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Operative Dentistry publishes articles that advance the practice of operative dentistry. The scope of the journal includes conservation and restoration of teeth; the scientific foundation of operative dental therapy; dental materials; dental education; and the social, political, and economic aspects of dental practice. Review papers and letters also are published.

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EDITORIAL

Patient Rights and State Board Examinations

Have you ever wondered what happens to the patients treated by candidates of dental licensing board examinations whose treatment was graded as a failure during the examination? Are they informed that their treatment is substandard or received a failing score, or are they allowed to be dismissed without a thought for their well-being? Is there a process for retreatment, if the procedure is graded as unsatisfactory?

In all probability, the patients in question will not be informed by any officer or agent of the examining board. The candidate that provided the treatment is typically the only one who will inform the patient that the examination procedure was a failure. Many patients, however, never find out the status of their candidates' grades, and while the grade is always addressed by the failed candidate to the board of examiners, the treatment he/she provided is not. Most of us recognize that there are many treatment procedures which are not only graded as a failure but are indeed a detriment to the well-being of the patient.

In today's litigious world, it surprises me that patients have not protested the fact that they have been treated under the auspices of a legal dental examining board and have not had the consequences of their treatment presented to them. When and where does informed consent come into the picture? In all probability, if patients were to challenge the treatment consequences on the issue of lack of informed consent, they would probably have a good case. It is my belief that patients need to be informed not only of the probability of receiving adequate care during the examination procedures, but also of the status of the treatment that was rendered. Many examining boards inform the patient that they are not responsible for the care delivered and that should the care be inadequate they should seek treatment from a licensed dentist. Is this either fair or legal?

Patients have rights. Patients should be informed that the examination they are sitting for typically has a failure rate of X% relative to clinical procedures. If that were done, I wonder how many patients would still give their consent and allow treatment to proceed. However, that is only half the problem. What about the care deemed by the examiners to be substandard or a failure? Why are patients not informed of treatment judged unsatisfactory? Should not the patients have the treatment corrected or redone? As far as I know, patients are not informed and treatment is typically not corrected at the direction of the examiners. Only one examining board that I know of has dealt with the idea of retreatment. Why not others?

Patients could and should be informed that the care they are receiving in an examination is unsupervised. Patients should be made to understand what type of failures typically occur during these examinations. They should also understand the consequences of the errors committed. After all, we all know that excessive preparation or mutilation of tooth structure or damage to adjacent teeth is not reversible.

If the fees for examining boards were raised to include retreatment by a licensed dentist, patients would be assured that they were fully informed about the treatment they were to receive and that if it did not meet the standard of care, it would be rectified by funds provided through the examination system. Such an action would create added administrative procedures for examining boards, but the results of such an action would go a long way towards correcting a long-standing inequity.

Are there any dental examining boards willing to address the issue?

David J Bales
Editor

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ORIGINAL ARTICLES

A Comparison of Glass-Ionomer Cements Used to Repair Cast Restorations

T J CARLSON • E A NAGUIB
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Summary

Based on SEM analysis, this study evaluates the usefulness of three glass-ionomer cements to repair margins of cast restorations. These findings are compared to those previously obtained for amalgam, resin, and direct gold used as repair materials. This information can assist the clinician in choosing the most appropriate repair material in selected cases.

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INTRODUCTION

When properly placed, cast restorations can be expected to provide a high-quality, long-lasting service to the patient. Defects such as caries or erosion do occur along margins which may require premature replacement of the casting. If such defects are limited in size and are in an accessible location, it is feasible to consider repairing the defect, rather than replacing the casting. This is particularly true if the restoration is an abutment for an existing fixed or removable prosthesis, or if the defect is solely the result of erosion, and not caries.

Investigators have compared marginal leakage of direct restorative materials (Martin, 1981; Hormati & Chan, 1980), and the micromorphology of amalgam, resin, and direct gold used to repair margins of castings (Carlson, Cochran & Lund, 1986). These studies have generally indicated that direct gold restorations offer superior margin adaptation when properly manipulated.

In recent years, a variety of glass-ionomer cement formulations have become popular as direct restorative materials. As a group they are tooth-colored, adhesive to tooth structure, and release fluoride (Phillips, 1982). In addition to traditional glass-ionomer cements, two modified materials are available. One is a silver-glass cermet (Chelon Silver/Ketac Silver, ESPE-Premