering the enamel walls in these areas (Fig. 15).

Also, it was noted during the pilot study that, in some samples of the Method 1 (Closed Sandwich Technique) restoration, on removing the matrix band the composite was found to have not fully set in the depth of the cavity, despite the incremental build-up. The light source was directed from the occlusal in all cases. Distance from the light source was approximately 6-7 mm from the top of the matrix band to below the C.E.J. The metal band caused a shadowing-effect and transmitted decreased light to this area, compared with a clear Mylar matrix band used with a clear, light-conducting interproximal wedge. This problem of incompletely-set composite was not seen during the final experiment.

In the Method 1 restoration, it was difficult to place glass ionomer cement only along the actual axial and pulpal dentine walls without excess spreading onto the matrix band, or buccal and lingual enamel walls of the cavity. For both Method 1 and 2, despite the appearance of fairly clean proximal buccal and lingual enamel walls, excess glass ionomer cement was found at the cavo-surface margins after matrix band removal. The reason for this appeared to be associated with the close adaptation of the matrix band. The band not only protected the adjacent tooth, but also limited the bur head from reaching the cavo-surface margins during the pilot study. The significance of this small amount of excess cement at the margins is unknown, but it can be speculated that it may alter the quality of the enamel bonding,

and the glass ionomer cement may show later wear and stain. In the final study, the matrix band was removed to allow direct vision to remove any excess set glass ionomer cement. With the Method 2 (Open) restoration, it was generally easier to place the glass ionomer cement and to cut back the minimal amount of excess with a bur.

The glass ionomer cement used was usually sufficiently radiopaque to allow easy detection of secondary caries. It was more radiopaque than dentine and less radiopaque than the Visio-Molar RO composite. Therefore, should caries occur under the restorations it could usually be detected on routine bite-wing radiographs.

Despite the restorations being placed under more than "ideal" circumstances large overhangs and flash of glass ionomer cement were often present immediately on matrix band removal (Fig. 16). The excesses were easily removed since the teeth were individually mounted, allowing direct access to the proximal areas. However, in the mouth, where adjacent teeth are present, it would be far more difficult to detect any excesses and remove them, because of the limited access available. Any remaining excesses could lead to plaque accumulation, affecting periodontal health.

Figure 15 - Example of Method 2 (Open Sandwich Technique) restoration showing presence of excess glass ionomer cement at the cavo surface margin of the proximal box.



Figure 16 - Restoration shown in Figure 15 immediately upon matrix band removal prior to finishing, showing gross excess of glass ionomer cement.



With the Method 2 restoration, in the proximal region where glass ionomer cement formed part of the external surface, the presence of surface voids gave a very rough surface regardless of the finishing technique. Such surfaces may accumulate more plaque, which may lead to gingivitis, especially given that such a method is advocated in deep proximal boxes. Charbeneau and Bozell (1979) have shown that Class V glass ionomer cement restorations placed near the gingiva do not lead to an increase in the presence or severity of gingivitis as such restorations are readily accessible to oral hygiene measures. However, Smales (1981) and Forss et al. (1991a) have shown that the rough surfaces of a glass ionomer cement can accumulate large amounts of (possibly altered) plaque if oral hygiene is not practised, or the surfaces are not accessible to such measures.

From a clinical point of view, Method 2 (Open Sandwich Technique) was less time consuming because of the reduced number of composite resin increments. Regardless of the method used, the placement of a Sandwich Technique restoration was more time consuming, and demanded greater concentration and attention to detail, than placing an amalgam restoration in the same situation. In the case of multiple restorations, it was demanding to constantly remember to protect the glass ionomer cement from dehydration, either by placement of a layer of cured Visio-Bond or by occasional water spray from a syringe. Also, with Method 2, the application of glass ionomer cement was simpler since it was fairly easy to syringe in and tamp into place correctly, as compared to Method 1 where it was difficult to keep the wall of the proximal box free of cement. It was for these reasons that overall, Method 2 (Open Sandwich Technique) was considered to have the easier manipulation.

6.3.2. MICROLEAKAGE

METHOD 1 (Closed Sandwich Technique)

The extent of dye penetration was variable. The Method 1 technique exhibited penetration of dye beyond the glass ionomer cement in only one restoration. This was seen as microleakage between the glass ionomer cement and dentine in one horizontal section, and in all vertical sections. The bottom horizontal section exhibited dye just under the glass ionomer cement, whereas the top section, less than 1.0 mm away, showed no evidence of microleakage. The corresponding vertical sections showed slight dye penetration along the gingival interface under the composite resin on both the left and right sections, penetrating between the glass ionomer cement and dentine, but with no leakage between the glass ionomer cement and composite.

In the vertical sections, all other sections showed dye penetration between the composite and dentine. No dye penetration occurred at any occlusal enamel margin. In the horizontal section 3/5 (three out of five) of the specimens exhibited no dye penetration, while 1/5 had dye penetration into the enamel margin, but not penetrating to dentine.

METHOD 2 (Open Sandwich Technique)

The extent of dye penetration was again variable, but was less than for Method 1. There were cases where slight dye penetration occurred between the glass ionomer cement and dentine but, unlike Method 1, in no case did dye penetrate to the internal line angle, let alone the axial wall. Many individual interfaces exhibited no dye penetration at all. In those cases where dye penetration did occur, it was only given a rating of 1. Scores for five left, and five right vertical sections could be combined to give a total of ten observations. Also, scores for five top, and five bottom

horizontal sections could be combined to give a total of ten observations. The cumulative incidence scores gave the following results with possible scores out of ten.

The number of interfaces where no or "0" dye penetrated was: for vertical sections- 7/10 (seven out of ten) occlusal interfaces, 7/10 glass ionomer cement - composite interfaces, and 4/10 glass ionomer cement tooth interfaces; and for 6/10 horizontal section interfaces. All the remainder achieved a score of "1" for dye penetration.

6.3.3. POROSITY

The observations of all specimens showed a high proportion of size 2 type porosity. Size 1 porosity was less often noted, and size 3 the least. Data are given in Tables 1 and 2. Trends were difficult to observe. If a certain size of porosity did occur at a particular region in over half of the sections, then it was considered common. Such was the case for three regions which exhibited size 2 porosity in 4/5 cases: these were Method 1 (Closed) proximal composite resin; Method 2 (Open) proximal glass ionomer cement , and Method 2 occlusal composite.

Method 2 proximal glass ionomer cement porosity and Method 1 proximal composite porosity were both probably related to the method of placement, using an incremental build up. Consecutive increments probably entrapped air, but the explanation for the high proportion of Method 2 occlusal composite porosities is unknown, since no size 2 porosity occurred in the corresponding region with Method 1.

Table 1 Distribution of Porosity Size
Vertical Section - Method 1 (Open Sandwich Technique)

Material and Region					
Glass Ionomer Cement			Composite		
		Proximal	Occlusal	Proximal	Occlusal
Porosity	1:	0	1	0	1
Size	2:	2	0	4	0
	3:	0	0	1	1

Table 2 Distribution of Porosity Size
Vertical Section - Method 2 (Closed Sandwich Technique)

Material and Region					
Glass Ionomer Cement			Composite		
		Proximal	Occlusal	Proximal	Occlusal
Porosity	1:	1	0	0	1
	2:	4	2	0	4
	3:	0	2	0	0

6.3.4. FILLING DEFECTS

Filling defects were relatively few. Only one filling defect was seen between the glass ionomer cement and dentine, and this was a size 2 defect near the pulpal-axial line angle of a Method 1 restoration. All other filling defects occurred at the composite - glass ionomer cement interface at various sites. It can be concluded that filling defects are least likely to occur at the glass ionomer cement-dentine interface.

6.3.5. SURFACE DYE PENETRATION AND CRACK DEPTH (GLASS IONOMER CEMENT-METHOD 2 ONLY)

Penetration occurred in all 5/5 cases. In 3/5 cases the dye penetrated less than one third of the depth of the glass ionomer cement (eg. Fig 9). In 1/5 cases the penetration was less than half way, and in 1/5 cases penetration was over half way, but did not reach fully to the pulpal floor.

6.4. SIGNIFICANCE

6.4.1. MICROLEAKAGE

In Method 1 (Closed Sandwich Technique), leakage occurred at the gingival margin below the composite resin in all cases, and in one case it penetrated the glass ionomer cement - dentine interface. Also, one case exhibited leakage beyond the composite - tooth interface, extending to between the glass ionomer cement - dentine interface.

In the horizontal sections microleakage between composite and acid-etched enamel in the cervical region was not surprising, since it is known that the quality of enamel for bonding in this region is not good, Gwinett (1967). Also, microleakage between the composite and dentine at the gingival floor is unremarkable, since Visio-Bond is not a dentine bonding agent. However, concern must be expressed at the presence of microleakage between the glass ionomer cement and dentine, although the release of fluoride from the cement may inhibit any recurrent caries.

Therefore, the glass ionomer cement lining did not present an absolute barrier to microleakage, as some authors have postulated, Mount (1991). The reasons for this may be numerous and could include water imbalance problems, but most likely the composite curing shrinkage caused a disruption of the glass ionomer cement - dentine bond in this gingival region, Gordon et al. (1985), Garcia-Godoy et al. (1988c). The composite - glass ionomer cement bond was not affected in this way and, therefore, this interface does stop microleakage as has also been shown previously, Gordon et al. (1985).

Method 2 (Open Sandwich Technique) exhibited microleakage to a lesser cavity depth than did Method 1, thus giving a lesser likelihood of a drastic outcome.

Although microleakage was detected in proportionally more cases, it was always less than half the cavity depth.

Therefore, Method 2 was more successful than Method 1 in reducing microleakage at the gingival floor of the proximal box.

6.4.2. POROSITY

The observation that a relatively high proportion of size 2 type porosity was seen, was probably related to the coarseness of the rating scale rather than to some other factor. Soh and Chang (1990) showed that a magnification factor of 9x optimised reliability by maximising void detection while minimising operator variability when looking at elastomeric impressions. The same may apply to filling defects. Difficulties with the placement of restorative materials into the deep proximal box region led to the incorporation of air bubbles, regardless of the actual material used. The significance of voids is that they may form stress foci within the material causing possible early mechanical failure, due to a considerable reduction in actual strength of the material, Walls (1986); as well as enhanced wear, Leinfelder (1988). However, since the porosities are within the proximal box, away from the occlusal surface, it is likely that the effects of occlusal stress are diminished. Surface voids are more likely to enhance plaque retention and growth.

6.4.3. FILLING DEFECTS

The significance of filling defects may be that they lead to increased microleakage, which is especially important at the restoration-tooth interface. However, since most filling defects occurred at the composite - glass ionomer cement interface, they may be considered of less significance and regarded as a special type of porosity within the restorative material body. In general the filling materials adapted well, even in the line angles. Should microleakage occur, then the fluoride released from the glass

ionomer cement will produce a cariostatic effect in several ways, Hicks et al. (1986), Wilson and McLean (1988), Forss and Seppa (1990).

6.4.4. CRACKS AND SURFACE STAINING (Method 2 Glass Ionomer Cement)

All external glass ionomer cement surfaces stained heavily. However, two specimens also exhibited fairly extensive horizontal cracks extending over one third of the cavity depth. Although none of these samples exhibited crack penetration to the pulpal wall, problems may occur with shallower cavities, or should a slightly deeper crack occur forming an open channel for microleakage from the external surface to the pulpal wall. The cause of these cracks is unknown, but may be related to inadvertent dehydration, or to the curing contraction of the composite.

6.4.5. THERMAL CYCLING

The clinical significance of in vitro thermal cycling tests with resin composites has been questioned, Jones et al. (1978), Sidhu and Henderson, (1992), Rossomando and Wendt (1993). The authors found that clinically-realistic temperatures did not significantly affect microleakage, and stated that such testing only assessed the initial seal produced and not necessarily the long-term sealability of the restorations. Wendt et al. (1992) showed that when thermocycling was used to simulate temperature extremes there was no significant increase of microleakage in composite restorations either in dye or water baths as opposed to restorations which were not thermocycled. They suggested that thermocycling of microleakage specimens for the purpose of analysing the effects of the coefficient of thermal expansion in resin composite be discontinued. Several authors have shown that the usual temperature changes in vivo under filled resins, Harper et al. (1980) and even within amalgams, Michalesco et al. (1991) are less than those generally used in vitro for testing microleakage. In resin-based materials, thermal diffusivity may be of more importance to marginal seal than coefficients of thermal expansion. In recent years,

attention has focused more on the effects of mechanical load cycling on microleakage, as this is thought to be more pertinent to the usual clinical situations, Rigsby et al. (1992).

Neither thermal nor mechanical cycling were used to assess microleakage in the present study. Many previous studies have shown the adequacy of the dye method used here, to detect microleakage at cavity margins placed in dentine especially. Stressing these margins merely enhances the degree of microleakage present. The use of a vacuum during microleakage testing may also enhance dye uptake in situations where little microleakage is present.

6.5. CONCLUSION

The use of the Sandwich Technique restoration in deep Class II cavities extending beyond the C.E.J. is technically difficult and time consuming, often leading to less than perfect results especially in the proximal box region. Regardless of whether Method 1 ("Closed" Sandwich Technique) or Method 2 ("Open" Sandwich Technique) was used, difficulties were encountered. Voids were created within either the glass ionomer cement or the composite placed in the depth of the box. Microleakage occurred along the gingival floor to varying degrees, and was more extensive for Method 1 than 2. The radiographic appearance of capsulated Ketac-Bond was sufficiently radiopaque to usually allow secondary caries to be detected.

Marginal flash and overhangs were detected immediately upon matrix band removal, and necessitated further careful trimming and finishing. This excess of material may be difficult to detect and modify in the clinical situation. In Method 2, the external glass ionomer cement surface showed the presence of surface defects, some of which were present as horizontal cracks extending almost the full depth of the restoration, and allowing a further potential route for microleakage. The quality of this region is suspect and requires further study.

From the results of the present study, the Sandwich Technique in the deep proximal Class II preparation poses problems in achieving a satisfactory result, but the method should be compared to other methods of restoring proximal surfaces under similar experimental conditions. Ultimately, long-term clinical trials are the only method to determine restoration deterioration and longevity, and in vitro tests can only be used to reveal material handling and other potential clinical problems.

7. CLINICAL CHARACTERISTICS OF SANDWICH TECHNIQUE RESTORATIONS PLACED IN VIVO.

7.1. INTRODUCTION

The in vivo study was designed to assess several modes of deterioration of Class I and II "Closed" Sandwich Technique restorations, and Class I Ketac-Silver cermet restorations, when compared to a limited number of amalgam restoration controls. The study also allowed assessment of the handling properties of the materials in a clinical situation.

The project was a joint study with Mr. Richard Wilkie who was involved with the assessment of Class II Ketac-Silver "Tunnel" restorations. Each of us was concerned with our own aspect of the study. My area of interest was Class I and II Sandwich Technique restorations and Class I Ketac-Silver restorations. We both shared the assessments of the Class I and II amalgam restoration controls. As far as possible, each operator tried to limit treatment of patients to those who needed restorations of his particular concern. However, sometimes an overlap did occur and the patient's treatment would be completed by one operator. This occurred in cases where both Class I and II Ketac-Silver restorations were placed in the same patient.

7.2. MATERIALS AND METHODS

7.2.1. NUMBERS OF RESTORATIONS

A total of 35 informed adult volunteer patients took part in the study. Restorations were placed, during a period from July 7 1988 to March 27 1990, in permanent premolars and molars:

38 Class I Sandwich Technique restorations

28 Class II Sandwich Technique restorations

57 Class I Ketac-Silver cermet restorations

21 Class I Amalgam (controls)

16 Class II Amalgam (controls)

7.2.2. PATIENT SELECTION/POPULATION

The study was approved by the Board of Directors of the South Australian Dental Service and by the Ethics of Human Experimentation Committee of The University of Adelaide. A notice was placed first in the Primary Care Clinic of the Adelaide Dental Hospital informing clinicians of the study and giving details of the types of patients required (Appendix A1). The need to satisfy several patient criteria were also discussed with individual staff dentists. The selection requirements to be included in the study were:

1. Numerous small primary Class I and II carious lesions,
2. Patient willing to be part of study and have photographs and impressions taken at approximately six-monthly intervals,
3. Availability for recall appointments for at least two years, and
4. Be co-operative.

The patients were then referred to the teaching clinics for an examination appointment with either operator. At this appointment, the patient was examined to

determine the treatment requirements and his or her suitability for the study. Bitewing radiographs were taken if this had not been done in the Primary Care Clinic. The patient was informed of the details of the study and was requested to consent to be part of it by signing a consent form (Appendix A2). Scaling, cleaning and oral hygiene measures and dietary advice were instituted where necessary. On the following appointments, restorations were placed, and on the final visit the restorations were polished and baseline records were taken. The patient was informed that he or she should contact the operator if there were any problems with any restoration before the review appointment, and a note was made in the patient's case-notes to refer him or her back to the operators should any problems arise.

7.2.3. RESTORATION PLACEMENT SEQUENCE

Initially, it was planned that approximately 80 each of Ketac-Silver Class I and II restorations would be placed with amalgam controls. Also, it had been planned that paired restorations would be placed on contralateral sides of the mouth with material choice being selected by coin toss. However, it became obvious after several months that the number of suitable patients with numerous small primary carious lesions was minimal.

Therefore, because of the lack of suitable patients and numbers of restorations it was not possible to have a randomly-selected paired study with one Ketac-Silver restoration matched with one amalgam restoration on the contralateral side in the same patient. As the clinical deterioration behaviour and longevity of Dispersalloy amalgam control restorations have been well established from numerous previous studies, the number of amalgam controls was reduced to only one amalgam per two to four test restorations. Therefore, each material was assessed taking into account operator and patient factors, and oral site factors. (It is known that restoration deterioration and longevity may be altered because of different factors present in operators and individual patients at various oral sites within the arches).

The selection of materials was decided by allocating a number to all of the proposed restorations to be placed in each patient, then asking a clinic dental assistant to choose a number. This first number decided the cavity to be restored with amalgam. The ratio of amalgam restorations placed per patient was approximately as follows: Patients with 1 to 4 test restorations had one amalgam control, and 5 to 8 test restorations had two amalgam controls. Despite the relatively small number of controls, it still took approximately one year to place adequate numbers of Ketac-Silver restorations.

Only at this stage was the placement of Sandwich Technique restorations commenced. Therefore, unfortunately, because of the early emphasis on the placement of Ketac-Silver, the Sandwich Technique restorations are limited to slightly shorter observation periods. The number of amalgam controls was kept again to a minimum, but it took nearly another year to place adequate numbers of Sandwich Technique restorations.

Ideally, Sandwich Technique restorations would have been placed in slightly larger cavities than were the Ketac-Silver small primary carious lesions. Many clinicians use the Sandwich Technique to replace existing amalgam restorations and, therefore, the limitation on using primary carious lesions only in the present study was removed; hence secondary carious lesions were also selected for restoration. The size of restorations varied and was sometimes quite minimal and barely into dentine, while at other times was much larger. But, excessively-large restorations extending more than three-quarters of the inter-cuspal width were discarded from the study, and most were fairly minimal in size.

7.2.4. MATERIALS

The restorative materials used in the study were:

1. Visio-Molar RO (fine particle hybrid with quartz filler 86% by weight) posterior resin composite with capsulated Ketac-Bond glass polyalkenoate (ionomer) cement linings (Sandwich Technique),
2. Ketac-Silver glass polyalkenoate (ionomer) cermet cement, and
3. Dispersalloy zinc-free high copper content admixed amalgam alloy (used as the control).

Other materials used are listed in Appendix A3

7.2.5. METHODS

Restorative techniques were first standardised by both operators in vitro, on extracted teeth. The methods attempted to simulate, as nearly as possible, clinical techniques used by many general practitioners. Placement procedure was performed in vivo under rubber dam. The teeth were first marked in centric occlusion for occlusal contacts, to identify possible areas of high occlusal loads. Conservative cavity forms were cut with rounded internal line angles. Bevels were not employed at cavo-surface margins.

A. CLASS I KETAC-SILVER RESTORATIONS

The cavity preparation was variable depending on the size of the lesion. The smallest preparations were little more than narrow fissure fillings. The "sticky" carious fissure region as detected by probing was entered with a very fine tapered diamond (Premier) point in a high-speed handpiece using air/water spray. The fissure was opened carefully to allow further probing and observation of the carious area. If carious dentine was found it was excavated with a No. 1 or 2 small round stainless steel bur at slow speed without water. The removal of all carious dentine at the bottom of the fissures was not always certain. Adjacent, apparently non-carious

fissures were also opened up to allow easier Ketac-Silver placement. It has been shown previously that glass ionomer cement is better retained in the fissure filling situation, where the fissure has been widened with a fine tapered bur than when used as a sealant, Gerke and Smales (1989). The viscosity of glass ionomer cement may prevent deep penetration of narrow fissures when used as a sealant, leading to early loss of material bulk.

Larger cavities were prepared with a high speed Jet 330 (Beaver) tungsten carbide bur under air/water spray to gain access for removal of the main bulk of carious tissue. Remaining carious dentine was removed with appropriate-sized stainless steel round burs at slow speed without water. At times, these larger cavities were identical in design to those used for small amalgam restorations. Any remaining adjacent non-carious fissures were also widened slightly using the fine tapered diamond point (Premier) as for the smaller cavities. At the time of restoration placement, the exact details of caries location and extent of cavity preparation were not recorded. This made analysis of restoration deterioration at a later date more difficult, since it was difficult to distinguish the extent of the original cavity in width or depth, from the surface appearance. With Ketac-Silver, the surface appearance of an over-filled widened fissure limited to enamel, can be the same (until wear occurs) as a fairly wide cavity which enters well into dentine, but where the restorative material is confined to within the margins of the preparation. However, subsequent photographs usually revealed the width of the preparations, except for some of the resin sandwich preparations.

The prepared cavity was conditioned with 25% polyacrylic acid (Ketac Conditioner) for 10 seconds, followed by a 20-second rinse with water, then by short blasts of dry oil-free air for 10-20 seconds. The Ketac-Silver was activated and mixed with a Silamat amalgamator for 8 seconds, then injected into the cavity usually in two increments. Each increment was tamped into place using a 3M Dental plastic sponge to force the material into all line angles and into the depths of any fissures.

The cavity was filled to excess and a small piece of unlubricated lead foil cut from that in a radiograph packet was adapted either by digital pressure or with a large ball burnisher hand instrument. Four minutes from the start of mixing, when the glass ionomer cement surface was hard to probing, the foil was removed and the excess cement was trimmed.

At the initial set, Ketac-Silver has poor physical properties, is subject to dehydration, and can be easily damaged from heat production if finishing is attempted. Therefore, initial occlusal adjustment and gross removal of flash was attempted at the placement visit, using an intermediate-speed small round finishing grade diamond point under air/water spray. Further finishing was performed after a minimum of two weeks to allow the glass ionomer cement to mature, because in vitro studies have shown that it is stronger and less prone to damage from dehydration at this stage, Blagojevic and Mount (1989). Final finishing was performed with a slow speed "Brownie" (Shofu) rubber polishing point under water spray. No special attention was paid to remove flash beyond the cavosurface margin since this was difficult to detect and, secondly, it was considered to be of little clinical consequence. No attempt was made to polish the material further, since Ketac-Silver restorations cannot be given a shiny lustre regardless of technique.

B. CLASS I SANDWICH TECHNIQUE RESTORATIONS

All cavities were small (less than three-quarters of the occlusal inter-cuspal width). Caries and old restorations were removed with a Jet 330 tungsten carbide bur, with no extension into adjacent fissures. Deeper caries was removed with the appropriate-size slow-speed round steel bur. The cavity was first conditioned with 25% polyacrylic acid for 10 seconds. Capsulated Ketac-Bond was mixed using a Silamat amalgamator for 8 seconds, injected into the cavity and tamped into place over the pulpal floor and any other areas of exposed dentine with a 3M plastic sponge. The base was allowed to set for 3-4 minutes until the cement was hard to

probe. Excess cement was then removed from the cavo-surface margin using a Jet 330 bur with air/water spray in an intermediate-speed handpiece. This left a layer of cement usually at least 1 mm thick over the pulpal floor, replacing the dentine.

The cement and enamel walls were etched with a 37% phosphoric acid gel for 15-20 seconds. The gel was rinsed away thoroughly with air/water spray for 20 seconds and the cavity dried with moisture-free air being careful not to excessively dehydrate the glass ionomer cement lining. An unfilled resin bonding agent (Visio-Bond), was applied to the cement and cavity walls and thinned out to a fine film using dry air, then cured for 10 seconds using a visible light source (3M - Visilux 2). The resin composite (Visio-Molar RO) was then placed in incremental layers of 2 mm thickness or less, using a small stainless steel plastic instrument and cured using the visible light source for 40 seconds.

The shade of the composite chosen was deliberately different from that of the tooth, to facilitate subsequent identification of the restoration. After removal of the rubber dam, the composite was initially trimmed to regain correct occlusion, and to remove gross excess only. A pear-shaped multi-fluted tungsten carbide (Komet) finishing bur was used under air/water spray in an intermediate-speed hand-piece to minimise heat production.

Final occlusal refinement and polishing was usually performed two weeks after the initial restoration placement, allowing for more complete curing and maturation of the composite and glass ionomer cement base. All finishing procedures were completed under air/water spray, using the same pear-shaped bur as mentioned earlier, and also using slow-speed with water spray with "Brownie" and "Greenie" (Shofu) rubber points. Great care was taken to avoid overheating or drying out of the restorative materials. Once again, no special attention was paid to the removal of areas of bonded flash or excess of material over unprepared occlusal pits, fissures and cuspal inclines.

C. CLASS II "CLOSED" SANDWICH TECHNIQUE RESTORATIONS

These were placed in a similar sequence, using the same materials and procedures as described for the Class I restorations. Subsequent to cutting the Class II cavity form and refining its outline, a thin stainless steel No. 1 matrix band (Tofflemire) was placed around the tooth and tightly wedged to minimize the amount of interproximal overhang of material and other marginal excess. A Ketac-Bond glass ionomer cement base approximately 1 mm thick was placed over the axial wall and pulpal floor.

After allowing the glass ionomer cement to set hard, excess was removed from the enamel margins using a tungsten carbide Jet 330 bur in an intermediate-speed handpiece with copious air/water spray. The matrix band was adapted closer and teeth were wedged apart using a wooden interproximal wedge (Wizard Wedge). The resin composite was built up in incremental layers and set using a visible light source. Increments were less than 2 mm in thickness.

After placement, gross occlusal reduction and removal of interproximal flash were performed using intermediate speed under air/water spray with tungsten carbide multi-fluted finishing burs (Komet), including pear-shaped and fine tapered burs.

Final trimming and polishing were usually performed two weeks later using intermediate speed multi-fluted tungsten carbide finishing burs (Komet) and slow speed with "Brownie" and "Greenie" (Shofu) rubber points under air/water spray.

D. CLASS I AND II AMALGAM CONTROLS

Several amalgam restorations (Class I and II) were placed to act as controls. These were selected at random as mentioned earlier and were few, since the deterioration and longevity of Dispersalloy amalgam restorations have been well established from many previous studies.

Dispersalloy capsulated amalgam was used, with capsulated Ketac-Bond linings in deep cavities. No cavity varnish was used. The amalgams were polished under air/water spray using steel plug-finishing burs (Shofu) and "Brownie" and "Greenie" (Shofu) rubber points in a slow-speed handpiece, at least one week after placement.

7.2.6. DATA COLLECTION

The final polishing visit was taken as baseline for the study. At this visit photographs were taken at 1.5 times magnification of the restorations with an Elicar MS-1 hand-held camera (with an Elicar V-HQ Medical Macro MC 90 lens with ring flash), using Kodak Ektachrome 100 ASA 35 mm colour transparency daylight film and front-surfaced intra-oral mirrors. Impressions were taken using a polyvinylsiloxane rubber impression material (Espe-Permagum). This was applied using a light-bodied syringe material for occlusal detail and heavy-bodied tray material in solid plastic disposable trays (Coe). If the patient was wearing a fixed orthodontic appliance or access was difficult, a wooden tongue spatula was used to support the impression material. Replicas were later prepared using grey Araldite resin to enable better visualisation of restorations where visual definition or contrast compared to adjacent tooth structure was difficult (especially for the Sandwich Technique) - (Appendix A4).

At approximately six-monthly review appointments, additional photographs and polyvinylsiloxane impressions were taken, and then certain clinical observations were made.

A. PATIENT DATA CARD (Appendix A5)

Clinical examination at baseline revealed evidence of:

1. bruxism,
2. poor oral hygiene,
4. heavy smoking,
5. lack of canine guidance, and
6. restoration contact on opposing teeth in centric occlusion.

Details were recorded on a patient card which included dates of restoration polishing and review, and failures. Details recorded about each restoration included:

1. restoration identification number,
2. tooth FDI identification number, and
3. restoration class and material insertion date.

This information was the same for Class I and II restorations.

B. RESTORATION DATA PROFORMA (Appendices A6 and A7)

Restorations were assessed at base line and then again at each approximate six-monthly review. Separate forms were used for each restoration at baseline, and at each subsequent review. Class I and II restorations had data recorded on slightly different proformas: Class I as file 37, and Class II as file 36.

C. BASELINE

Initial baseline data were recorded as follows (same for both Class I and II):

1. Patient and Restoration identification details

- file number and restoration identification code; date of observation
- hospital register number; name; date of birth; toothcode (FDI)

2. Tooth surfaces restored O - occlusal

M - mesial

D - distal

3. Restoration width (modified after Wilson et al., 1986)

Score 0 - less than or equal to 1/4 of intercuspal distance, and/or proximal margins just extend into interproximal embrasures.

Score 1 - greater than 1/4 of intercuspal distance, and/or proximal margins obviously extend into interproximal embrasures.

Assessed from colour transparencies.

4. Filling defect

Score 0 - no

Score 1 - yes

Assessed from bitewing radiographs.

5. Restoration Class

Score 1 - Class I preparation

Score 2 - Class II preparation

6. Occlusal contact

Score 0 - none

Score 1 - contact on restoration

Determined by using ultra-thin occlusal foil articulating paper between opposing teeth and asking patient to tap together firmly. Presence of coloured ink remaining on restoration indicated occlusal contact and was detected from the transparencies.

7. Oral hygiene

Score 0 - good to average oral hygiene

Score 1 - poor oral hygiene with large amount of plaque present and gingivitis

Determined by subjective clinical assessment.

8. Bruxism

Score 0 - no obvious wear facets on posterior teeth, none or minimal bruxing

Score 1 - obvious wear facets on posterior teeth and bruxing

Determined by clinical judgement.

9. Smoking

Score 0 - less than or equal to 20 cigarettes smoked per day

Score 1 - greater than 20 cigarettes per day

Determined by asking patient.

10. Canine guidance

Score 0 - absent

Score 1 - present

Determined by clinical examination, for the dental quadrants restored.

11. Restorative dental material

01 - Amalgam Class I

02 - Silver Cermet Fissure filling Class I

03 - Sandwich Technique Class I

04 - Amalgam Class II

05 - Silver Cermet Tunnel Class II

06 - Sandwich Technique Class II

12. Operator

01 - Lidums

02 - Wilkie

13. Insertion date

D. CLINICAL PARAMETERS

Clinical parameters were assessed using either direct clinical examination or indirect rating methods including assessment from colour transparencies and impressions or replicas.

The colour transparencies taken were compared with four Standard Sets of enlarged (2x magnification) transparencies to assess baseline values for most of the clinical parameters, and later deterioration of the restorations, as has been described elsewhere, Smales and Creaven (1985). The standard sets showed examples of progressive deterioration of selected clinical characteristics for the parameters, which were arranged linearly as near-interval scales. Other clinical parameters were assessed using ordinal scales.

As much information as possible was recorded using indirect rather than direct rating methods, to decrease assessment variability. Coloured replicas of the tooth-coloured posterior composite restorations were required, for assessments of their marginal integrity and surface texture, because of the inadequate contrast present. All indirect assessments were made jointly with the supervisor, Dr. R.J. Smales.

Clinical characteristics of the restorations assessed were:

1. Retention (loss of material bulk including loss of flash beyond margins of preparations) and occlusal wear
 2. Surface cracks or crazing
 3. Surface roughness (disregarding cracks or crazing) and surface voids
 4. Surface staining/tarnishing
 5. Margin staining
 6. Margin fracture (discrepancy, discontinuity, or breakdown).
-
-

For Class II only, in addition

7. Gingivitis adjacent to restoration
8. Proximal contacts

Scoring was either by linear scale (range 0-8 or 0-12) or by ordinal scales:

Score 0 - ideal

Score 1 - slight change

Score 2 - moderate change

Score 3 - unsatisfactory situation

Clinical characteristics were assessed as follows for Class I - (File 37):

1. Retention (Bulk loss)

Rating scale 0-3

Score 0 - no bulk loss

Score 1 - loss of flash by fracture from uncut

fissure extensions and cusp slopes

Score 2 - loss of material from preparation

Score 3 - no evidence of material

Assessed by viewing transparencies and replicas.

2. Occlusal wear

Rating scale 0-3

Score 0 - no loss of material

Score 1 - slight loss of material

Score 2 - moderate loss of material (cavity walls exposed)

Score 3 - gross loss of material (base exposed)

Assessed by viewing transparencies and replicas.

3. Surface roughness (including surface voids but disregarding cracks and crazing)
Rating scale 0-12
Score 0 - perfectly smooth, glossy appearance
Score 12 - grossly pitted and rough surface
- or presence of any surface voids/exposed porosities
Assessed by comparing to standard transparencies and replicas.

 4. Surface staining/tarnishing
Rating Scale 0-12
Score 0 - no obvious staining or tarnishing
Score 12 - severely stained or tarnished surface
Assessed by comparing to standard transparencies.

 5. Margin staining
Rating Scale 0-8
Score 0 - no obvious marginal staining
Score 8 - severe marginal staining or tooth discolouration adjacent to restoration
Assessed by comparing to standard transparencies.

 6. Marginal fracture (discrepancy or breakdown)
Rating Scale 0-12
Score 0 - no marginal discrepancy
Score 12 - severe marginal degradation
Assessed by comparing to standard transparencies.
-

Clinical characteristics except bulk loss were assessed in the same fashion for Class II restorations (File 36). In addition, two further clinical parameters were assessed:

1. Gingivitis adjacent to restoration

Rating scale 0 - 3

Score 0 - none

Score 1 - slight bleeding on probing

Score 2 - visible colour changes of gingival margins

Score 3 - extensive colour changes of attached
gingiva or swelling

Assessed by direct clinical examination following probing with a blunt periodontal probe.

2. Proximal contacts

Rating Scale 0 - 3

Score 0 - tight - heavy forceful pressure required

Score 1 - moderate - firm pressure required

Score 2 - loose - light pressure required

Score 3 - open - no contact with floss

Assessed directly with waxed dental floss.

For the Visio-Molar RO posterior composite restorations, marginal fracture or discrepancy and surface roughness were determined by preparing replicas from the polyvinylsiloxane impressions using Araldite grey epoxy resin. Only the presence of surface and margin staining could be determined from the colour transparencies for the composites. The other two characteristics were too difficult to determine because of the similarity in colour of the resin to the tooth.

All rating scores allowed for the "benefit of the doubt". In cases where changes were only very marginally different and open to subjective assessment, the "better" score or lower rating number was given.

E. RESTORATION FAILURE AND GENERAL TOOTH STATUS

These data were recorded using a dichotomous scale

Score 0 - No

Score 1 - Yes

1. Tooth Extraction - True Failure
Tooth extracted as a direct result of failure of the restoration.

2. Tooth Extraction - Apparent Failure
Tooth extracted for reasons other than those directly related to the restoration
eg. for endodontic, periodontic or orthodontic reasons.

3. Restoration Replaced - True Failure
Restoration replaced due to failure of the restorative material eg fracture, recurrent caries.

4. Restoration Replaced - Apparent Failure
Restoration replaced for reasons other than those directly related to the restorative material
eg. if a Class I restoration is replaced by a Class II restoration because of interproximal caries, or when a restoration needs to be extended because of tooth structure failure.

5. Restoration Replaced - Different Material

Restoration replaced with a restorative material type different from the original.

6. Restoration All Lost

Restoration is completely absent.

7. Restoration Fractured, Partially Lost or Mobile

Restoration exhibits fracture, partial loss or mobility and the material is still at least partially present. Surface cracking or crazing of Ketac-Silver was included here.

8. Tooth Fracture and/or Enamel Margin Ridge Fracture

Tooth is fractured or restoration shows enamel ridge fracture.

9. Recurrent Marginal Caries

Score 0 - questionable caries

- none or slight decalcification or staining

Score 1 - needs treatment

- probe sticks/softening; staining, cavitation and evidence from bitewing radiographs.

10. Restoration Repair

Restoration has failed in some way and has required repair.

11. Pulp Problem

Patient reports experiencing pulpal pain.

12. Tender to Percussion
Pain is elicited on percussion.
13. Tooth Has Root Canal Treatment
Endodontic treatment has been instituted.
14. Tooth Discolouration
Tooth colour change may be of intrinsic origin eg. from tetracycline staining, or extrinsic eg. following endodontic treatment.

This restoration observation proforma was used for computer entry of data for subsequent statistical analysis. The BMDP program 3V (Dixon, 1990) on a Vax 11/785 computer (Digital) was used to perform the calculations. Separate analysis for each clinical factor was performed using a mixed model ANOVA, which included a random effects term for patients, a covariate effect for restoration age, and a fixed effect for each material, the statistical significance of which was determined by a likelihood ratio test. An alpha probability of 0.05 or less was assumed to indicate significant differences between the scored means over the study period. The BMDP life-table survival program 1L was used to analyse the failure rates of the restorations over the study period for the different materials, Dixon (1990).

Repeat assessments were made (with RJS) of 30 restorations from indirect records several months after the collection of the six-month data. Weighted Kappa values ranged from 0.48 for marginal staining to 0.86 for occlusal wear, indicating significant statistical agreement, Chilton (1982). The complete analyses are shown in Appendix A8.

7.3. RESULTS

CLASS I RESTORATIONS - FILE 37

A. BASELINE DISTRIBUTION PARAMETERS

Except for width of restoration and operator, all other baseline distribution parameters showed no significant differences ($P>0.05$) between the three materials (ref. Tables B1-B12 in Appendix B, File 37).

For width of restorations, proportionally more Sandwich Technique restorations were placed that were equal to or wider than 1/4 intercuspal width than for the other types of restoration. The reason for this was because some of these Sandwich restorations were replacements for existing failed conventional amalgam restorations.

For restoration type versus operator, Lidums placed proportionally more amalgam restorations than did Wilkie.

Therefore, only two of the 11 parameters showed a significant distribution difference when compared to restoration material. This is a very low number for a clinical study.

B. FAILURES

Table 3 shows the numbers of true failures of Class I restorations over two years. One apparent failure and no true failures occurred for the amalgam restorations. No failures occurred of the resin composite Sandwich Technique restorations. Ketac-Silver exhibited failure in 19 restorations where cracking and crazing of the occlusal surface occurred (33.3 per cent of the restorations placed).

There were no restoration repairs or marginal carious lesions. There was one apparent failure for a Class I Ketac-Silver from an unrelated tooth extraction.

Table 3. Number of true failures of Class I restorations over 2 years.

Class	(N)*	<i>Reason for failure</i>			Total
		Replaced	Lost	Cracked/ fractured	
Class I preparations					
Amalgam	(21)	0	0	0	0
Cermet	(57)	0	0	19 (cracked)	19
Sandwich	(38)	0	0	0	0

* Number of restorations placed.

Table 4 shows that the sizes of preparation were not related to the occurrence of surface cracking.

Surface cracking was also not statistically significant for any baseline parameters: bruxing; occlusal width; operator; tooth type; occlusal contact; or patient age ($p > 0.05$).

Table 4. Number of Class I Ketac-Silver cermet restorations showing surface cracking or crazing, by size of preparation.

Cavity size	<i>Surface cracking</i>		Total
	Yes	No	
$\leq 1/4$ occlusal width	13	27	40
$> 1/4$ occlusal width	8	9	17
$\chi^2 = 0.551, df = 1, P = 0.46,$			

Spearman rho = 0.138

Table 5 shows the number of restorations assessed at each recall period, and the life table survivals for each material.

Figure 17 is a diagrammatic representation of the survival analysis shown in Table 5. It shows that Ketac-Silver (fissure filling) restorations failed fairly rapidly, from surface crazing and cracking, usually after 6-12 months.

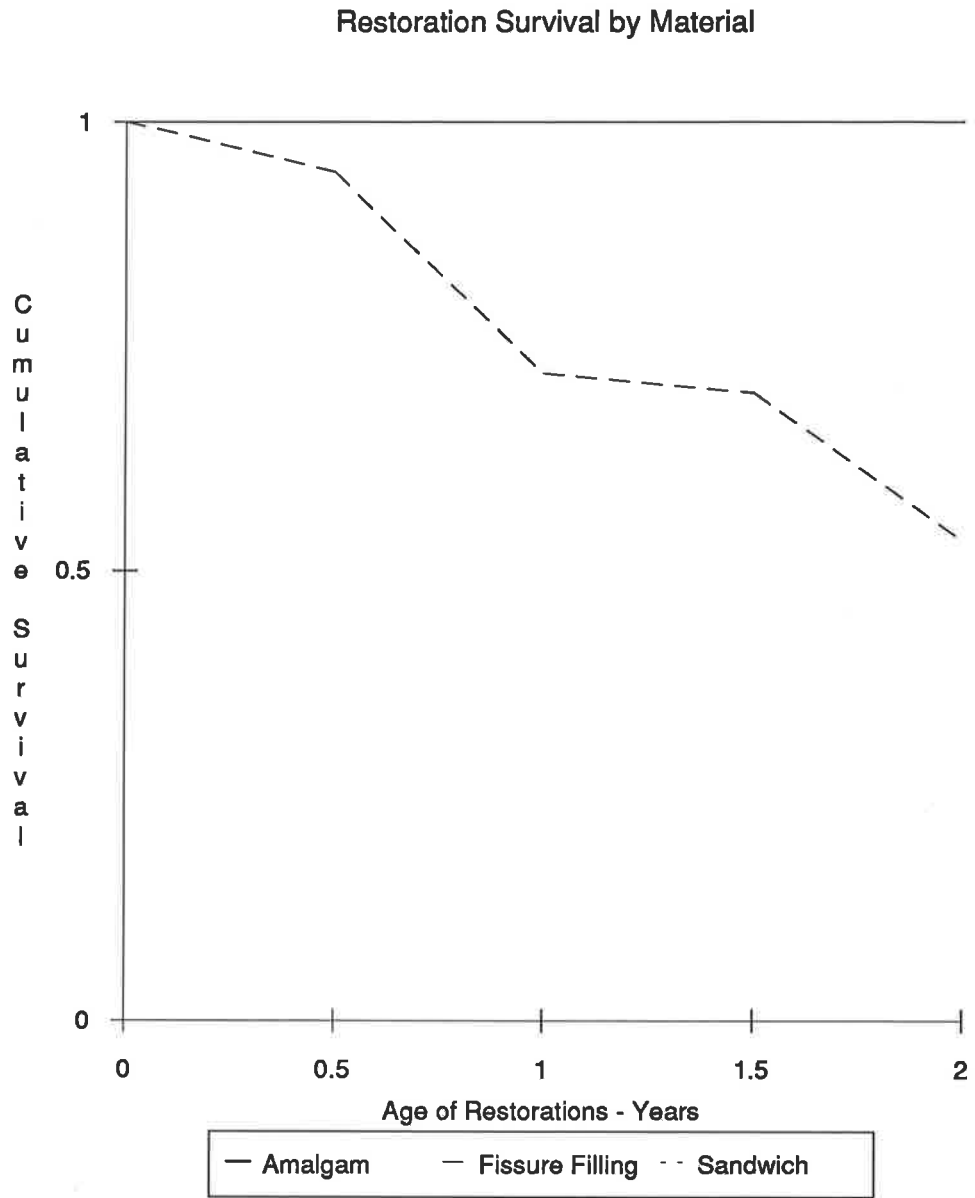
Table 5. Life table distribution of Class I restoration survivals by material.

Class I Materials	Period (Yrs)	Intact at start	Failures	Withdrawn and censored	Cumulative % survivals \pm SEr%
Amalgam	0.0-0.5	21	0	3	100 \pm 0.0
	0.5-1.0	18	0	1	100 \pm 0.0
	1.0-1.5	17	0	0	100 \pm 0.0
	1.5-2.0	17	0	17	100 \pm 0.0
Sandwich	0.0-0.5	38	0	11	100 \pm 0.0
	0.5-1.0	27	0	4	100 \pm 0.0
	1.0-1.5	23	0	15	100 \pm 0.0
	1.5-2.0	8	0	8	100 \pm 0.0
Cermet	0.0-0.5	57	3	7	94 \pm 3.2
	0.5-1.0	47	11	1	72 \pm 6.4
	1.0-1.5	35	1	4	70 \pm 6.5
	1.5-2.0	30	4	26	53 \pm 8.8

Mantel-Cox statistic = 16.85, df = 2, $P < 0.001$.

There were no failures of Dispersalloy amalgam or Visio-Molar RO Sandwich Technique restorations. None of the cracked Ketac-Silver restorations was repaired or replaced at this stage, but all are to be kept under observation for signs of further deterioration. There were no failures from marginal carious lesions.

Figure 17. Restoration Survival by Material - Class I -
(File 37)



C. DETERIORATION

Ideal rating assessments for clinical factors assessed

Table 6 shows the percentage of restoration observations showing ideal rating assessments for the different clinical parameters examined over 2 years. Ketac-Silver exhibited the lowest percentage of ideal ratings for all clinical factors except for surface and marginal staining. Only 3 per cent of Ketac-Silver observations for surface roughness showed an ideal rating assessment. The Dispersalloy amalgam restorations showed the most surface discolouration or tarnishing.

TABLE 6. Percentage of Class I Restoration observations showing ideal rating assessments over 2 years. Number of observations shown in parentheses.

Class I preparations	Bulk losses	Occlusal wear	Surface voids	Surface roughness	Surface staining	Marginal staining	Marginal fracture
Amalgam	89(62/70)	99(69/70)	100(59/59)	31(18/59)	39(27/70)	99(69/70)	69(48/70)
Cermet	47(79/167)	55(92/167)	81(134/165)	3(5/165)	92(153/167)	93(156/167)	68(113/167)
Sandwich	88(87/99)	92(91/99)	95(78/82)	61(50/82)	99(96/97)	85(82/97)	68(67/99)
Ratings scale	0,1,2,3,	0,1,2,3	0,12	0-12	0-12	0-8	0-12
Ideal rating	0	0	0,1	0	0,1	0,1	0,1

Mean scores and their significance for clinical factors assessed

Table 7 shows the mean scores with ANOVA results over the study period for the clinical parameters or factors assessed. Table 8 shows the results of the asymptotic t-tests for the same factors and is to be read in conjunction with Table 7. Apart from surface voids and surface roughness, all factors deteriorated with time over the study, $P < 0.001$. Although there were significant statistical differences found between the materials (apart from marginal fracture), only one clinical factor had unsatisfactory assessments given. Ketac-Silver exhibited excessive surface cracking and crazing which gave a high score for surface roughness. All other parameters had low mean scores. Ketac-Silver generally had poorer mean ratings for most clinical parameters. When scores were ranked for each clinical factor, in most instances Dispersalloy amalgam and Visio-Molar/Ketac-Bond Sandwich restorations were significantly better. However, amalgam restorations had the most surface discolouration or tarnishing, and the Sandwich restorations the most marginal staining.

TABLE 7. Mean Scores (\pm SD) and mixed model ANOVA results for the three Class I restorative materials (358 observations for each factor).

Material	Bulk Losses	Occlusal wear	Surface voids	Surface roughness	Surface staining	Marginal staining	Marginal fracture
Amalgam	0.12 \pm 0.32	0.01 \pm 0.11	0.00 \pm 0.00	2.00 \pm 1.41	1.96 \pm 1.45	0.10 \pm 0.35	1.19 \pm 1.01
Cermet	0.64 \pm 0.67	0.49 \pm 0.56	0.18 \pm 0.34	5.89 \pm 3.33	0.24 \pm 0.81	0.21 \pm 0.66	1.20 \pm 1.10
Sandwich	0.15 \pm 0.36	0.14 \pm 0.35	0.04 \pm 0.19	1.70 \pm 2.22	0.06 \pm 0.41	0.63 \pm 1.06	1.27 \pm 1.08
χ^2 (df=2)	80.08	93.96	16.34	115.72	170.47	11.98	0.33
P (from likelihood ratio test)	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.003*	0.85

*Significant difference present between materials. Apart from surface voids and surface roughness, all clinical factors deteriorated significantly over the study, $P < 0.001$.

Table 8. Asymptotic t-tests of Class I materials for
predicted cell means*

Material	Amalgam	Cermet	Clinical factor (best to worst)
Cermet	-8.58		BULK LOSSES
Sandwich	-0.94	-6.57	<u>Amalgam Sandwich</u> Cermet
Cermet	-10.07		OCCLUSAL WEAR
Sandwich	-2.81	-5.46	Amalgam <u>Sandwich</u> Cermet
Cermet	-3.85		SURFACE VOIDS
Sandwich	-0.87	-2.58	<u>Amalgam Sandwich</u> Cermet
Cermet	-10.08		SURFACE ROUGHNESS
Sandwich	0.60	-10.69	<u>Sandwich Amalgam</u> Cermet
Cermet	13.96		SURFACE STAINING
Sandwich	13.69	-1.56	<u>Sandwich Cermet</u> Amalgam
Cermet	-0.32		MARGINAL STAINING
Sandwich	-3.35	3.33	<u>Amalgam Cermet</u> Sandwich
Cermet	0.32		MARGINAL FRACTURE
Sandwich	0.57	-0.38	<u>Sandwich Cermet</u> Amalgam

*Values of 2.0 or greater considered to be of statistical significance. Materials connected by horizontal lines are statistically, not significantly different.

D. CORRELATIONS BETWEEN SELECTED CLINICAL FACTORS

Apart from marginal fracture being associated with marginal staining, and possibly occlusal wear with bruxism, there were no other significant correlations present (Table 9).

Table 9. Correlations between selected clinical factors for Class I restorative materials.

Clinical factor	Marginal staining	Restoration width	Bruxism	Surface cracking
Marginal fracture				
χ^2	18.361	1.917	1.063	0.083
P	<0.001*	0.384	0.303	0.773
rho	0.536	-0.040	-0.143	-0.040
Occlusal wear				
χ^2		3.159	4.418	0.166
P		0.206	0.036*	0.684
rho		0.134	0.192	0.045

*significant difference at the 5% probability level or less

E. DETERIORATION OVER TIME (ref. appendix B)

Appendix B Figures B1-B6, illustrate the deterioration over time for each clinical parameter assessed (using linear regressions).

Occlusal Retention and Wear

Two materials exhibited little loss of substance. For some amalgams, flash was seen to chip off. Sandwich Technique restorations had slightly more fracture of marginal excess than did amalgam. Ketac-Silver showed marked changes, especially in some areas where flash was seen to wear off or fracture off within a short period.

Surface Roughness and Voids

Amalgam and Sandwich Technique restorations had similar low roughness ratings. Ketac-Silver had much higher roughness ratings, made worse by surface crazing and cracking, and voids.

Surface Staining

Ketac-Silver and Sandwich Technique restorations exhibited very little surface staining. Amalgam gave progressively higher surface staining or discolouration scores, as it tarnished over time.

Marginal Staining

All materials had low marginal staining. Sandwich Technique restorations had slightly higher scores initially, as several replaced previous amalgam restorations.

Marginal Fracture

There was no obvious difference between the materials. All had low ratings.

CLASS II RESTORATIONS - FILE 36A. BASELINE DISTRIBUTION PARAMETERS

There were no significant differences between amalgam and Sandwich Technique restorations for any of the baseline clinical parameters assessed. (ref. Tables B13-B24 in Appendix B, File 36)

B. FAILURES

Only two failures occurred in this study. Two Sandwich Technique restorations failed - one fractured, one became mobile following debonding, Table 10.

Table 10. Number of true failures of Class II restorations over 2 years.

Class	(N)*	<i>Reason for failure</i>			Total
		Replaced	Lost	Cracked/fractured	
Class II preparations					
Amalgam	(16)	0	0	0	0
Sandwich	(28)	0	1(mobile)	1(fractured)	2

*Number of restorations placed.

There were no restoration repairs or marginal caries. There was one apparent failure for the Class II amalgams from a tooth fracture.

Table 11 shows the number of restorations assessed at each recall period, and the life table survivals for each material.

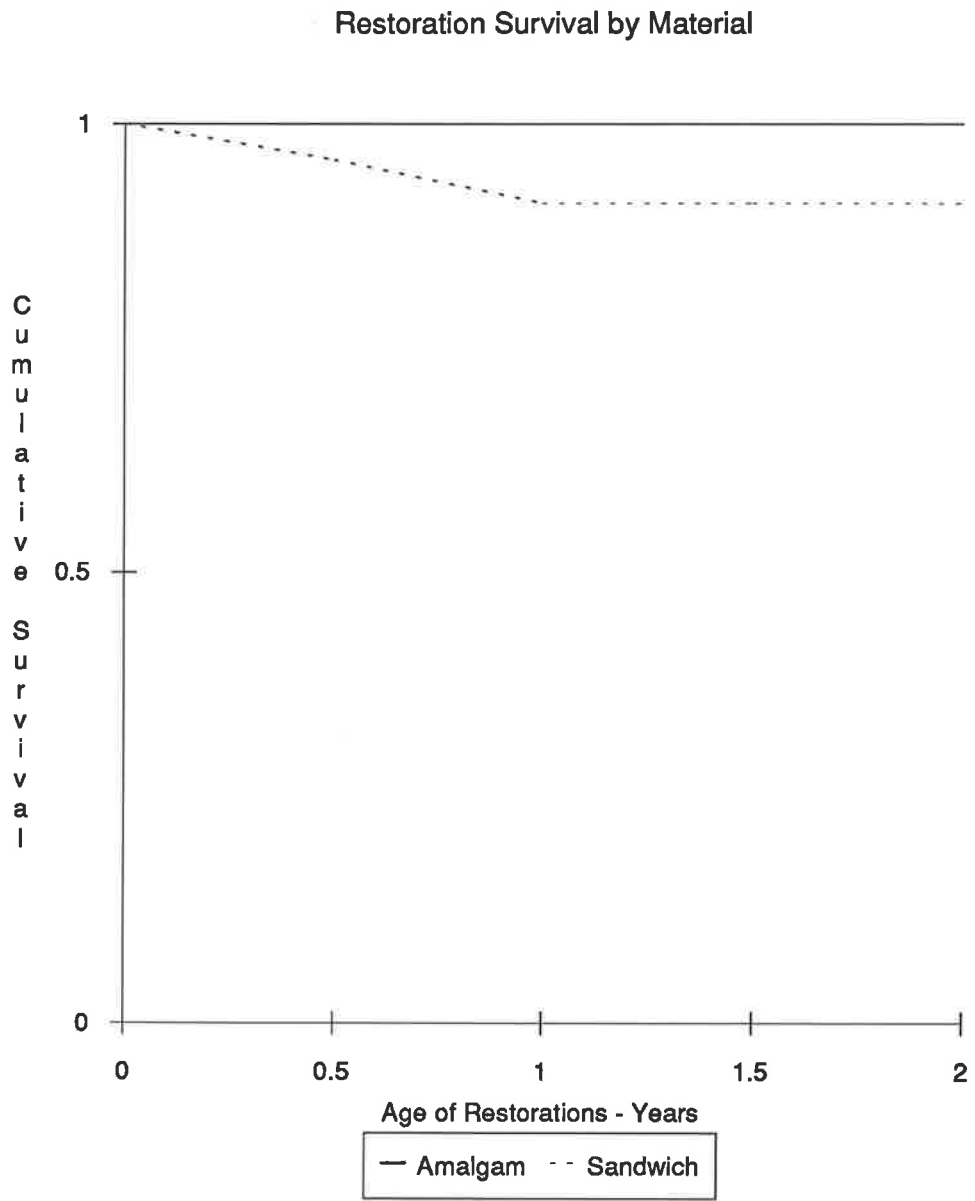
Figure 18 is a diagrammatic representation of the survival analysis shown in Table 11. The failure rate was very low, with no amalgam restorations having failed.

Table 11. Life table distribution of Class II restoration survivals by material.

Class II Materials	Period (yrs)	Intact at start	Failures	Withdrawn and censored	Cumulative % survivals \pm SEr%
Amalgam	0.0-0.5	16	0	1	100 \pm 0.0
	0.5-1.0	15	0	0	100+0.0
	1.0-1.5	15	0	2	100 \pm 0.0
	1.5-2.0	13	0	13	100 \pm 0.0
Sandwich	0.0-0.5	28	1	6	96 \pm 3.9
	0.5-1.0	21	1	2	91 \pm 6.0
	1.0-1.5	18	0	17	91 \pm 6.0
	1.5-2.0	1	0	1	91 \pm 6.0

Mantel-Cox statistic = 1.31, df = 1, P = 0.25

FIGURE 18 Restoration Survival by Material - Class II -
(File 36)



C. DETERIORATION

Ideal rating assessments for clinical factors assessed

Table 12 shows the percentage of restorations showing ideal rating assessments over 2 years. In most instances Sandwich Technique restorations had more ideal ratings than did amalgam restorations. However, the amalgam restorations had less gingivitis and open contacts, and fewer surface voids.

TABLE 12. Percentages of Class II restoration observations showing ideal rating assessments over 2 years. Number of observations shown in parentheses.

Class II preparations	Gingivitis adjacent	Proximal contacts	Occlusal wear	Surface voids	Surface roughness	Surface staining	Marginal staining	Marginal fracture
Amalgam	47(16/34)	15(5/34)	89(57/64)	100(64/64)	36(23/64)	25(16/64)	77(49/64)	45(29/64)
Sandwich	33(21/63)	3(2/63)	97(86/92)	90(83/92)	52(48/92)	97(89/92)	92(85/92)	63(58/92)
Ratings scale	0,1,2,3	0,1,2,3	0,1,2,3	0,12	0-12	0-12	0-8	0-12
Ideal rating	0	0	0	0	0,1	0,1	0,1	0,1

Mean scores and their significance for clinical factors assessed

The mean scores with ANOVA results for the observations over two years are shown in Table 13, together with the associated asymptotic t-tests for the same clinical factors. The mean scores were all very low. There was a significant difference between materials only for surface staining or discolouration, and marginal staining. Amalgam corrosion caused the surface tarnishing. Although there were statistically significant differences between the materials, no unsatisfactory clinical assessments were given. Sandwich Technique restorations gave better mean scores than did amalgam restorations for all parameters except surface voids.

TABLE 13. Mean scores (\pm SD) and mixed model ANOVA results for the two Class II restorative materials over 2 years (164 observations for each factor).

Material	Occlusal wear	Surface voids	Surface rough stain	Surface stain	Marginal fracture	Marginal
Amalgam	0.11 \pm 0.32	0.00 \pm 0.00	2.49 \pm 1.68	2.53 \pm 1.38	0.84 \pm 1.21	2.06 \pm 1.47
Sandwich	0.09 \pm 0.28	0.11 \pm 0.31	2.32 \pm 3.47	0.11 \pm 0.52	0.28 \pm 0.59	1.38 \pm 1.29
t (asymptotic) [†]	-1.64	-2.41	0.009	16.54	3.38	1.14
χ^2 (df=2)	2.61	4.51	0.06	89.68	10.99	1.27
P (from likelihood ratio test)	0.27	0.11	0.97	<0.001*	<0.01*	0.53

[†] t value of 2.0 or greater considered to be of statistical significance.

* significant difference present between materials. Apart from surface voids, all clinical factors deteriorated significantly over the study, $P < 0.002$.

D. CORRELATIONS BETWEEN SELECTED CLINICAL FACTORS

Correlations between several selected factors were generally fairly weak but marginal fracture, marginal staining and bruxism showed some association, as did occlusal wear and restoration width (Table 14).

Table 14. Correlations between selected clinical factors for Class II restorative materials.

<u>Clinical factor</u>	Marginal staining	Restoration width	Bruxism
Marginal fracture			
χ^2	14.906	5.536	8.192
P	0.005*	0.019*	0.004*
rho	0.258	-0.251	0.492
Occlusal wear			
χ^2		7.700	3.732
P		0.021	0.053
rho		-0.414	0.260

* significant difference at the 5% probability level

E. DETERIORATION OVER TIME (ref Appendix B)

Appendix B Figures B7-B13 illustrate the deterioration over time for each clinical parameter assessed (using linear regressions).

Gingivitis

Amalgam and Sandwich Technique restorations both exhibited very low gingivitis scores adjacent to the restorations (average = 0.5). Most readings were either 0 or 1. There was very little change with time.

Proximal contacts

Sandwich Technique restorations showed a greater frequency for open or light contacts and, therefore, gave higher scores. This changed little during the duration of the study. Amalgams had slightly lower scores initially but became slightly worse with time, and by the end of the study the mean score was about the same as for the Sandwich Technique restorations.

Occlusal wear

Very little occlusal wear was detected for either material during the study. Slightly more wear was detected for the Sandwich Technique than for the amalgam restorations.

Surface Roughness and Voids

Sandwich Technique restorations showed slightly higher roughness and void mean scores than did amalgam, but both were fairly low. Both materials gave progressively worse scores with time, with Sandwich Technique restorations showing more rapid deterioration, because of the exposure of subsurface porosities.

Surface Staining

Sandwich Technique restorations showed very low baseline scores with only very slight increases with time. Amalgam showed more obvious surface staining or tarnishing at baseline but the scores were still low. As the study progressed amalgam gave higher scores as a result of tarnishing.

Marginal Staining

Both amalgam and Sandwich Technique restorations gave very low baseline mean scores with very slight increases over time. Sandwich Technique restorations showed slightly lower baseline scores with almost negligible deterioration over time when compared to amalgam.

Marginal fracture

Amalgam and Sandwich Technique restorations both gave the same low initial scores, but amalgam restorations deteriorated fairly obviously with time, whereas Sandwich Technique restorations exhibited very little deterioration.

7.4. DISCUSSION

7.4.1. DESIGN OF THE STUDY

It was initially planned that approximately 80 of each type of test restoration would be placed with a smaller number of amalgam controls.

In a clinical research study such as this it is not possible to have a completely random selection of patients and restorations since their availability is determined by certain criteria such as the willingness to participate in the study and the presence of suitable lesions in adult patients. The sample size was restricted to a fairly small number of restorations. The amalgam material acted as a control, and, since its clinical behaviour is well documented, a small number was adequate to show that nothing unusual was occurring in the mouths of the patients. The number of Ketac-Silver restorations was also adequate since trends and failure modes were very pronounced. The number of Sandwich Technique restorations was enough to show its clinical behaviour trends well. Unfortunately, there were some patients who did not attend for review appointments and we cannot be sure how their restorations later behaved. The numbers of "withdrawn" restorations are shown in the life tables, Tables 5 and 11.

Since the requirement that only primary carious lesions be restored was later removed, there were more restorations placed of larger size using the Sandwich Technique than with the other two materials. This was considered reasonable since many clinicians use the Sandwich Technique to replace existing amalgam restorations. The size of the Sandwich restorations was larger, which may introduce some degree of bias since the composite was exposed to a greater degree to the effects of the oral environment than were the other two materials. Also occlusal protection from the adjacent enamel was less than with the other two materials.

The time period of two years was enough to allow trends to be seen. In the case of Ketac-Silver, modes of deterioration were very obvious after just six months. Data from this two year study may predict clinical performance of a longer duration.

The placement of the restorations was done by two operators who both first practised the techniques on extracted teeth to ensure uniform placement and finishing to a high quality. Handling techniques for Ketac-Silver and Sandwich technique restorations were more tedious and critical than for amalgam. Care was taken not to adversely affect water balance of the glass ionomer cement materials (Ketac-Silver and Ketac-Bond) since it is known that early changes in water balance may adversely affect the physical properties of these materials. For restoration type versus operator, Lidums placed proportionally more amalgam restorations than did Wilkie.

Thus, only two of the 11 baseline distribution parameters showed a significant difference when compared to the restorative material (ie. versus operator and versus restoration width). This is a very low number for a clinical study.

The assessment methods used were simple and sufficient for detecting overall deterioration trends between restorative materials.

As many assessments as possible were made by using indirect techniques ie. colour transparencies and replicas. Direct clinical observations were limited to very obvious and easily delineated factors, and most recorded either the presence or absence of a certain parameter.

Expanded linear scales, using standard sets of transparencies, allowed non-parametric criteria to be converted to near parametric measurements. This permitted more powerful statistical analysis of the data.

Also, the use of extended linear scales allowed detection of small differences between restorative materials for all clinical characteristics. The use of simple descriptive criteria or rating scales, as used in many clinical studies, are usually restricted to three or four categories or parameters only and thus, significant differences between materials are often not detected, Smales (1983).

7.4.2. CLASS I RESTORATIONS

KETAC-SILVER

Ketac-Silver cermet cement has been suggested by several authors to be a superior restorative material to Ketac-Fil (Espe GmbH) ionomer cement.

The cermet material has a faster setting reaction and is radiopaque, allowing detection of recurrent caries. The inclusion of sintered silver particles in Ketac-Silver was also thought to improve the physical properties of the Type II restorative glass ionomer cement (Ketac-Fil) giving better flexural strength and abrasion resistance, McLean and Gasser (1985). But, this assumption has been disproved, Walls et al. (1987), Forss et al. (1991b) .

The improvements were envisaged to produce a restorative material which could be used on the occlusal surfaces of posterior teeth in stress-bearing areas, as an alternative to amalgam or Sandwich Technique composite in Class I restorations. Ketac-Silver bonds to tooth structure and, therefore, cavity preparation involves little more than the removal of the carious lesion and unsupported tissue. The sustained release of fluoride provides prevention against future lesions.

According to the results of an in vitro study by Walls et al. (1987), the addition of silver particles sintered to the glass powder does influence the physical properties of glass ionomer cement, but not all alterations are advantageous. There is an improvement in compressive strength, compressive fatigue limit and 2-body abrasion

resistance. There is also a reduction in susceptibility to erosion in pH 4.0 buffer, and a reduced setting time. However, flexural strength and the modulus of elasticity are reduced, rendering the material more brittle. There is an increased susceptibility to 3-body abrasive wear, and Walls et al. (1987) warned that the long-term wear of this material under occlusal loads may be suspect.

The clinical handling and placement of these materials has been discussed by several authors. Smales et al. (1990) remarked that Ketac-Silver was difficult to manipulate because it adhered to metal instruments and tended to be pulled away from cavity margins. They also commented on the inconsistency of mixes and working times. Hickel and Voss (1990) felt that the short time required to fill a cavity with Ketac-Silver may be an advantage in young, difficult-to-manage children. However, it should be noted that Ketac-Silver needs to be kept dry for four minutes while it is setting and, therefore, the time period is similar to that required to place an amalgam. Also, Ketac-Silver needs to be finished either on the same or at a subsequent visit.

Slight widening of the occlusal fissures in the current study, and the use of the new angulated finer delivery nozzle (Aplicap System), allowed for easier injection of Ketac-Silver into the occlusal cavity and fissures. Tamping with a 3M plastic sponge seemed to force the material into the line angles and depths of the fissures, and pressure applied to the lead foil covering the occlusal surface held the material in place fairly easily. No problems with inconsistency of mixes or working times were noted in this study. Previous studies, Smales et al. (1990), have remarked on the poor handling characteristics of Ketac-Silver. However, both operators in the present study felt that it was an easy material to use provided the clinician made no attempt at traditional condensation or carving similar to that required for amalgam. Use of a thin lead foil under positive pressure, as recommended by Blagojevic and Mount (1988), ensured that no cavity was underfilled.

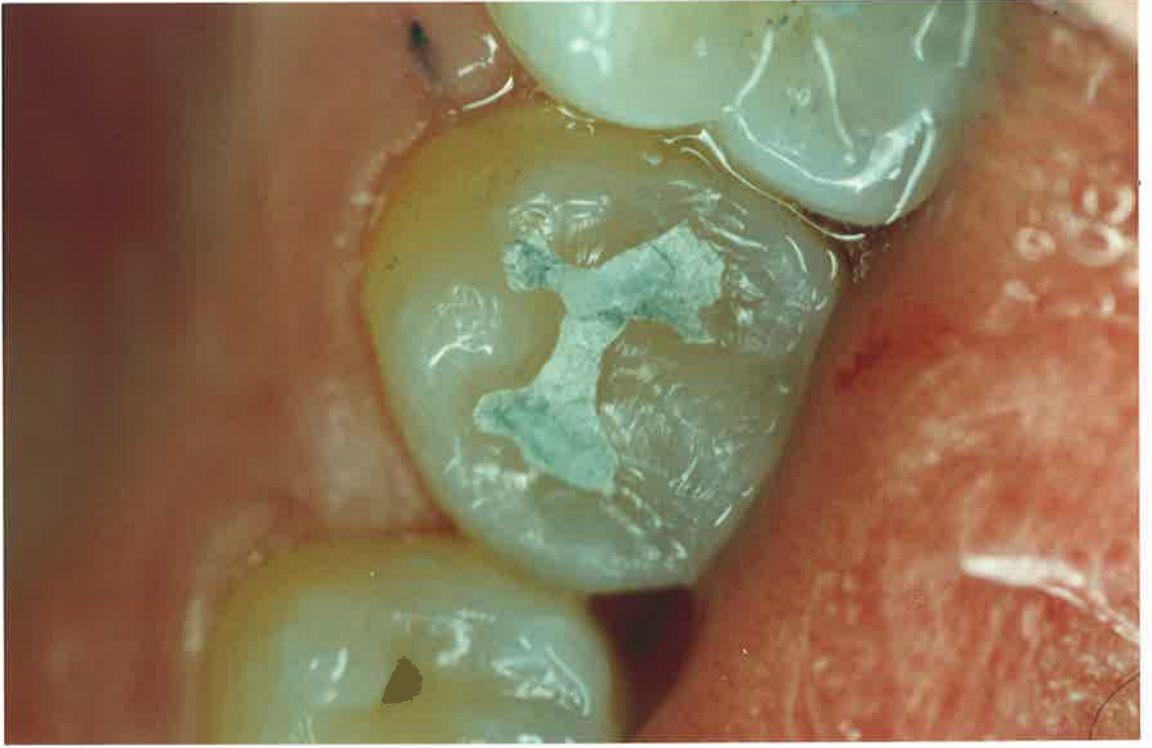
Finishing was also considered fairly straight-forward as long as the clinician did not aim to achieve a highly-polished surface or attempt to remove all areas of excess or flash on cuspal inclines. Excess beyond the cavosurface margin was difficult to detect and was considered to be clinically unimportant.

Nearly all studies except that of Setcos et al. (1989) show Ketac-Silver to be an unsatisfactory material to use in stress loaded Class I restorations. Eighty six percent of Ketac-Silver restoration observations in the study of Smales et al. (1990) showed ideal rating assessments for bulk loss, compared to only 47% in the current study. Both studies found bulk losses of Ketac-Silver material from the enamel surfaces adjacent to the limit of the Class I cavity. As wear occurred, porosities within the body of the restoration were exposed and, in some cases, the exposed porosities then disappeared as wear continued. Similar observations were made by Croll et al. (1988), and Hickel and Voss (1990). Several in vitro studies have shown this lack of wear resistance and, therefore, it was predicted that clinically, similar behaviour would be seen. Smales and Joyce (1978), and Walls et al. (1987) using in vitro abrasive wear testing, showed that glass ionomer cement was brittle. Exposure of cavity walls within two years by excess wear of a restorative material is considered clinically unacceptable. In the present study, Ketac-Silver showed excess wear in both occlusal contact and non-occlusal contact areas. The latter wear occurs as a result of food abrasion or acid erosion (Fig. 19).

Figure 19 - Examples of Ketac-Silver Class I Deterioration.

Slides 1 and 2 show the deterioration of a fissure filling about seven months from base line. Features which are seen include: extensive surface cracking and crazing; loss of flash beyond limits of cavity preparation, from cuspal inclines and from fissure extensions; and marginal ditching.

Slide 1 - Baseline



Slide 2 - Seven months



Slides 3 and 4 show deterioration of a fissure filling about twelve months from baseline. Features include: crazing and cracking surface; increased surface roughness; loss of flash from cuspal inclines and from fissure extensions; and marginal ditching.

Slide 3 - Baseline



Slide 4 - Twelve months



Slides 5 and 6 show deterioration of two Class I restorations about six months from baseline. Features include: surface cracking and crazing; increased surface roughness; loss of flash; and marginal ditching.

Slide 5 - Baseline



Slide 6 - Six months



In the current study, many more (33.3%) of the Ketac-Silver restorations placed exhibited surface cracking and crazing. There were several reasons for the higher incidence of cracking and crazing. This study had Ketac-Silver restorations of relatively larger size and, therefore, less protection was offered by the adjacent tooth structure. There were also differences in methodology. In the present study, the restorations were usually left two weeks prior to the final polish, whereas in the Smales et al. (1990) study Ketac-Silver was polished at placement. In both studies most cracking and crazing became apparent within six to twelve months of placement.

In narrow and protected occlusal fissures Ketac-Silver restorations were found to exhibit cracking and crazing less frequently, Smales et al. (1990). Ketac-Silver gains some degree of protection in narrow fissures and Smales et al. (1990) showed fissure fillings to perform satisfactorily.

Glass ionomer cements are not as strong as posterior resin composites and Garcia-Godoy (1986) also suggested that they may be more susceptible to wear unless confined to the depths of a fissure to avoid occlusal loads.

Smales et al. (1990) observed failure of Ketac-Silver occlusal restorations in 11.4% of all cases as a result of surface cracking or crazing. They noted that the larger, Class I cavity preparations accounted for nearly all these problems compared to the smaller, modified odontotomy - enameloplasty - sealant fissure preparations. Fissure fillings appeared to have fewer problems in clinical deterioration than did conventional Class I restorations. Smales et al. (1990) suggested that occlusal stress may be the main cause of cracking and crazing.

In the present study, early changes in water balance of the Ketac-Silver restorations may also have contributed to failures despite every care being taken not to affect it during setting, finishing or at subsequent appointments.

Currently, the manufacturer (Espe) recommends placement of Ketac-Glaze over Ketac-Silver following its insertion to maintain the water balance of the material. In 1988 there was no such recommendation in the instructions and therefore no resin coating was placed in the present study. It is unknown what affect, if any, this may have had on the clinical results.

The rate of Ketac-Silver degradation seen in the current study is considered clinically unacceptable compared to amalgam or Sandwich Technique restorations. The 'washout' occurred very soon after placement of the restoration (in the first 6-12 months) and probably continues for the life of the restoration. In longer-serving small restorations the Ketac-Silver material may gain some degree of protection from the tooth structure surrounding the restoration, so allowing the wear rate to decrease. In larger Ketac-Silver restorations, cracking, crazing and loss of occlusal material will allow overeruption of opposing teeth if occlusal stops on restorations are worn down. Poor clinical results from the use of Ketac-Silver restorations in permanent teeth have been reported in nearly all studies. However, Setcos et al. (1989), in a clinical study of Class I restorations, surprisingly, found less anatomical change in form over three years for Ketac-Silver than for a posterior resin composite. However, they did note that Ketac-Silver showed evidence of porosity in many restorations. In agreement with the present study, Ketac-Silver also showed less marginal staining than did the posterior resin composite.

Cracking, pitting and occlusion abrasion have also been observed in clinical studies of Class I Ketac-Silver restorations in primary molars, Croll et al. (1988), Croll and Phillips (1991). However, these findings may not be directly compared to the present study. Hickel and Voss (1990) found, in their clinical study of restorations placed in deciduous molars, that loss of anatomical form and abrasion were greater in Ketac-Silver than in amalgam. Also, small air bubbles were exposed with wear. They concluded that Ketac-Silver cannot be recommended in permanent teeth because of

its high failure rate in primary molars. Several, two-year or longer clinical studies of Ketac-Silver Class I restorations in deciduous molars have shown surface pitting and occlusal abrasion, Hickel and Voss (1990), Lovadino et al. (1990), Croll and Phillips (1991).

Hicks et al. (1986), Hattab et al. (1989), and Swift (1989) reported that glass ionomer cement materials resist caries-like attacks at the enamel/restoration interface, providing protection against secondary caries formation, and Retief et al. (1984) have demonstrated fluoride uptake into enamel 7.5mm from the restoration margin.

Our study confirmed the observations of the two-year clinical study by Lovadino et al. (1990) that, despite the structural breakdown of Ketac-Silver, secondary caries was not seen at the occlusal or adjacent proximal enamel areas. In contrast, Lovadino et al. (1990) showed that 13% of teeth restored with Class I amalgam presented with proximal or occlusal caries. The possibility of secondary caries occurring at a later stage remains, since less fluoride is released from Ketac-Silver than from other glass ionomer cements such as Ketac-Fil, Thornton et al. (1986), Swift (1989), Forss and Seppa (1990).

In conclusion, Ketac-Silver cannot be considered a viable alternative to amalgam or Sandwich Technique resin composite in larger Class I restorations placed in permanent teeth.

SANDWICH TECHNIQUE AND AMALGAM

The Sandwich Technique restoration was the most difficult to place. Placing Ketac-Bond using the (Aplicap) capsule delivery system tended to inject excess material which was difficult to handle. Further tamping often caused the material to spread excessively over the enamel margins of the cavity. Removal of excess from the cavo-surface margin using a Jet 330 bur was difficult since the Ketac-Bond was a similar colour to the tooth, and the operators could not be sure that sound tooth

structure was not being removed unnecessarily. Despite a deliberate attempt to use a composite shade different from that of the tooth, it was often difficult to see the restoration margins clearly on colour transparencies and, therefore, it was also necessary to use Araldite replicas for assessment of some clinical parameters. This problem of lack of colour contrast precluding rating of composite restorations for some clinical factors has been reported elsewhere, Smales et al. (1990).

There are few published clinical studies involving Sandwich Technique restorations. There are no published studies on Class I restorations. Several studies have looked at the use of the Sandwich Technique in Class II and V cavities where the potential benefit from the technique is greatest. These restorations may finish beyond the cemento-enamel junction and, therefore, good quality enamel bonding is not possible.

Recently, reports of clinical studies involving Sandwich Technique restorations have been less common. Most published studies are from the 1980's and have shown Sandwich Technique restoration behaviour to be either equivalent to or slightly poorer than amalgam restorations. However, nearly all studies have shown Sandwich Technique restorations to be superior to Ketac-Silver restorations.

Most in vitro studies of Sandwich Technique restorations have been of Class V restorations and these results cannot readily be applied to the current study, as Class I and II restorations are subject to greater direct functional stresses, from occlusal loads.

The number of published in vitro studies investigating acid etching of glass ionomer cements in the Sandwich Technique has decreased over the last 2-3 years with the development of visible-light cured glass ionomer cement materials. These materials have been shown to have better properties than the conventional glass ionomer cement lining materials: easier manipulation and placement, faster set, better

physical properties and adhesion, and less susceptibility to dehydration. They also do not need to be etched to enable resin to bond to them. As a result of this new development, research emphasis has now shifted.

In looking at the clinical behaviour of resin composite in the Class I and II restoration the results of restorations placed with and without glass ionomer cement linings should be compared, to establish the effect that the glass ionomer cement may have on the deterioration or failure of the restoration.

A large bulk of resin composite will undergo considerable polymerisation shrinkage resulting in loss of the dentine bond, then microleakage, sensitivity and caries, and possibly cusp fracture. Bryant (1992) suggests that the use of glass ionomer cement to replace lost dentine, reducing the total bulk of composite, combined with an incremental placement technique will minimise many of the problems associated with polymerisation shrinkage.

There were no failures of Sandwich Technique or amalgam Class I restorations during the study. These restorations were also considered to be clinically successful during the study.

The rate of deterioration of the Sandwich Technique restorations was clinically comparable to amalgam despite there being a higher proportion of relatively larger Sandwich Technique restorations. A longer review period may show the later emergence of significant differences. Both materials were superior to Ketac-Silver for most of the parameters measured. Amalgam showed the most surface discolouration or tarnishing, which was generally minor and not considered to be detrimental to the clinical function of the restorations.

7.4.3. CLASS II RESTORATIONS

SANDWICH TECHNIQUE

Manipulation of the Class II Sandwich Technique restoration was technically more difficult than for the Class I restoration, as was also noted by Grogono et al. (1990). It was more difficult to be sure that all excess Ketac-Bond base had been removed from the enamel margins in the proximal box. Pre-wedging was needed to ensure a tight contact area. Saliva seepage and bleeding, especially in patients with gingivitis, made perfect moisture control difficult to achieve to allow optimal conditions for good resin bonding, despite the use of rubber dam.

The Sandwich Technique has been suggested by several authors as an alternative to conventional amalgam for restoring Class II cavities. The purported advantages include bonding to both dentine and enamel, with the glass ionomer cement offering some degree of protection to secondary caries because of available fluoride release should microleakage occur. Also, a less destructive cavity is needed and a tooth-coloured restoration has aesthetic appeal.

In the present study, all Ketac-Bond bases were completely covered by Visio-Molar ("Closed" Sandwich Technique) because of a concern that perhaps the glass ionomer cement lining material may erode if exposed to the oral environment ("Open" Sandwich Technique).

Varying degrees of failure of the open Sandwich Technique restorations as a result of glass ionomer cement base "wash-out" have been observed in three clinical trials, Grogono et al. (1990), Welbury and Murray (1990), Knibbs (1992). Welbury and Murray (1990) and Knibbs (1992) stated that the Sandwich Technique cannot be advocated as an alternative to amalgam in Class II restorations, under the reported conditions the materials used. Knibbs (1992) thought that the most likely reason for failure was related to the difficulty of placing the glass ionomer cement, initially. He

noted that, since the technique of open Sandwich restorations is now widely practised, there is a great need for further clinical information. Although not strictly comparable, a recent in vitro study of primary molars restored using Ketac-Silver open Sandwich restorations also showed obvious cervical enamel microleakage, Fuks et al. (1992).

When glass ionomer cement linings are used in clinical studies, bulk fracture and debonding of the composite occur with similar frequency, Grogono et al. (1990), Welbury and Murray (1990), Knibbs (1992). But, the incidence of secondary caries seems to be far less, with only one case of secondary caries being reported in any Sandwich Technique study. This occurred where the loss of glass ionomer cement material from an open Sandwich restoration apparently allowed ingress of plaque, Knibbs (1992). The fluoride release from the glass ionomer cement usually appears to have a strong cariostatic effect.

In the present study, the failure rate of the closed Sandwich Technique restorations was similar to other clinical studies over two years of posterior composite resin restorations with, or without, fully-enclosed glass ionomer cement linings, Grogono et al. (1990), Knibbs (1992). Two failures occurred (one from isthmus fracture, and one from loss of bonding retention). It was also more difficult to achieve a tight proximal contact with Sandwich Technique than with amalgam restorations. In general, the occlusal clinical parameters measured were similar for the Sandwich Technique and amalgam. Amalgam had less gingivitis and open contacts, and fewer surface voids.

Early types of large, coarse-particle posterior resin composite restorations showed poor wear resistance. This problem was considered a function of the resin matrix material and its bonding to the filler particles, and is now no longer considered a problem with modern smaller, graded-particle hybrid materials. Failures of current generation materials, used without glass ionomer cement linings, are usually attributed to secondary caries, bulk fracture or debonding. Sensitivity from pulpal

problems have also been a reason for replacing restorations, Hendriks et al. (1986), Robinson et al. (1988), Bayne et al. (1989), Letzel (1989), Cunningham et al. (1990). Failure rates for current posterior composite materials were fairly low in these controlled clinical studies, with 10% over 4-5 years, which compares to approximately 4% for the same period for the amalgam controls. Leinfelder (1988) suggested that a well-placed small posterior composite restoration can be expected to last for 10 years.

Deterioration and failure studies of Sandwich Technique restorations show that, when using modern composite resin materials, occlusal wear is not a problem but, that placement technique rather than the actual material used determines the longevity of the restoration. Poor placement (eg. non-incremental placement and curing of a large bulk of resin composite) results in leakage at the gingival margin, sensitivity and eventually recurrent caries.

AMALGAM

There were no failures of Dispersalloy amalgam. Some slight surface tarnishing and marginal fracture occurred, but not to a clinically significant degree. This was considered the easiest material to place. Dispersalloy was the most satisfactory material for restoring Class II restorations in this two year-study.

7.4.4. GENERAL

For the various restorative materials, marginal fracture was found to be associated with marginal staining. The reasons for this are unclear but, perhaps areas where marginal staining occurs indicates that the material is starting to lift away or debond from the tooth, and eventually marginal fracture occurs, or staining may occur in retentive margins following such fracture.

Occlusal wear and bruxism were also found to be correlated. This is logical given that the effects of bruxism on a restoration is more likely to cause rapid occlusal wear.

7.5. CONCLUSION

Deterioration occurred with time for all the three materials tested. The slow rate of deterioration and failure for amalgam and Sandwich Technique Class I and II restorations was clinically acceptable over two years for the parameters measured under the conditions of the present study. The clinical performance of Ketac-Silver was unacceptable for a longer-term stress loaded restorative material, and its use needs to be questioned, especially in areas where structural integrity is important. Ketac-Silver may have the advantage of some dentine adhesion and fluoride release, but its poor clinical performance with excessive wear, and cracking and crazing were unsatisfactory.

8. BIBLIOGRAPHY

- Aboush Y.E.Y., Jenkins C.B.G. The effect of poly(acrylic acid) cleanser on the adhesion of a glass polyalkenoate cement to enamel and dentine. *J. Dent.* 1987 15:147-152.
- Andreas S.B., Koth D.L., Bayne S.C. Effect of dentin hydrostatic pressure on bond strengths to dentin. *J. Dent. Res.* 1988 67 (Special Issue): 363 Abstr. 2007.
- Andreas S.B., Bayne S.C., Heymann H.O., Kanoy B.E. Intrapulpal composition and fluid flow effects on dentin bond strengths. *J. Dent. Res.* 1989 68 (Special Issue): 321 Abstr. 1114.
- Barry T.I., Clinton D.J, Wilson A.D. The structure of glass ionomer cement and its relationship to the setting process. *J. Prosthet. Dent.* 1979 58:1072-1079.
- Bass E.V., Wing G. The mixing of encapsulated glass ionomer cement restorative materials. *Aust. Dent. J.* 1988 33:243.
- Bassiouny M.A., Harrison M.R., Achour A.Y. Sealing ability of tunnel preparation restoratives. *J. Dent. Res.* 1989 68 (Special Issue): 208 Abstr. 210.
- Bates J.F., Stafford G.D., Harrison A. Masticatory function - a review of the literature. III Masticatory performance and efficiency. *J. Oral Rehabil.* 1976 3: 57-67.
- Bayne S.C., Taylor D.F., Roberson T.M., Wilder A.D., Sturdevant J.R., Heymann H.O., Lisk M.W. Long term clinical failures in posterior composites. *J. Dent. Res.* 1989 68 (Special Issue): 185 Abstr. 32.
- Beech D.R., Soloman A., Bernier R. Bond strength of polycarboxylate acid cements to treated dentine. *Dent. Mater.* 1985 1:154-157.
- Bertolotti R.L. Removal of "black-line" margins and improving aesthetics of porcelain-fused-to-metal crowns. *Quintess. Int.* 1987 18:645-647.
- Blagojevic B., Mount G.J. A laboratory study of glass ionomer cement in relation to clinical dentistry. *Aust. Dent. J.* 1988 33: 320-321.
- Blagojevic B., Mount G.J. Benchwork on glass ionomer cement. *Aust. Dent. J.* 1989 34:364-366.

- Brännström M. Dentin and pulp in restorative dentistry. Dental Therapeutics 1981, Nacka, Sweden.
- Bryant R.W. Direct posterior composite resin restorations: A review. Factors influencing case selection Aust. Dent. J. 1992 37:81-87.
- Buonocore M.G. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J. Dent. Res. 1955 34:849-853.
- Calamia J., Vaidyanathan T.K., Calamia S., Mychajliw P. Shear bond strength of etched glass ionomer materials. J. Dent. Res. 1986 65 (Special Issue): 765 Abstr. 355.
- Caples R.M., McInnes-Ledoux P.M., Weinberg R. Effect of polyacrylic acid application time on the bond strength of a glass ionomer base material to dentin. J. Dent. Res. 1988 67 (Special Issue): 140 Abstr. 223.
- Causton B.E. The physico-mechanical consequences of exposing glass ionomer cements to water during setting. Biomaterials 1981 2:112-115.
- Causton B.E., Johnson N.W. Improvement of polycarboxylate adhesion to dentine by use of a new calcifying solution. Br. Dent. J. 1982 152:9-11.
- Causton B.E., Miller B., Sefton J. The deformation of cusps by bonded posterior composite restorations: an in vivo study. Br. Dent. J. 1985 159:397-400.
- Causton B.E., Sefton J., Williams A. Bonding Class II composite to etched glass ionomer cement. Br. Dent. J. 1987 163:321-324.
- Charbeneau G.T. and Bozell R.R. Clinical evaluation of a glass-ionomer cement for restoration of cervical erosion. J. Am. Dent. Assoc. 1979 98; 936-939.
- Chilton N.W. Design Analysis in Dental and Oral Research. 2nd ed. New York, Praeger, 1982; 419-421.
- Chin Y.H., Tyas M.J. Adhesion of composite resin to etched glass ionomer cement. Aust. Dent. J. 1988 33:87-90.
- Craig R.G. Edit. Restorative Dental Materials 7th ed. St Louis, C.V. Mosby, 1985.
- Crisp S., Wilson A.D. Reactions in glass ionomer cements I. Decomposition of the powder. J. Dent. Res. 1974 53:1408-1413.

- Crisp S., Lewis B.G., Wilson A.D. Characterisation of glass ionomer cements 2. Effect of powder:liquid ratio on the physical properties. *J. Dent.* 1976a 4:287-290.
- Crisp S., Lewis B.G., Wilson A.D. Glass ionomer cements: chemistry of erosion. *J. Dent. Res* 1976b 55:1032-1041.
- Crisp S., Lewis B.G., Wilson A.D. Characterisation of glass ionomer cements. A study of erosion and water absorption in both neutral and acidic media. *J. Dent.* 1980 8:68-74.
- Croll T.P., Phillips R.W. Six years' experience with glass-ionomer-silver cermet cement. *Quintess. Int.* 1991 22:783-793.
- Croll T.P. Riesenberger R.E., Miller A.S. Clinical and histologic observations of glass ionomer-silver cermet restorations in six human primary molars. *Quintess. Int.* 1988 19:911-919.
- Cunningham J., Mair L.H., Foster M.A., Ireland R.S. Clinical evaluation of three posterior composite and two amalgam restorative materials: 3-year results. *Br. Dent. J.* 1990 169:319-323.
- Dennison J.B., Ziemiecki T.L., Charbeneau G.T. Retention of unprepared cervical restorations utilizing a dentin bonding agent - two year report. *J. Dent. Res.* 1986 65 (Special Issue): 173 Abstr. 35.
- Dixon W.J. BMDP Statistical Software. Berkeley, University of California Press, 1990.
- Donly K., Wild T., Jensen M. Cuspal reinforcement in primary teeth: an in-vitro comparison of three restorative materials. *J. Dent. Res.* 1988 67 (Special Issue): 380 Abstr. 2135.
- Draheim R.N., Titus H.W., Garcia-Godoy F. Shear bond strengths of posterior composites to base materials. *J. Dent. Res.* 1987 66 (Special Issue): 209 Abstr. 821.
-
- Feilzer A.J., Davidson C.L., De Gee A.J. Setting stress in glass ionomer cements and composites. *J. Dent. Res.* 1986 65 (Special Issue): 778 Abstr. 476.

- Fisher M.A., Arcoria C.J., Wagner M.J. Microleakage in glass ionomer-lined amalgam restorations. *J. Dent. Res.* 1989 68 (Special Issue): 208 Abstr. 214.
- Forss H., Seppa L. Prevention of enamel demineralization adjacent to glass ionomer filling materials. *Scand. J. Dent. Res.* 1990 98:173-178.
- Forss J., Seppa L., Alakuijala P. Plaque accumulation on glass ionomer filling materials. *Proc. Finn. Dent. Soc.* 1991a 87: 343-350.
- Forss H., Seppa L., Lappalainen R. In vitro abrasion resistance and hardness of glass-ionomer cements. *Dent. Mater.* 1991b 7:36-39.
- Forsten L. Short - and long term fluoride release from glass ionomers and other fluoride-containing filling materials. *Scand. J. Dent. Res.* 1990 98: 179-185.
- Forsten L. Fluoride release and uptake by glass ionomers. *Scand. J. Dent. Res.* 1991 99: 241-245.
- Fuks A.B., Holan G., Simon H., Lewinstein I. Microleakage of Class 2 glass-ionomer-silver restorations in primary molars. *Oper. Dent.* 1992 17:62-69.
- Fuss J., Mount G.J., Makinson O.F. The effect of etching on a number of glass ionomer cements. *Aust. Dent. J.* 1990 35:338-344.
- Garcia R., Caffesse R.G., Charbeneau G.T. Gingival tissue response to restoration of deficient cervical contours using a glass ionomer material. A 12 month report. *J. Prosthet. Dent.* 1981 46:393-398.
- Garcia-Godoy F. The preventive glass ionomer restoration. *Quintess. Int.* 1986 17:617-619.
- Garcia-Godoy F., Draheim R.N., Titus H.W. Shear bond strength of a posterior composite resin to glass ionomer bases. *Quintess. Int.* 1988a 19:357-359.
- Garcia-Godoy F., Draheim R.N., Titus H.W., Chiesa D. Microleakage of composite restorations with etched and non-etched glass ionomer bases. *J. Dent. Res.* 1988b 67 (Special Issue): 196 Abstr. 668.
- Garcia-Godoy F., Draheim R.N., Titus H.W., Chiesa D. Microleakage of composite restorations with etched and non-etched glass ionomer bases. *Am. J. Dent.* 1988c 1:159-162.

- Garcia-Godoy F., Malone W.F.P. The effect of acid etching on two glass ionomer lining cements. *Quintess. Int.* 1986 17:621-623.
- Garcia-Godoy F., Malone W.F.P. Effect of various etching times on two glass ionomer lining cements. *Texas Dent. J.* 1987 104:12-15.
- Garcia-Godoy F., Malone W.F.P. Microleakage of posterior composite resins using glass ionomer cement bases. *Quintess. Int.* 1988 19:13-17.
- Gerke D.C., Smales R.J. The modified odontotomy - enameloplasty - fissure sealant preparation and restoration. *J. Dent. Res.* 1989 68 (Aust. & N.Z. Divis.), 550 Abstr. P 11.
- Goetsch T., Krejci I., Lutz F., Reich T. Deformation of cavity walls induced by different composite restorative techniques. *J. Dent. Res.* 1989 68 (Special Issue): 342 Abstr. 1282.
- Goldman M. Polymerisation shrinkage of resin-based restorative materials. *Aust. Dent. J.* 1983 28:156-161.
- Gordon M., Masschaert J.M., Soelberg K.B., Bogdan M.S. Microleakage of low composite resins over a glass ionomer cement base in Class V restorations. *Quintess. Int.* 1985 12:817-820.
- Grogono A.L., McInnes P.M., Zink J.H., Weinberg R. Posterior composite and glass ionomer/composite laminate restorations: 2-year clinical results. *Am. J. Dent.* 1990 3:147-152.
- Gwinnett A.J. The ultrastructure of prismless enamel of permanent human teeth. *Arch. Oral Biol.* 1967 12:381-389.
- Hagger O. Swiss patent no. 278946, 1951.
- Halverson B.A., Hamilton P.M. Increased cusp fracture resistance with glass ionomer bases. *J. Dent. Res.* 1987 66 (Special Issue): 130 Abstr. 189.
- Harper R.H., Schnell R.J., Swartz M.L., Phillips R.W. In vivo measurements of thermal diffusion through restorations of various materials. *J. Prosthet. Dent.* 1980 43: 180-185.
- Hassan F., Nathanson D. Shear bond strength of composite to etched glass ionomer cement. *J. Dent. Res.* 1987 66 (Special Issue): 132 Abstr. 203.

- Hattab F.N., Mok N.Y.C., Agnew E.C. Artificially formed caries like lesions around restorative materials. *J. Am. Dent. Assoc.* 1989 118:193-197.
- Hembree J.H. Jnr. Marginal leakage of Class II posterior composite restorations using a glass ionomer cement as a liner. *J. Dent. Res.* 1987 66 (Special Issue): 293 Abstr. 1493.
- Hendriks F.H.J., Letzel H., Vrijhoef M.M.A. Composite versus amalgam restorations. A three-year clinical evaluation. *J. Oral Rehab.* 1986 13: 401-411.
- Hickel R., Voss A. A comparison of glass cermet cement and amalgam restorations in primary molars. *J. Dent. Child.* 1990 57:184-188.
- Hicks M.J., Flaitz C.M., Silverstone L.M. Secondary caries formations in vitro around glass ionomer restorations. *Quintess. Int.* 1986 17:527-532.
- Hicks M.J., Silverstone L.M. Fissure sealants and dental enamel. A histological study of microleakage in vitro. *Caries Res.* 1982 16:353-360.
- Hinoura K., Moore B.K., Swartz M.L., Phillips R.W. Tensile bond strength between glass ionomer cement and composite resin. *J. Dent. Res.* 1986 65 (Special Issue): 344 Abstr. 1576.
- Hinoura K., Onose H., Moore B.K., Phillips R.W. Bonding agent influence on the glass ionomer - composite resin bond. *J. Dent. Res.* 1987a 66 (Special Issue): 132 Abstr. 202.
- Hinoura K., Moore B.K., Phillips R.W. Tensile bond strength between glass ionomer cement and composite resins. *J. Am. Dent. Assoc.* 1987b 114:167-172.
- Hinoura K., Onose H., Moore K., Phillips R.W. Effect of the bonding agent on the bond strength between glass ionomer cement and composite resin. *Quintess. Int.* 1989a 20:31-35.
- Hinoura K., Suzuki H., Kuroda T., Onose H. Factors influencing bond strengths between unetched glass ionomers and resins. *J. Dent. Res.* 1989b 68 (Special Issue): 251 Abstr. 557.
-
- Hotz P., McLean J.W., Sced I., Wilson A.D. The bonding of glass ionomer cements to metal and tooth substrates. *Br. Dent. J.* 1977 142:41-47.

- Hume W.R., Mount G.I. In vitro studies on the potential for pulpal cytotoxicity of glass ionomer cements. *J. Dent. Res.* 1988 34: 29-32.
- Ironside J.G. Some aspects of posterior composite resin restorations. *J. Dent. Res.* 1988 67 (Special Issue): 634 Abstr. 79.
- Jones J.C., Grieve A.R., Kidd E.A. An in vitro comparison of marginal leakage associated with three resin based filling materials. *Br. Dent. J.* 1978 145: 299-302.
- Joynt R.B., Davis E.L., Wieczkowski G. Jnr., Laura J. Bond strength durability between dentinal bonding agents and tooth structure. *J. Dent. Res.* 1988 67 (Special Issue): 379 Abstr. 2134.
- Kanca J. III. Effect of reduced etching times on microleakage of composite resins. *J. Dent. Res.* 1988 67 (Special Issue): 309 Abstr. 1575.
- Kent B.E., Lewis B.G., Wilson A.D. Glass ionomer formulations: I. The preparation of novel fluoroaluminosilicate glasses high in fluorine. *J. Dent. Res.* 1979 58:1607-1619.
- Khalife L., Hottel T.L., Rasmussen S. Bonding of composite restorations with etched glass ionomer cement bases. *J. Dent. Res.* 1988 67 (Special Issue): 198 Abstr. 680.
- Kinloch A.J. The science of adhesion Part 1. Surface and interfacial aspects. *J. Mater. Sci.* 1980 15:2141-2166.
- Knibbs P.J., Plant C.G. A clinical assessment of a rapid setting glass ionomer cement. *Br. Dent. J.* 1986 161:323-326.
- Knibbs P.J. The clinical performance of a glass (polyalakenoate) (glass ionomer) cement used in a "sandwich" technique with a composite resin to restore Class II cavities. *Br. Dent. J.* 1992 172:103-107.
- Knibbs P.J., Plant C.G., Pearson G.J. A clinical assessment of an anhydrous glass ionomer cement. *Brit. Dent. J.* 1986 161:99-103.
-
- Kramer I.R.H., McLean J.W. Alterations in the staining reaction of dentine to a constituent in a self-polymerising resin. *Br. Dent. J.* 1952 6:150-153

- Krejci I., Lutz F., Krejci D. The influence of different base materials on marginal adaptation and wear of conventional Class II composite resin restorations. *Quintess. Int.* 1988 19:191-198.
- Leary R., Kilgus G., Leinfelder K.F. In vitro microleakage of glass ionomer and dentin bonding agents. *J. Dent. Res.* 1989 68 (Special Issue): 187 Abstr. 44.
- Letzel H. Survival rates and reasons for failure of posterior composite restorations in multicentre clinical trial. *J. Dent.* 1989 17: 510-517.
- Leinfelder K.F. Posterior composite resins. *J. Am. Dent. Assoc.* 1988 117: 21E-26E.
- Lim K.C. The microleakage of a glass ionomer cement using two methods of moisture protection. *Quintess. Int.* 1987 18:835-839.
- Lovadino J.R., Navarro M.F.L., Souza M.H.S., Franco E.B. Clinical evaluation of cermet glass ionomer restorations. *J. Dent. Res.* 1990 69 (Special Issue):921 Abstr. 14.
- McCulloch A.J., Smith B.G.N. In vitro studies of cusp reinforcement with adhesive restorative material. *Br. Dent. J.* 1986 161:450-452.
- McLean J.W. Limitations of posterior composite resins and extending their use with glass ionomer cements. *Quintess. Int.* 1987 18:517-529.
- McLean J.W. Glass ionomer cements. *Br. Dent. J.* 1988 164:293-301.
- McLean J.W., Gasser O. Glass-cermet cements. *Quintess. Int.* 1985 16:333-342.
- McLean J.W., Powis D.R., Prosser H.J., Wilson A.D. The use of glass ionomer cements in bonding composite resins to dentine. *Br. Dent. J.* 1985 158:410-414.
- McLean J.W., Wilson A.D. The clinical development of the glass ionomer cement II. Some clinical applications. *Aust. Dent. J.* 1977a 22:120-127.
- McLean J.W., Wilson A.D. The clinical development of the glass ionomer cement III. The erosion lesion. *Aust. Dent. J.* 1977b 22:190-195.
-
- Marshall S.J., Marshall G.W., Harcourt J.K. The influence of various cavity bases on the micro-hardness of composites. *Aust. Dent. J.* 1982 27:291-294.

- Mathis R.S., Dewald J.P., Moody C.R., Ferracane J.L. Marginal leakage in Class V composite restorations with glass ionomer liners. *J. Dent. Res.* 1988 67 (Special Issue): 195 Abstr. 662.
- Michailescu P.M., Marciano J., Abadie M., Sakaas D. Thermocycling procedure: in vivo and in vitro studies. *J. Dent. Res.* 1991 70 (Special Issue): 757 Abstr. 143.
- Mitchem J., Gronas D. Adhesion to dentin with and without varying degrees of wetness. *J. Dent. Res.* 1989 68 (Special Issue): 321 Abstr. 1115.
- Mitchem J.C., Terkla L.G. The bonding of resin dentine adhesives under simulated physiological conditions. *J. Dent. Res.* 1987 66 (Special Issue): 268 Abstr. 1293.
- Moore B.K., Swartz M.L., Phillips R.W. Abrasion resistance of metal in reinforced glass ionomer materials. *J. Dent. Res.* 1985 64 (Special Issue):371 Abstr. 1766.
- Mount G.J. Glass ionomer cements: Clinical considerations. In: *Clinical Dentistry*. James W. Clark. Harper and Rowe, Philadelphia, 1984 Chap. 20A.
- Mount G.J. Longevity of glass ionomer cements. *J. Pros. Dent.* 1986 55:682-685.
- Mount G.J. The significance of the wettability of composite resin bonding. *J. Dent. Res.* 1987 66 (Special Issue): 824 Abstr. 61.
- Mount G.J. Glass ionomer cements obtaining optimum aesthetic results. *Dental Outlook.* 1988a 14:3-9.
- Mount G.J. A method of testing the union between glass ionomer cement and composite resin. *Aust. Dent. J.* 1988b 33:462-466.
- Mount G.J. The wettability of bonding resins used in the composite resin/glass ionomer "sandwich technique". *Aust. Dent. J.* 1989a 34:32-35
- Mount G.J. The tensile strength of the union between various glass ionomer cements and various composite resins. *Aust. Dent. J.* 1989b 34:136-146.
-
- Mount G.J. *An atlas of glass ionomer cements - A clinician's guide.* Martin Dunitz, London, 1989c.

- Mount G.J. Clinical requirements for a successful "sandwich" - dentine to glass ionomer cement to composite resin. *Aust. Dent. J.* 1989d 34:259-265.
- Mount G.J. Adhesion of glass-ionomer cement in the clinical environment. *Oper. Dent.* 1991 16:141-148.
- Mount G.J., Makinson O.F. Clinical characteristics of a glass ionomer cement. *Br. Dent. J.* 1978 145:67-71.
- Mount G.J., Makinson O.F. Glass ionomer restorative cements: Clinical implications of the setting reaction. *Oper. Dent* 1982 7:134-140.
- Negm M.M., Beech D.R., Grant A.A. An evaluation of mechanical and adhesive properties of polycarboxylate and glass ionomer cements. *J. Oral Rehab.* 1982 9:161-167.
- Ngo H., Earl M.S.A., Mount G.J. Glass ionomer cements: A 12-month evaluation. *J. Prosthet. Dent.* 1986 55:203-205.
- Pereira J.C., Manfio A.P., Franco E.B., Lopes E.S. Clinical evaluation of Dycal under amalgam restorations. *Am. J. Dent.* 1990 3:67-70.
- Perkins E., McInnes-Ledoux, Weinberg R. In vitro microleakage of glass ionomer/composite laminate Class V restorations. *J. Dent. Res.* 1988 67 (Special Issue): 309 Abstr. 1574.
- Phair C.B., Fuller J.L. Microleakage of composite resin restorations with cementum margins. *J. Prosthet. Dent.* 1985 53:361-364.
- Phillips R.W. *Skinner's Science of Dental Materials.* 9th edit. Philadelphia, W.B. Saunders, 1991 570.
- Phillips R.W. Restorative materials containing fluoride. *J. Am. Dent. Assoc.* 1988 116:762-763.
- Pollack B.F., Blitzer M.H. Aesthetic veneering: materials and techniques. *Gen. Dent.* 1983 31:483-488.
- Powis D.R., Folleras T., Merson S.A., Wilson A.D. Improved adhesion of a glass ionomer cement to dentin and enamel. *J. Dent. Res.* 1982 61:1416-1422.

- Powis D.R., Prosser H.J., Wilson A.D. Marginal leakage of dental restorative materials. Unpublished report (1985) London: Laboratory of the Government Chemist.
- Prevost A.P., Fuller J.L., Peterson L.C. The use of an intermediate layer in the acid etch procedure: retentive strength, microleakage and failure mode analysis. *J. Dent. Res.* 1982 61:412-418.
- Prevost A.P., Forest D., Tanguay R., De Grandmont P. Radiopacity of glass ionomer dental materials. *Oral Surg. Oral Med. Oral Pathol.* 1990 70:231-235.
- Prosser H.J. Powis D.R. Wilson A.D. Glass ionomer cements of improved flexural strength. *J. Dent. Res.* 1986 65:146-148.
- Quiroz L., Lentz D.H. Laboratory evaluation of etching time on three different glass ionomers. *J. Dent. Res.* 1987 66 (Special Issue): 131 Abstr. 197.
- Reeh E.S., Douglas W.H., Messer H.H. Stiffness of endodontically-treated teeth related to restoration technique. *J. Dent. Res.* 1989 68:1540-1544.
- Reel D.C., Lyon H.E., Mitchell R.J. Fracture resistance of amalgam restorations placed over various basing agents. *Compend. Contin. Educ. Dent.* 1987 17:282-287.
- Retief D.H. Are adhesive techniques sufficient to prevent microleakage? *J. Dent. Res.* 1986 65 (Special Issue): 716 Abstr. S11.
- Retief D.H. Fluoride uptake, distribution and retention in dental tissues from restorative dentistry. *J. Dent. Res.* 1988 67 (Special Issue): 110 Abstr. S60.
- Retief D.H., Bradley E.L., Denton J.C., Switzer P. Enamel and cementum fluoride uptake from a glass ionomer cement. *Caries Res.* 1984 18:250-257.
- Rigsby D.F., Retief D.H., Bidez M.W., Russell C.M. Effect of axial load and temperature cycling on microleakage of resin restorations. *Am. J. Dent.* 1992 5: 155-159.
-
- Robinson A.A., Rowe A.H.R., Maberley M.L. A three-year study of the clinical performance of a posterior composite and a lathe cut amalgam alloy. *Br. Dent. J.* 1988 164: 248-252.

- Rossomando K.J., Wendt S.C. Evaluation of thermocycling in microleakage analysis. *J. Dent. Res.* 1993 72 (Special Issue): 223 Abstr. 959.
- Roulet J.F., Rosansky J., Berlin F.U. In vitro marginal integrity of combined glass ionomer cement - composite filling. *J. Dent. Res.* 1986 65 (Special Issue) 812: Abstr. 779.
- Scherer W., Kaim J., Ehrlich B. Reinforced glass ionomer cement to amalgam: bond and interface study. *J. Dent. Res.* 1989 68 (Special Issue): 251 Abstr. 556.
- Setcos J.C., Braun C.J., Phillips R.W. Clinical evaluation of glass ionomer cermet over 3 years: In: Okabe T. Takahashi S. eds. Transactions International Congress on Dental Materials. The Academy of Dental Materials and The Japanese Society for Dental Materials and Devices. 1989 315-316.
- Sheth P.J., Sheth J.J., Jensen M.E. Glass ionomer cements: To etch or not to etch? *J. Dent. Res.* 1988 67 (Special Issue): 140 Abstr. 220.
- Shimokobe K., Komatsu H., Matsui I. Fluoride content in human enamel after removal of the applied glass ionomer cement. *J. Dent. Res.* 1987 66 (Special Issue): 131 Abstr. 196.
- Shortall A.C., Wilson H.J. New materials, bonding treatments and changes in restorative practice. *Br. Dent. J.* 1988 164:396-400.
- Sidhu S.K., Henderson L.J. Dentin adhesives and microleakage in cervical resin composites. *Am. J. Dent.* 1992 5: 240-244.
- Simonsen R.J., Stallard R.E. Sealant-restorations utilising filled composite resin: one year results. *Quintess. Int.* 1977 8:77-84.
- Smales R.J. Plaque growth on dental restorative materials. *J. Dent.* 1981 9: 133-140.
- Smales R.J. Evaluation of clinical methods for assessing restorations. *J. Prosthet. Dent.* 1983 49:67-70.
-
- Smales R.J., Creaven P.J. Evaluation of three clinical methods for assessing amalgam and resin restorations. *J. Prosthet. Dent.* 1985 54:340-346.

- Smales R.J., Gerke D.C., White I.L. Clinical evaluation of occlusal glass ionomer, resin, and amalgam restorations. *J. Dent.* 1990 18:243-249.
- Smales R.J., Joyce K. Finished surface texture, abrasion resistance and porosity of ASPA glass ionomer cement. *J. Prosthet. Dent.* 1978 40:549-553.
- Smith D.C. A new dental cement. *Br. Dent. J.* 1968 125:381.
- Smith G.E. Surface deterioration of glass ionomer cement during acid etching: An SEM evaluation. *Oper. Dent.* 1988 13:3-7.
- Smith G.E., Soderholm K-J.M. Etching time effects upon glass ionomer - resin shear bond strengths. *J. Dent. Res.* 1987 66 (Special Issue): 131 Abstr. 199.
- Sneed W.D., Hooper S.W. Shear bond strength of a composite resin to an etched glass ionomer. *Dent. Mater.* 1985 1:127-128.
- Soh G., Chong Y.H., Determination of an optimal magnification for examining voids in elastomeric impressions. *Int. J. Prosthodont.* 1990 3:573-576.
- Suzuki M., Gwinnett A.J., Jordan R.E. Relationship between composite resins and dentin treated with bonding agents *J. Dent. Res.* 1986 65 (Special Issue): 764 Abstr. 350.
- Swartz M.L., Phillips R.W., Clark H.E. Long-term F release from glass ionomer cements. *J. Dent. Res.* 1984 63:158-160.
- Swift E.J. In vitro caries - inhibitory properties of a silver cermet. *J. Dent. Res.* 1989 68:1088-1093.
- Tam L.E., Pulver E., McComb D., Smith D.C. Physical properties of calcium hydroxide and glass-ionomer base and lining materials. *Dent. Mater.* 1989 5:145-149.
- Thornton J.B., Retief D.H., Bradley E.L. Fluoride release from and tensile bond strength of Ketac-Fil and Ketac-Silver to enamel and dentin. *Dent. Mater.* 1986 2:241-245.
- Tjan A.H., Glancy J.F. Resistance to acid seepage and degradation of glass ionomer liners. *J. Dent. Res.* 1989 68 (Special Issue): 272 Abstr. 730.
- Tobias R.S., Browne R.M., Plant C.G., Ingram D.V. Pulpal response to a glass ionomer cement. *Br. Dent. J.* 1978 144:345-350.

- Torstenson B., Brännström M. The contraction gap under various composite resin restoration systems. *J. Dent. Res.* 1986 65 (Special Issue): 829 Abstr. 930.
- Tyas M.J. Clinical performance of three dentine bonding agents in Class V abrasion lesions without enamel etching. *Aust. Dent. J.* 1988 33:177-180.
- Tyas M.J., Toohey A., Clark J. Clinical evaluation of the bond between composite resin and etched glass ionomer cement. *Aust. Dent. J.* 1989 34:1-4.
- Tyas M.J. Clinical studies related to glass ionomers. *Oper. Dent. Supp.* 5, 1992 191-198.
- Um C.M., Oilo G. The effect of early water contact on glass-ionomer cements. *Quintess. Int.* 1992 23:209-2214.
- Vaidyanthan J., Vaidyanthan T.K., Schulman A. Demineralisation and ion binding action of a polycarboxylate cement liquid on human dental enamel. *J. Biomed. Mater. Res.* 1984 18:871-880.
- Van Noort R. Controversial aspects of composite resin restorative materials. *Br. Dent. J.* 1983 155:380-383.
- Walls A.W.G. Glass polyalkenoate (glass ionomer) cements: A review. *J. Dent.* 1986 14:231-246.
- Walls A.W.G., Adamson J., McCabe J.F., Murray J.J. The properties of a glass polyalkenoate (ionomer) cement incorporating sintered metallic particles. *Dent. Mater.* 1987 3:113-116.
- Warren Jnr. J.A., Soderholm K.-J.M. Bonding amalgam to glass ionomer with PAA. *Dent. Mater.* 1988 4:191-196.
- Wasserstein A., Gordon M. Microleakage in three designs of glass ionomer under composite restorations. *J. Dent. Res.* 1988 67 (Special Issue): 712 Abstr. 3.
- Welbury R.R., McCabe J.F., Murray J.J., Rusby S. Variables affecting bonding of composites to etched glass ionomers. *J. Dent. Res.* 1988 67 (Special Issue): 198 Abstr. 681.
-
- Welbury R.R., Murray J.J. A clinical trial of the glass-ionomer cement - composite resin "sandwich" technique in Class II cavities in permanent premolar and molar teeth. *Quintess. Int.* 1990; 21:507-512.

- Wendt S.L., McInnes P.M., Dickinson G.L. The effect of thermocycling in microleakage analysis. *Dent. Mater.* 1992 8:181-184.
- Wexler G., Beech D.R. Bonding of a composite restorative material to etched glass ionomer cement. *Aust. Dent. J.* 1988 33:313-318.
- Wilson A.D., Crisp S., Raddon J.M. The hydration of a glass ionomer (ASPA) cement. *Br. Polym. J.* 1981 13:66-70.
- Wilson A.D., Crisp S. Ionomer cements. *Br. Polym. J.* 1975 7:279-296.
- Wilson A.D., Groffman D.R., Kuhn A.T. The release of fluoride and other chemical species from a glass ionomer cement. *Biomaterials* 1985 6:431-433.
- Wilson A.D., Kent B.E. A new translucent cement for dentistry: The glass ionomer cement. *Br. Dent. J.* 1972 132:133-135.
- Wilson A.D., McLean J.W. *Glass ionomer cement*. Chicago, Quintessence, 1988.
- Wilson A.D., Prosser H.J. A survey of inorganic and polyelectrolyte cements. *Br. Dent. J.* 1984 157:449-545.
- Wilson A.D., Prosser H.J., Powis D.M. Mechanism of adhesion of polyelectrolyte cements to hydroxylapatite. *J. Dent. Res.* 1983 62:590-595.
- Woolford M. Composite resin attached to glass polyalkenoate (ionomer) cement - the laminate technique. *J. Dent.* 1993 21: 31-38.
- Ziemięcki T.L., Dennison J.B., Charbeneau G.T. Evaluation of Scotchbond: retention of cervical erosion restorations after one year. *J. Dent. Res.* 1985 64 (Special Issue): 276 Abstr. 917.
-

9. APPENDIX**APPENDIX A (A1-A8)****APPENDIX A1 - NOTICE REQUESTING PATIENT ALLOCATION FOR
THE STUDY****RESEARCH ON ALTERNATIVES TO AMALGAMS IN TREATING SMALL CARIOUS LESIONS****REQUIREMENTS:**

Pairs of minimal primary carious lesions.

A. Class I pairs

B. Class II pairs

Pairs can be in any posterior location.

PATIENT ALLOCATIONS:

Appointments with postgraduate Combined Prosthodontic student on:

Monday A.M./P.M.

Wednesday A.M./P.M.

Friday A.M.

RESTORATIVE MATERIALS:

Class I - GIC/Composite Resin Sandwich Technique will be compared with Amalgam restorations

Class II - Tunnel technique restored with Ketac Silver will be compared with Amalgam restorations

Restoration appointment will include photographs and impressions of restorations.

REVIEW OF PATIENTS:

- 6, 12 and 24 month post insertion

- placement of restoration will depend on patient co-operations and availability for subsequent review.

CONTACT:

Dr. Arnis Lidums and Dr. Richard Wilkie - Ext. 341/261
Clinic 2 - Receptionist Ext. 233

APPENDIX A2 - PATIENT CONSENT FORM

THE UNIVERSITY OF ADELAIDE

BOX 498, G.P.O., ADELAIDE, SOUTH AUSTRALIA 5001

Please address correspondence to

April 29, 1988

Dear Patient,

As newer improved filling materials and methods become available, we use them for treating tooth decay.

Instead of using only silver amalgam now to fill decayed teeth, resin and glass-ionomer materials have also been used for the past few years. The advantages of using these last two materials include less drilling, stronger teeth, and a more natural looking appearance.

The purpose of the present study is to follow up patients in whom all three materials may be used to treat decayed teeth and to compare the results. As part of the follow-up, colour photographs of the fillings will be taken once or twice yearly, over 3 years where possible. In some instances, small impressions and x-rays will also be required. The x-rays needed will be the same as those normally taken at dental visits, and lead aprons are used in all instances to screen patients.

The filling methods used and recall appointments are as for normal routine dental treatments. Your consent and co-operation in this study is appreciated and will also be of benefit to other patients.

Thank you.

Yours sincerely,

Dr. R. Wilkie
Dr. A. Lidums

Phone number for enquiries: 223.9233 (Clinic 2)

I consent for myself _____ to take part in the above study of amalgam, resin and glass-ionomer tooth-filling materials.

Signature: _____

Date: _____

I, _____ have described to the patient the nature of the procedures to be carried out. In my opinion he/she understood the explanation.

Signed: _____

Date: _____

APPENDIX A3 - DENTAL MATERIALS USED FOR CLINICAL STUDY

<u>NAME</u>	<u>MANUFACTURER</u>	<u>ADDRESS</u>
Dispersalloy	Johnson & Johnson	East Windsor, NJ, USA
Visio-Bond	Espe GmbH	Seefeld, Oberbay, Germany
Visio-Molar Radiopaque (RO)	Espe GmbH	Seefeld, Oberbay, Germany
Ketac-Conditioner	Espe GmbH	Seefeld, Oberbay, Germany
Ketac-Silver	Espe GmbH	Seefeld, Oberbay, Germany
Ketac-Bond	Espe GmbH	Seefeld, Oberbay, Germany
Greenstones & Whitestones "Brownie & Greenie" abrasive points	Shofu	Kyoto, Japan
Stainless Steel Matrix Bands Tofflemire	Teledyne-Getz	Illinois, U.S.A
Wizard Wedges	Teledyne-Getz	Illinois, U.S.A.
Plastic Sponges	3M Dental Divis.	St Paul, MN, USA
Permagum	Espe GmbH	Seefeld, Oberbay, Germany
Komet Burs	Brasseler	Lemgo, Germany
Silamat	Vivadent	Schaan, Liechtenstein
Visilux 2	3M Dental Divis.	St Paul, MN, U.S.A.

Premier Burs	Premier Dental	Scarborough, Ont, Canada
Jet 330 Burs	Beaver Dental	Morrisburg, Ont, Canada
Araldite	Ciba-Geigy (Polymer Div.)	Thomastown, Melbourne, Australia

Camera - Elicar MS-1 and Elicar V-HQ Medical Macro MC 90mm f/2-5 lens, with ring flash.

Tapak Int. Inc. Tokyo, Japan

Film - Kodak Ektachrome 35mm 100 ASA daylight film.

Eastman Kodak Co. Rochester, NY, USA

APPENDIX A4 - ARALDITE REPLICAS

The basic technique for making the replicas was the same as described by Ironside (MDS Research Report, 1987). A grey dye colourant was added to give better contrast for better definition of the features observed. This was prepared by mixing 1 part Araldite DW 0131 White to 7 parts Araldite DW 0137 Black.

The Araldite mixture consisted of the following ingredients:

(A) Araldite M or D	100ml
(B) Hardener HY964	100ml
(C) Grey Colourant	3ml
(D) Accelerator	3.2ml

Parts (A) and (B) were mixed in 250 ml specimen jars using a wooden tongue spatula for approximately 10 minutes. Grey colourant and accelerator were added and the mixture mixed for a further 5 minutes. Entrapped air was removed by placing the jars in a sealed evacuator until bubbles stopped coming out of the solution. The Araldite mixture was then poured slowly into the boxed impressions, delivered by a 10ml plastic disposable syringe, allowing the solution to slowly wet out the impression surfaces. When the Araldite had hardened (usually at about 1 week) the replicas were removed from the impressions. To accelerate the setting reaction, the Araldite replicas could be placed in a 37°C oven for about 2-4 days.

APPENDIX A6 - RESTORATION DATA PROFORMA - File 37 - Class I

1
17 TOOTH SURFACES _____ HOSP. NO. _____ PATIENT'S NAME: _____
FILE

3	8 Observation	14	Xtrn	16 Rest.	Replaced	20	(BWX)				
Rest.No.	Day Mth.Year	True Fail.	Appar. Fail.	True Fail.	Appar. Fail.	Diff. Mat.	Rest.All Lost	Rest.Fract. Part Lost, Mobile	Tooth Fract.	Recurr. Decay	Rest. Repair
24				27			30				
Pulp Problem	Tender to Percuss	Tooth RCF	Tooth Discol. (slide)	Partial Abuts	Gen. Plaque	Gen. Gingivitis	Gen. Staining	Gen. Bruxism	Gen. Toothbrush Abrasion		
34	37	40	43	46	49	52	55				
(slide/Replica) (58 Artic.Paper)	61(slide)	64(slide/Rep)	67(slide)	70(slide)	73(slide/Rep)	76	79				
Occlus. Attrit.Rest.	Retention	Surface Roughened (porosity or voids)	Surface Stain/Tarnish	Margins Stained	Margins Fractured						
82		88		102							
Hosp. No.		Surname,	Initials	Day Mth.Year							
108	110	115		121	123	125					
FDI Code	O M D Surfaces (slides/BWX)	Class	Slides/Casts	MAT. 01=Amalgm/C1.1 02=Fissure K-S	OPER. 01=Lidums 02=Wilkie 03=Smales	Day Mth.Year Insertion					

INITIAL VISIT ONLY

width restn. Filling defect

Occlusal contact poor O.H. Bruxer > 20cigs/day Camrine Guide

ALL BLANKS PUNCHED AS ZERO

REASON FOR FAILURE

Dr R. Wilkie
Dr R.J. Smales

'CLINRES' 1988 - THE UNIVERSITY OF ADELAIDE, DEPARTMENT OF DENTISTRY

Ketac Silver
(Tunnel Method)

1

36

TOOTH SURFACES _____

HOSP. NO. _____

PATIENT'S NAME: _____

FILE

I = Yes	3	8 Observation	14	Xtrn	16 Rest.	Replaced	20	(BWX)	
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
0 = No	24		27				30		
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	34 (probe)	37 (floss)	40	43	46	49	52	55	
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	Gingivitis Rest.	Open Prox. Contacts							
	(slide/Replica)								
	58 Artic. Paper	61 (slide/Rep)	64 (slide/Rep)	67 (slide)	70 (slide)	73 (slide/Rep)	76	79	
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	Occlus. Attrit. Rest.	Proximal Attrit. Rest.	Surface Roughened (porosity or voids)	Surface Stain/Tarnish	Margins Stained	Margins Fractured			
INITIAL VISIT ONLY	82		88		102				
	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>				
	Hosp. No.		Surname,	Initials	Day Mth. Year			BIRTHDATE	
	108	110	115		121	123	125		
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	FDI Code	O M D Surfaces (slides/BWX)	Class	Slides/Casts	MAT.	OPER.	Day Mth. Year	Insertion	
					01=Amalgm/C1.1 02=Tunnel K-S 03=Sandwich C1.2	01=Lidums 02=Wilkie 03=Smales			

ALL BLANKS
PUNCHED AS ZERO

REASON FOR FAILURE

APPENDIX A8

KAPPA

INTRA EXAMINER AGREEMENT

$K = \frac{Po - Pe}{1 - Pe}$

Po = observed proportion of agreement

1 - Pe

Pe = expected proportion of agreement

Weighted Kappa

$w_o(i,j) = wgt(i,j) \times obs(i,j)$

$w_e(i,j) = wgt(i,j) \times exp(i,j)$

$P_o = P_o + w_o(i,j)$

$P_e = P_e + w_e(i,j)$

$wgt(i,j) = 1 - (i-j)^2 / 9$

i = original rating score

j = duplicate rating score

Agreement scores	Weighting
Within ± 0.0	1.00
" ± 1.0	0.89
" ± 2.0	0.56
" ± 3.0 or more	0.00

Clinical factor	(rating score)	Percentage agreement		Kappa Values	
		Identical score	Within ± 1 scores of original score	Kappa	Weighted Kappa
Occlusal wear	(0,1,2,3)	83.33	100.00	0.713	0.856
Occlusal retention	(0,1,2,3)	86.67	100.00	0.626	0.775
Surface roughness	(linear 0-12)	40.00	73.33	0.256	0.530
Surface staining	(linear 0-12)	66.67	80.00	0.443	0.680
Marginal staining	(linear 0-8)	56.67	90.00	0.268	0.475
Marginal fracture	(linear 0-12)	46.67	90.00	0.271	0.490
Fractured/crazed	(0,1)	100.00			

APPENDIX B

CLASS I - (File 37)

BASELINE

Table B1 The distribution of restorations placed by widths of occlusal preparation

Class I	<i>Preparation > 1/4 intercuspal width</i>		Total
	Yes	No	
Amalgam	6	15	21
Cermet	19	38	57
Sandwich	31	7	38
$\chi^2 = 25.2396, df = 2, p < 0.001$ (significant)			

Table B2 The distribution of restorations placed by filling defects on bitewings

Class I	<i>Filling defect - Bitewings</i>		Total
	Yes	No	
Amalgam	0	21	21
Cermet	1	56	57
Sandwich	0	38	38
$\chi^2 = 1.0389, d.f. = 2, P > 0.01$ (not significant)			

Table B3 The distribution of restorations placed by occlusal contact in centric occlusion

Class I	<i>Occlusal contact in C.O.</i>		Total
	Yes	No	
Amalgam	2	18	20
Cermet	8	44	52
Sandwich	8	28	36
$\chi^2 = 1.5004$, d.f. = 2, $P > 0.10$ (not significant)			

Table B4 The distribution of restorations placed by poor oral hygiene

Class I	<i>Poor oral hygiene</i>		Total
	Yes	No	
Amalgam	5	16	21
Cermet	9	48	57
Sandwich	11	27	38
$\chi^2 = 2.4111$, d.f. = 2, $P > 0.10$ (not significant)			

Table B5 The distribution of restorations placed by evidence of bruxing

Class I	<i>Bruxing</i>		Total
	Yes	No	
Amalgam	6	14	20
Cermet	16	38	54
Sandwich	7	29	36
$\chi^2 = 1.3204$, d.f. = 2, $P > 0.10$ (not significant)			

Table B6 The distribution of restorations placed by frequency of smoking

<i>>20 cigarettes per day</i>			
Class I	Yes	No	Total
Amalgam	3	16	19
Cermet	6	43	49
Sandwich	1	35	36
$\chi^2 = 3.1568$, d.f. = 2, $P > 0.10$ (not significant)			

Table B7 The distribution of restorations placed by presence of canine guidance

<i>Canine guided</i>			
Class I	Yes	No	Total
Amalgam	5	14	19
Cermet	13	36	49
Sandwich	12	24	36
$\chi^2 = 0.5395$, d.f. = 2, $P > 0.10$ (not significant)			

Table B8 The distribution of restorations placed by dental arches

<i>Dental arches</i>			
Class I	Maxillary	Mandibular	Total
Amalgam	7	14	21
Cermet	28	29	57
Sandwich	21	17	38
$\chi^2 = 2.6363$, d.f. = 2, $P > 0.10$ (not significant)			

Table B9 The distribution of restorations placed by tooth types

<i>Teeth restored</i>			
Class I	Premolars	Molars	Total
Amalgam	1	20	21
Cermet	6	51	57
Sandwich	0	38	38
$\chi^2 = 4.5267$, d.f. = 2, $P > 0.10$ (not significant)			

Table B10 The distribution of restorations placed by operators

<i>Operators</i>			
Class I	Lidums	Wilkie	Total
Amalgam	17	4	21
Cermet	34	23	57
Sandwich	16	22	38
$\chi^2 = 8.5298$, d.f. = 2, $P < 0.025$ (significant)			

Table B11 The distribution of restorations placed by patient age groups

<i>Patient age groups</i>				
Class I	0-20	21-40	41+ years	Total
Amalgam	10	10	1	21
Cermet	30	26	1	57
Sandwich	17	20	1	38
$\chi^2 = 1.0725, df = 4, p > 0.10$ (not significant)				

Table B12 Distribution of patients by age groups

<i>Patient age groups</i>				
Class I	0-20	21-40	41+ years	Total
	16	17	2	35

APPENDIX B - CLASS I - (File 37)

FIGURE B1

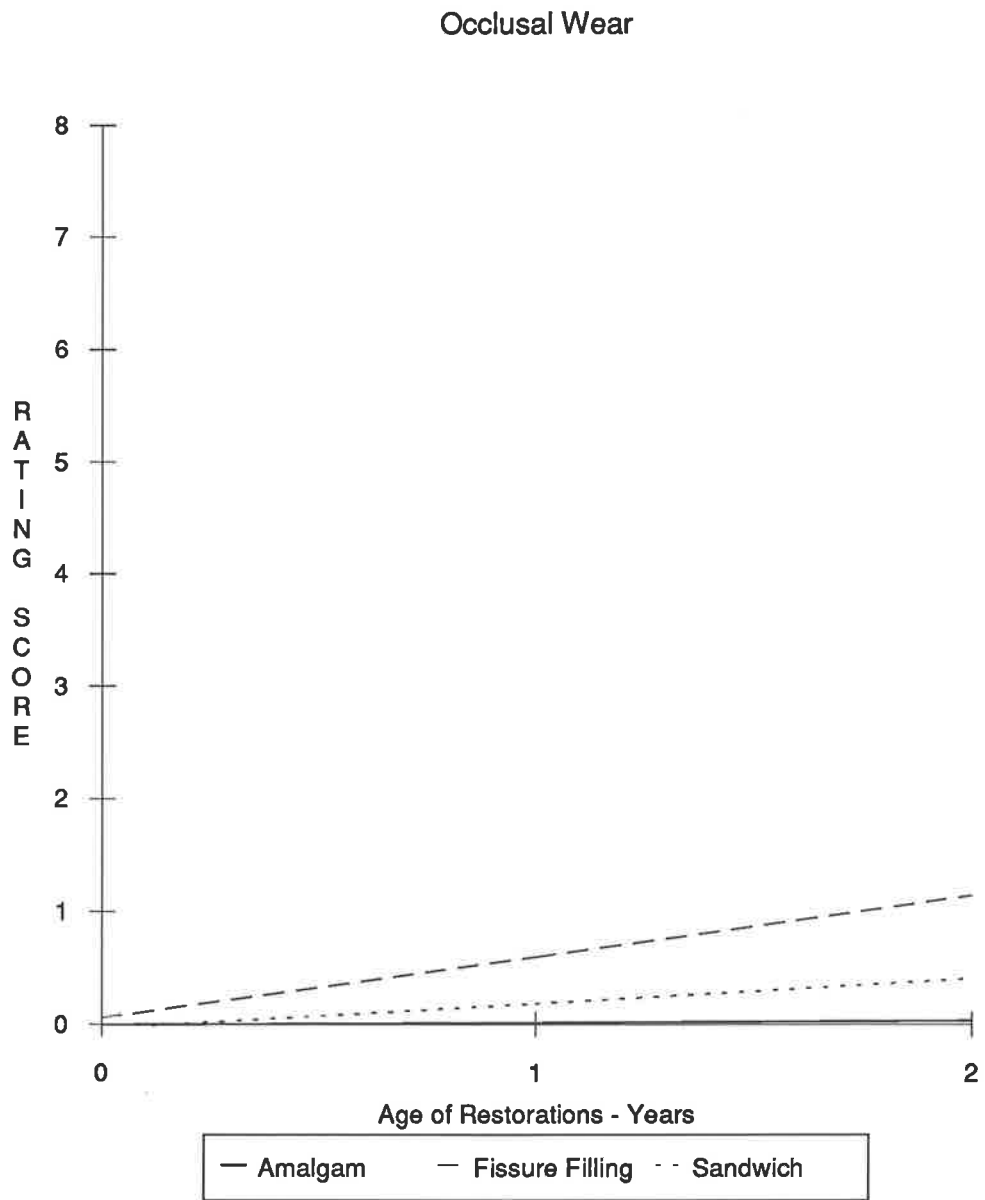


FIGURE B2

Occlusal Retention

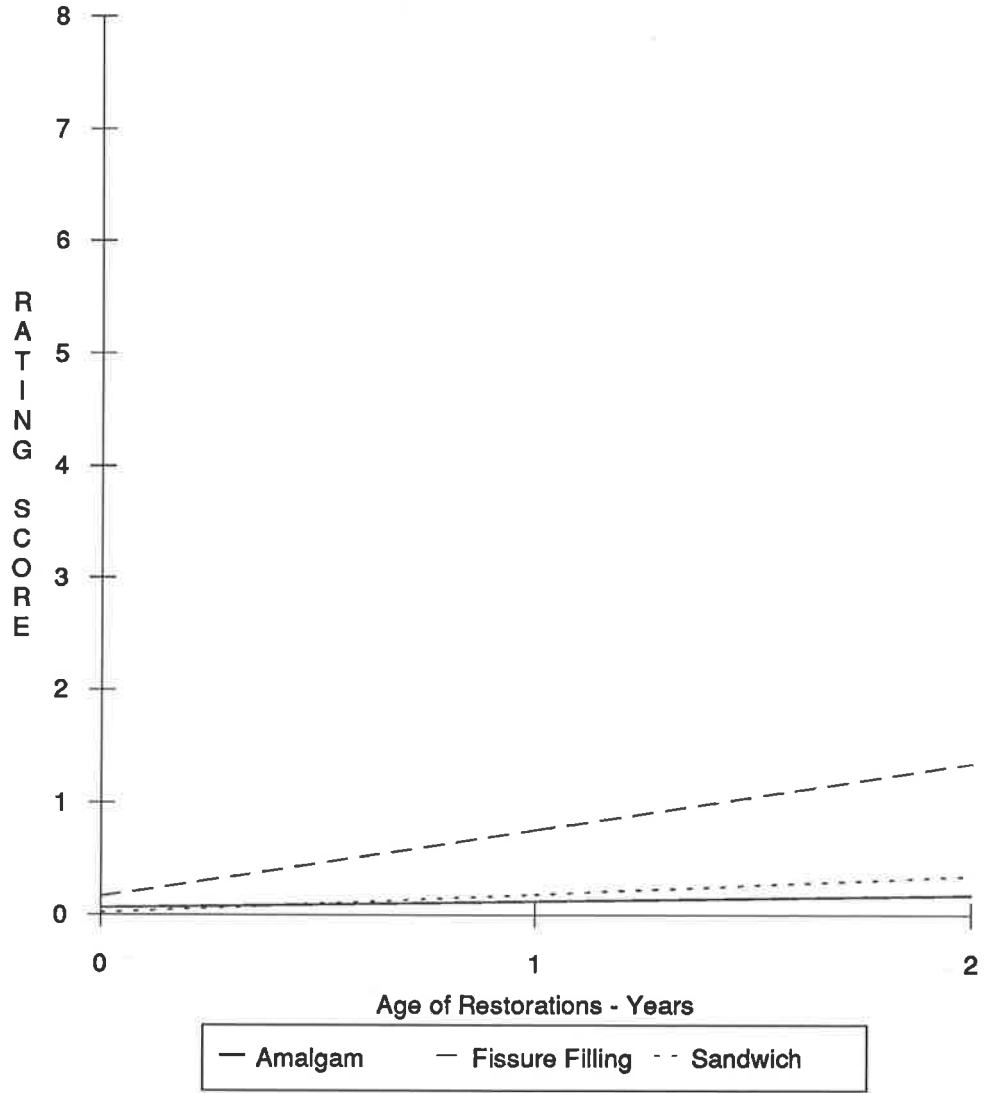


FIGURE B3

Surface Roughness and Voids

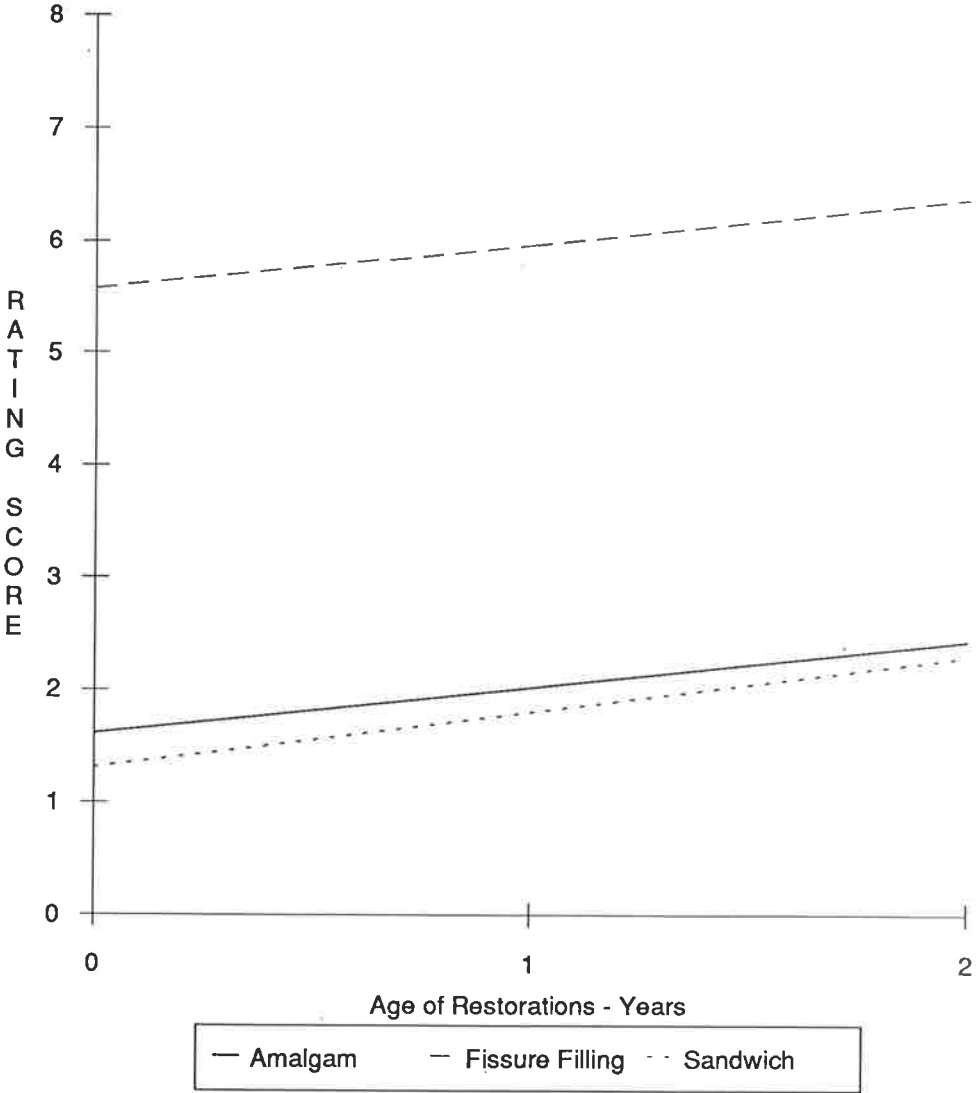


FIGURE B4

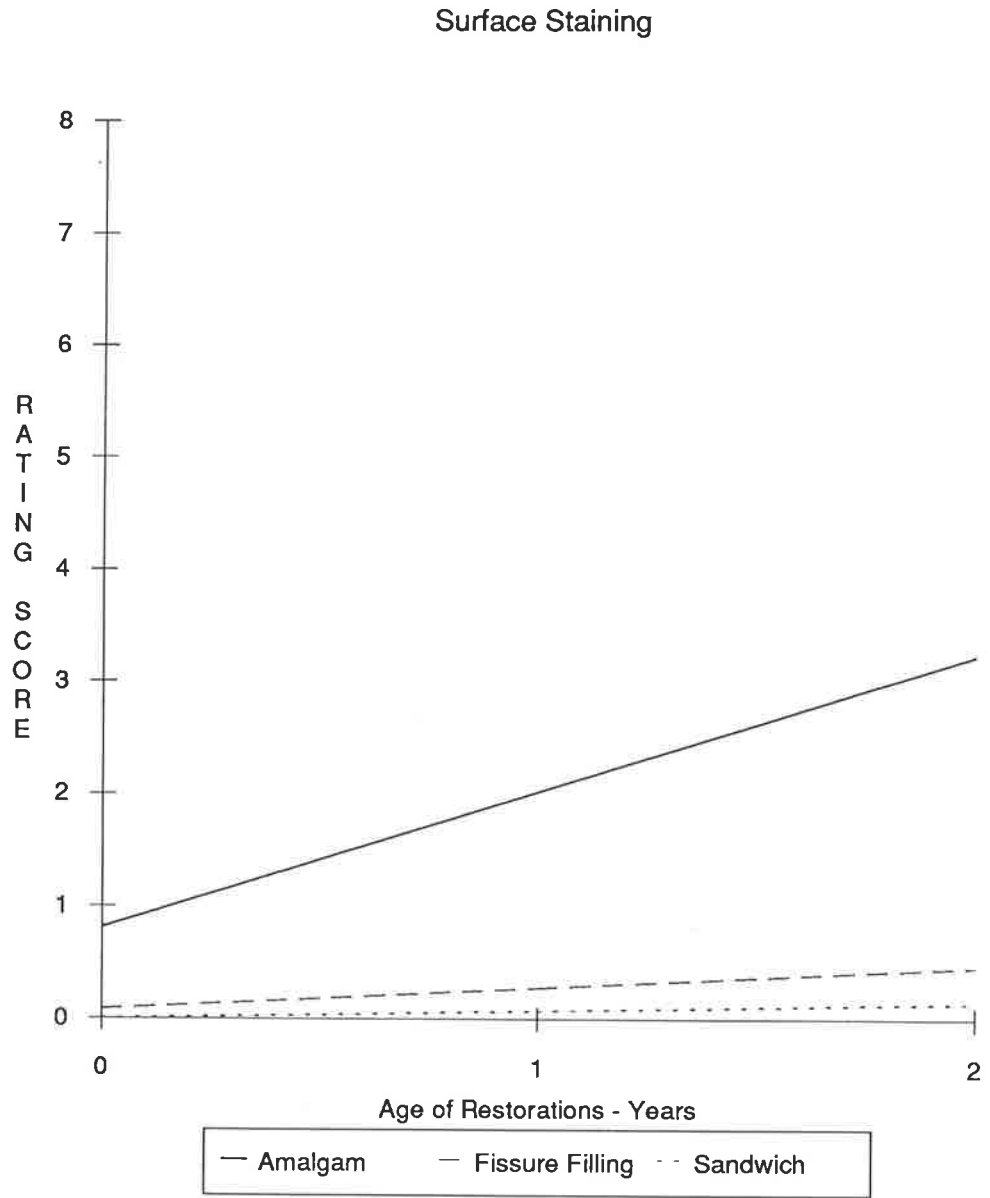


FIGURE B5

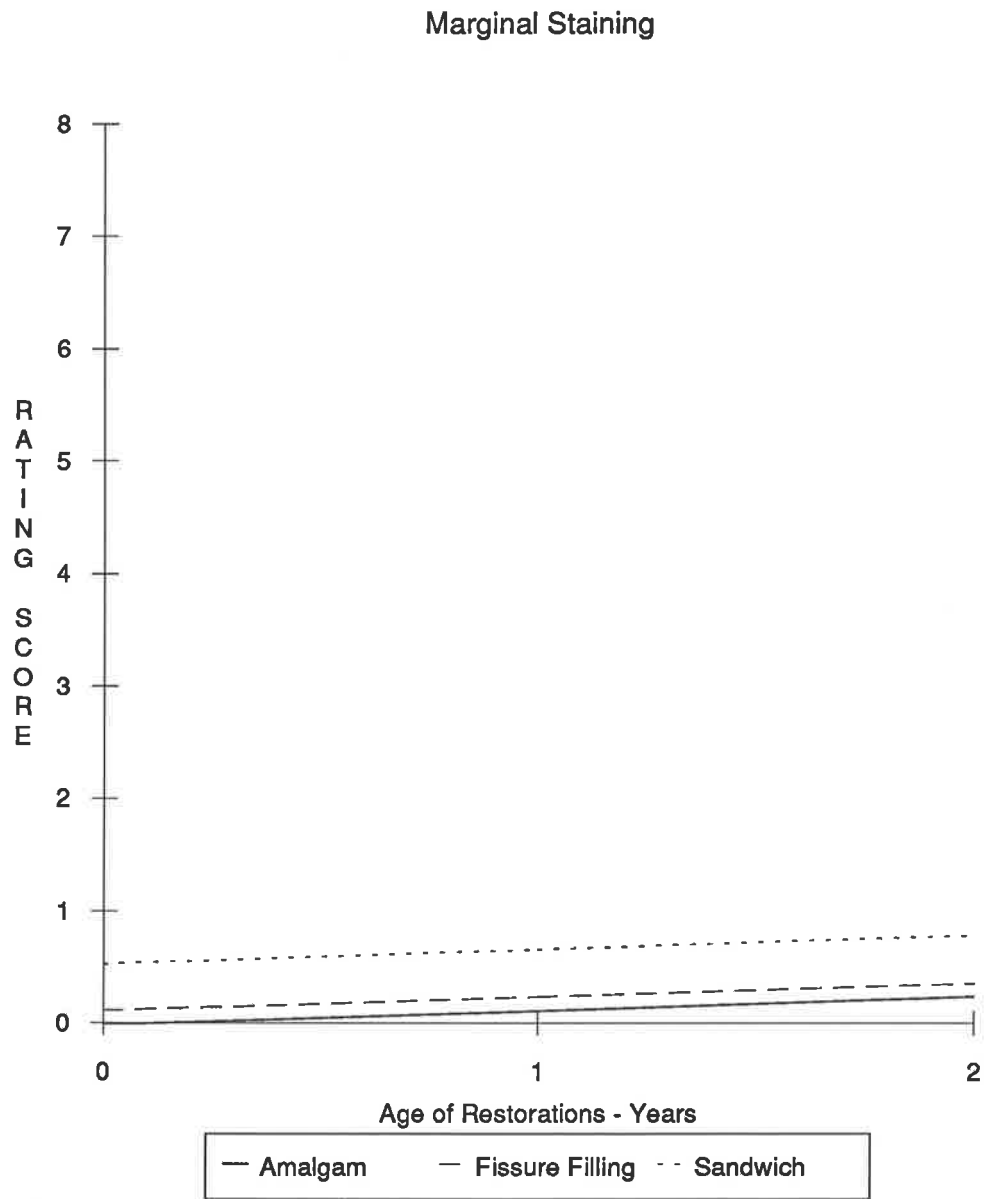
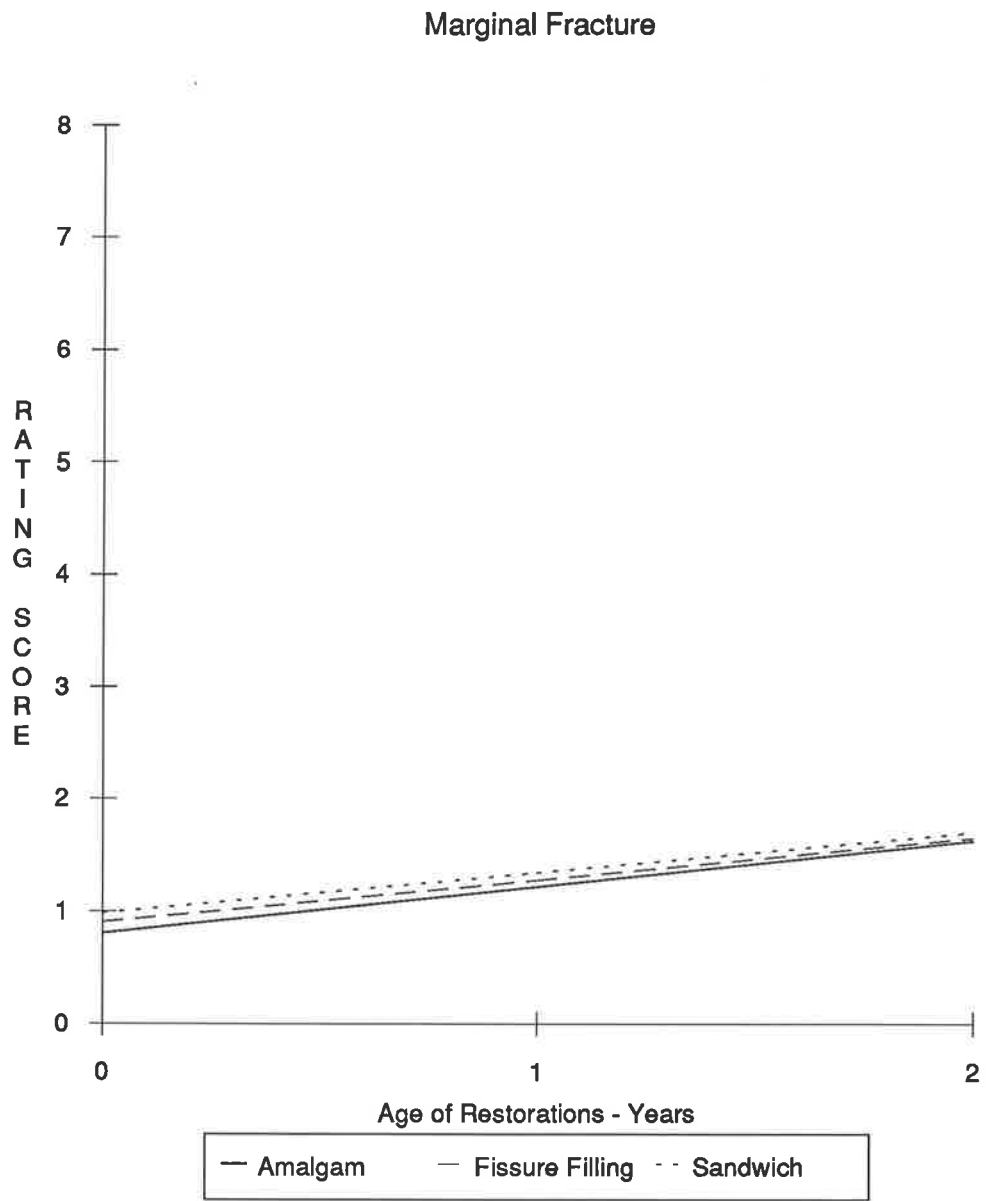


FIGURE B6



CLASS II - (File 36)

BASELINE

Table B13 The distribution of restorations placed by width of occlusal preparations

<i>Preparation > 1/4 intercuspal width</i>			
Class II	Yes	No	Total
Amalgam	13	3	16
Sandwich	19	9	28
$Y\chi^2 = 0.3693, d.f. = 1, P > 0.10$ (not significant)			

Table B14 The distribution of restorations placed by filling defects on bitewings

<i>Filling defect - Bitewings</i>			
Class II	Yes	No	Total
Amalgam	0	16	16
Sandwich	0	28	28
$Y\chi^2 = \text{CAN'T DO}$			

Table B15 The distribution of restorations placed by occlusal contact in centric occlusion

<i>Occlusal Contact in C.O.</i>			
Class II	Yes	No	Total
Amalgam	7	9	16
Sandwich	13	15	28
$Y\chi^2 = 0.0204, d.f. = 1, P > 0.10$ (not significant)			

Table B16 The distribution of restorations placed by poor oral hygiene

<i>Poor oral hygiene</i>			
Class II	Yes	No	Total
Amalgam	2	14	16
Sandwich	9	19	28
$\chi^2 = 1.1785, \text{d.f.} = 1, P > 0.10$ (not significant)			

Table B17 The distribution of restorations placed by evidence of bruxing

<i>Bruxing</i>			
Class II	Yes	No	Total
Amalgam	9	7	16
Sandwich	10	1	28
$\chi^2 = 1.0131, \text{d.f.} = 1, P > 0.10$ (not significant)			

Table B18 The distribution of restorations placed by frequency of smoking

<i>> 20 cigarettes per day</i>			
Class II	Yes	No	Total
Amalgam	2	14	16
Sandwich	0	28	28
$\chi^2 = 1.3516, \text{d.f.} = 1, P > 0.10$ (not significant)			

Table B19 The distribution of restorations placed by presence of canine guidance

<i>Canine guided</i>			
Class II	Yes	No	Total
Amalgam	8	8	16
Sandwich	18	10	28
$\chi^2 = 0.3701$, d.f. = 1, $P > 0.10$ (not significant)			

Table B20 The distribution of restorations placed by dental arches

<i>Dental arches</i>			
Class II	Maxillary	Mandible	Total
Amalgam	9	7	16
Sandwich	20	8	28
$\chi^2 = 0.4777$, d.f. = 1, $P > 0.10$ (not significant)			

Table B21 The distribution of restorations placed by tooth types

<i>Teeth restored</i>			
Class II	Premolars	Molars	Total
Amalgam	3	13	16
Sandwich	15	13	28
$\chi^2 = 3.7628$, d.f. = 1, $P > 0.05$ (not significant)			

Table B22 The distribution of restorations placed by operators

<i>Operators</i>			
Class II	Lidums	Wilkie	Total
Amalgam	7	9	16
Sandwich	13	15	28
$\chi^2 = 0.0204$, d.f. = 1, $P > 0.10$ (not significant)			

Table B23 The distribution of restorations placed by patient age groups

<i>Patient age groups</i>				
Class II	0-20	21-40	41+ years	Total
Amalgam	7	9	0	16
Sandwich	11	15	2	28
$\chi^2 = 1.2057$, d.f. = 2, $P > 0.10$ (not significant)				

Table B24 Distribution of patients by age groups

<i>Patient age groups</i>				
Class II	0-20	21-40	41+ years	Total
	9	14	3	26

APPENDIX B - CLASS II - (File 36)

FIGURE B7

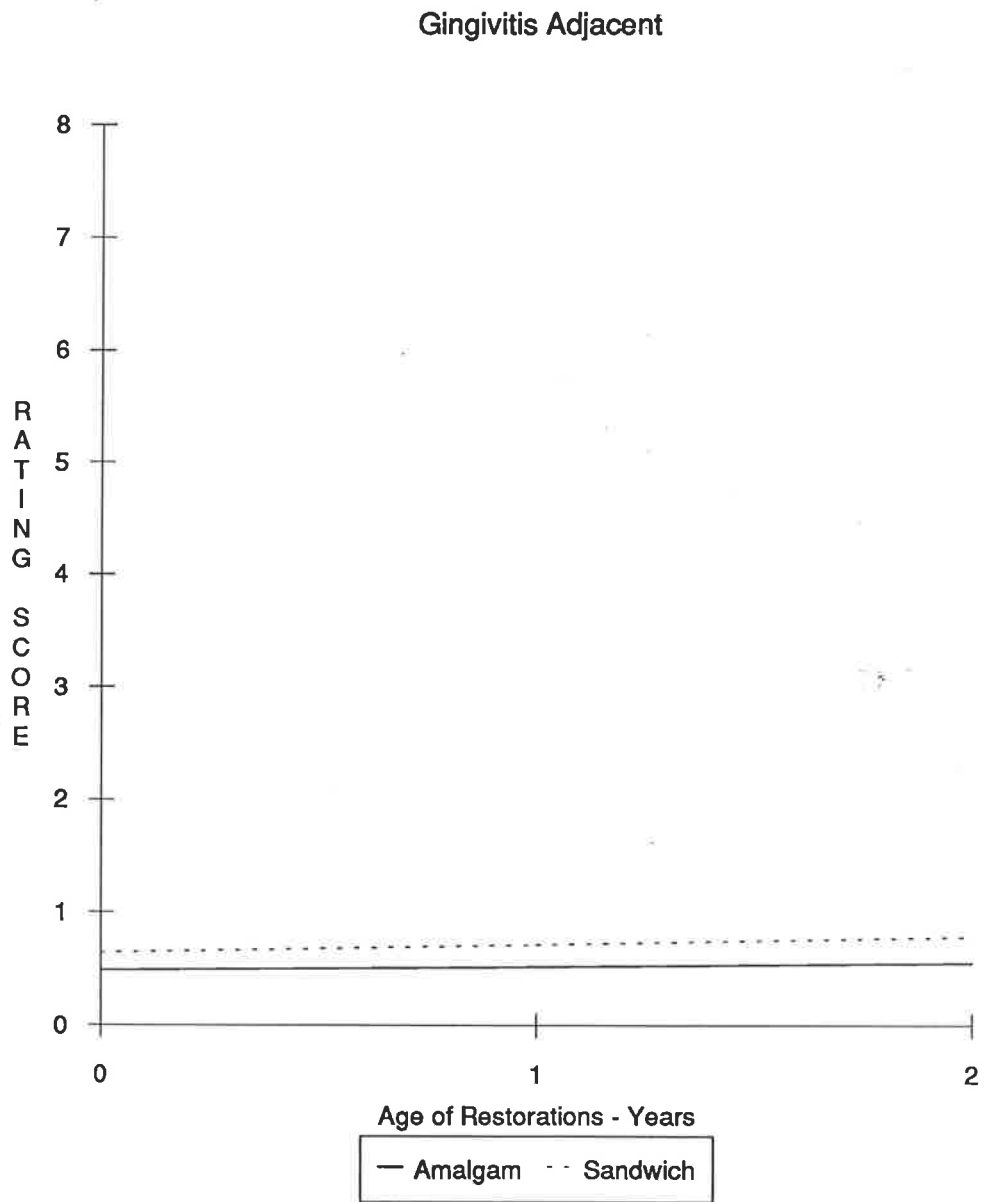


FIGURE B8

Proximal Contacts

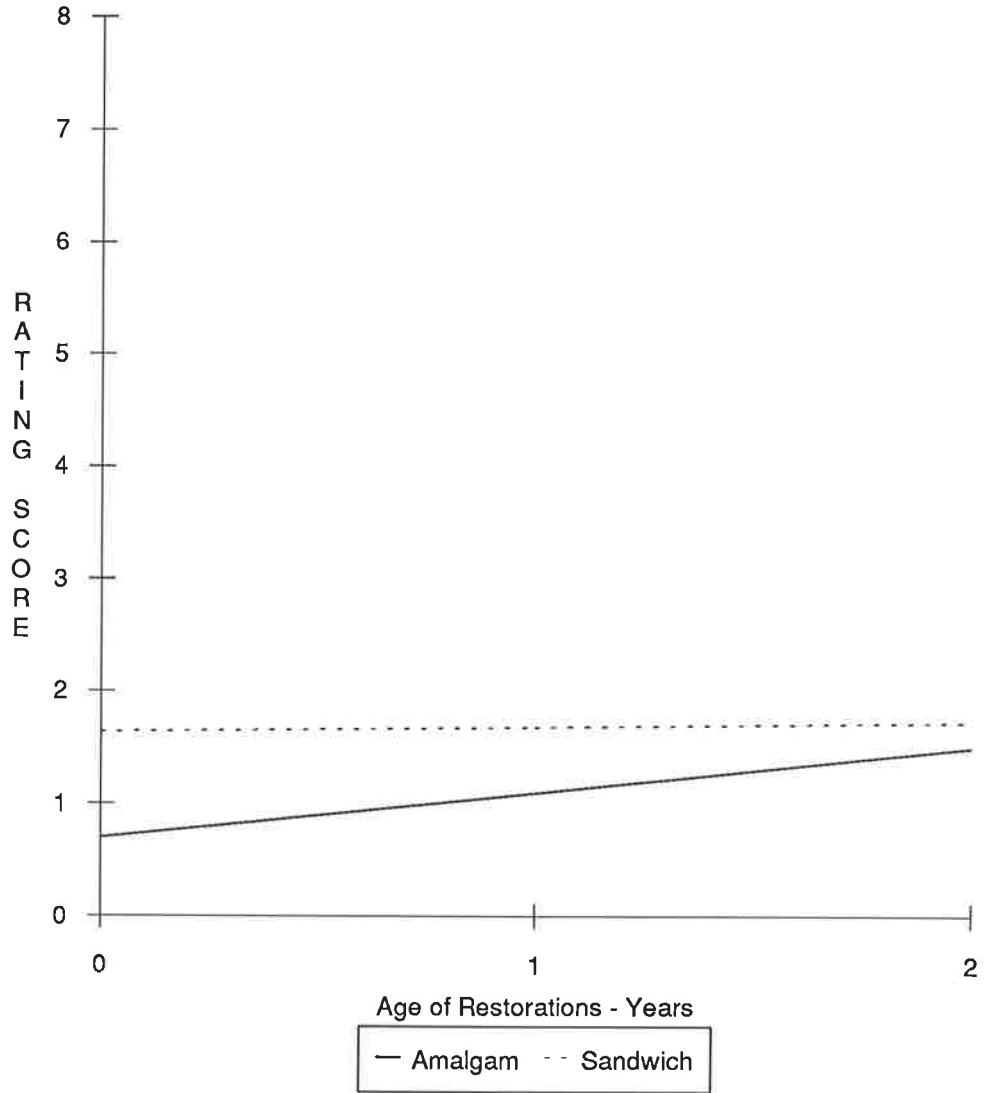


FIGURE B9

Occlusal Wear

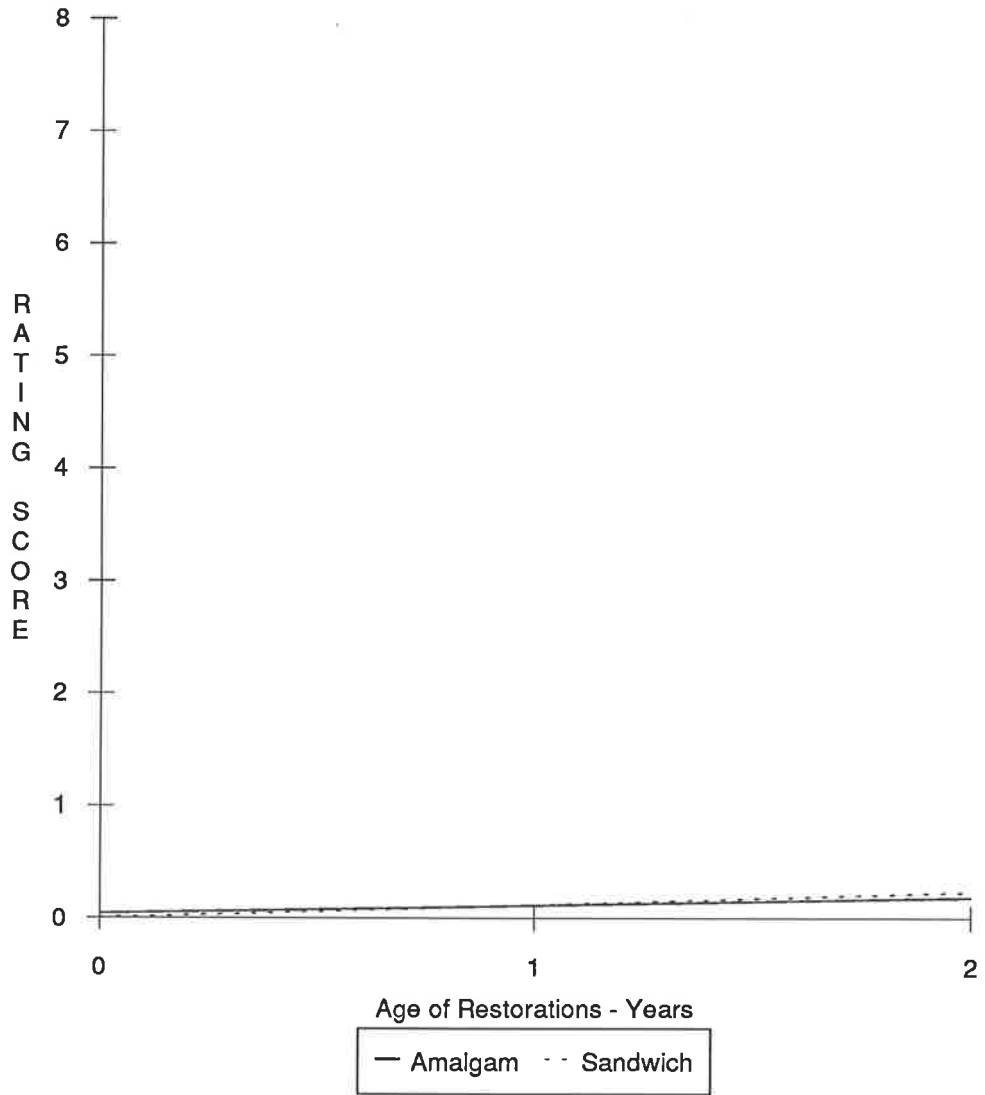


FIGURE B10

Surface Roughness and Voids

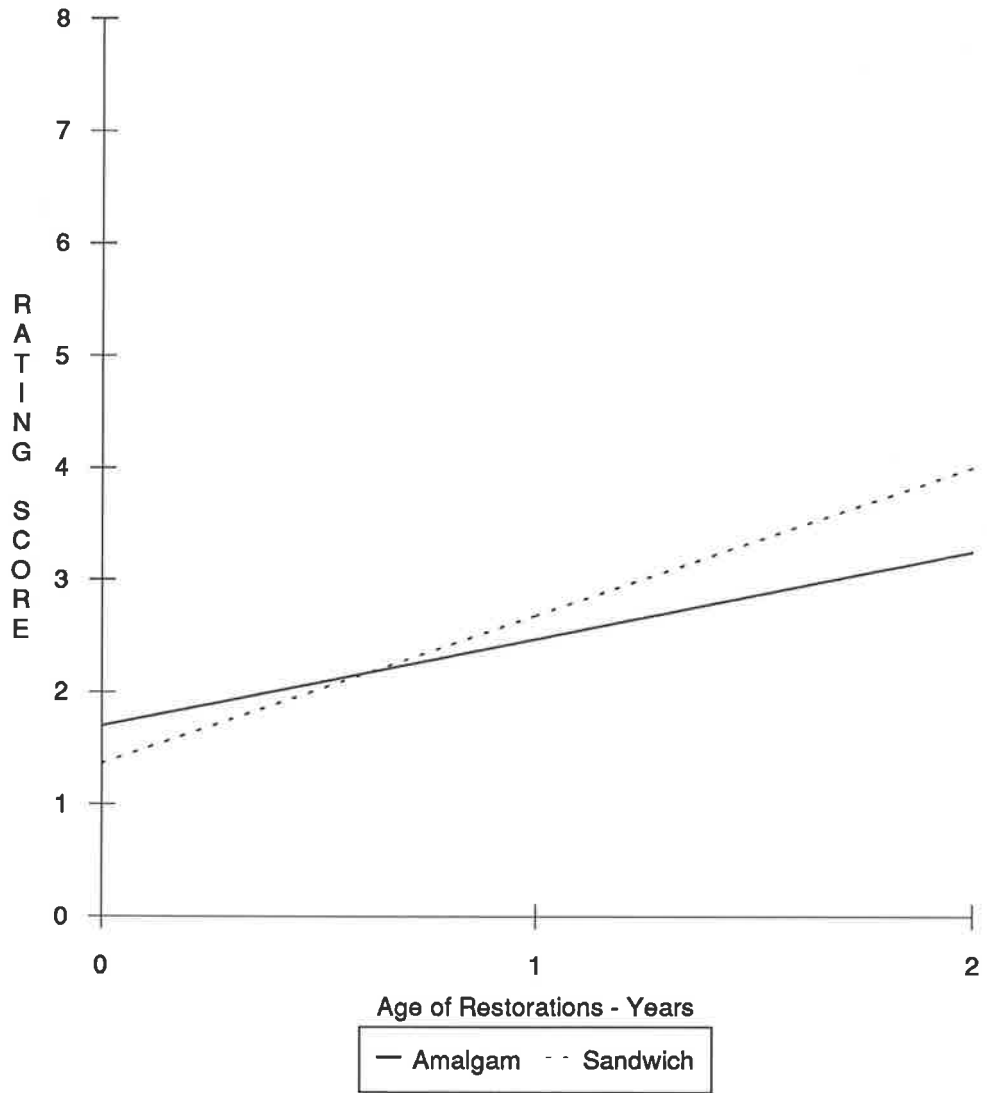


FIGURE B11

Surface Staining

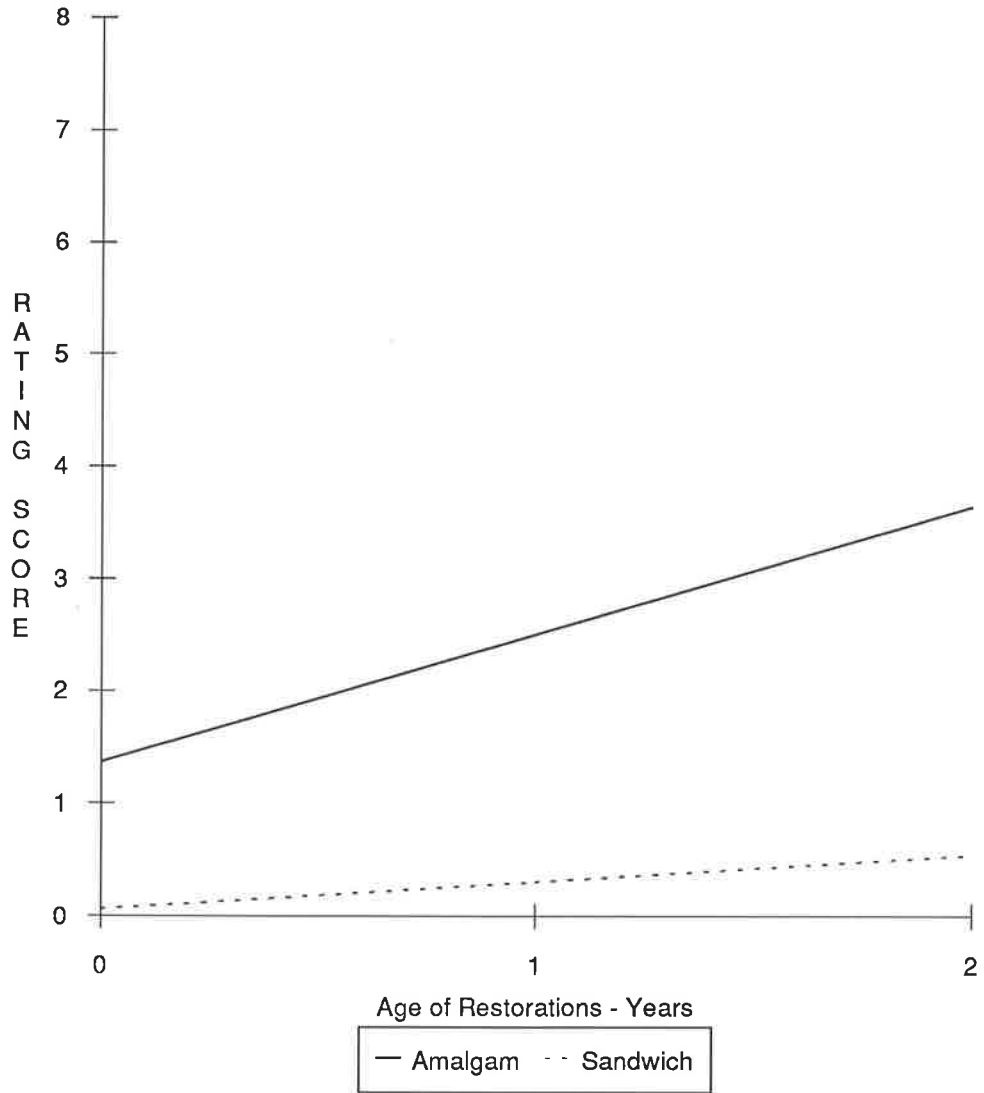


FIGURE B12

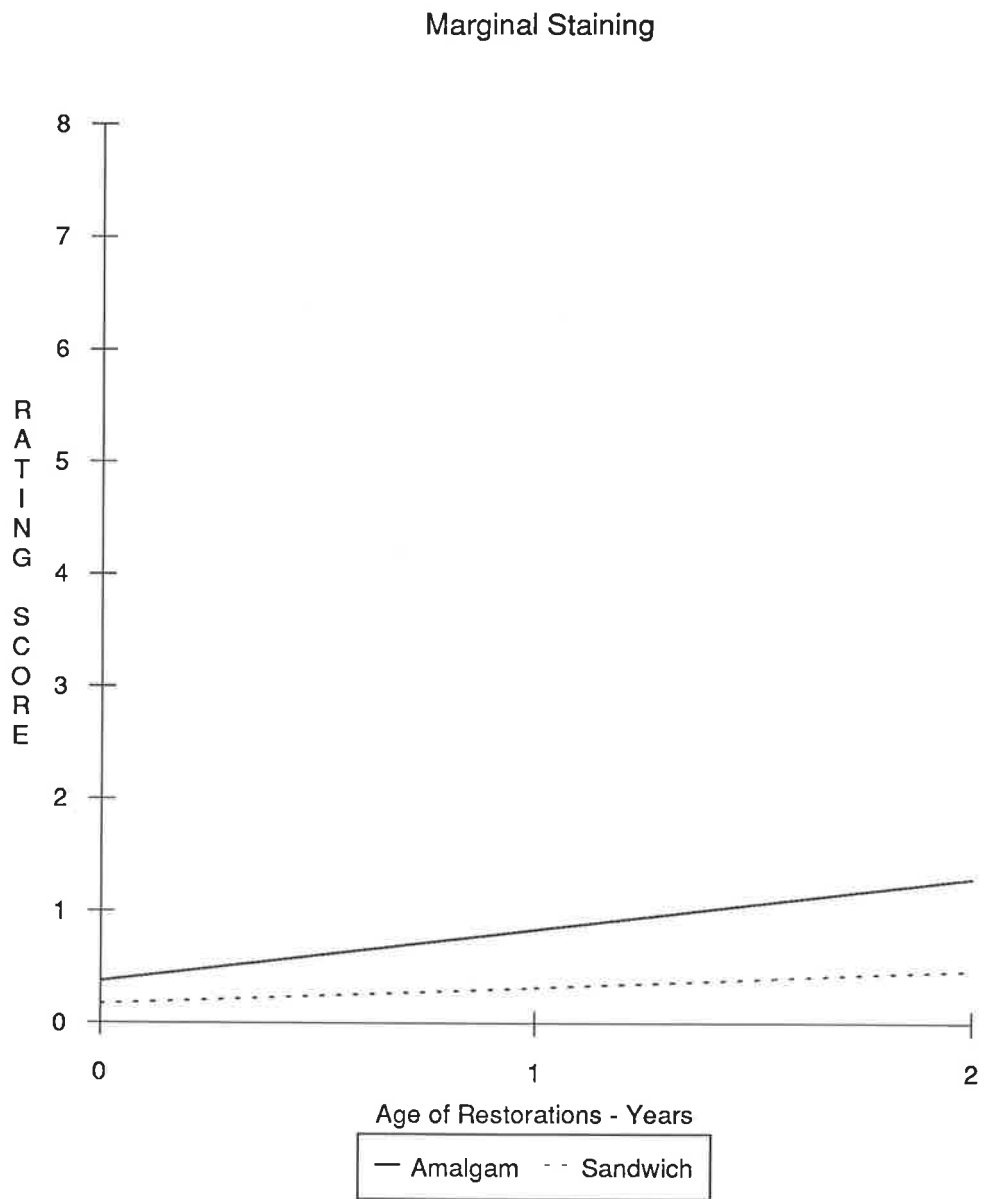


FIGURE B13

Marginal Fracture

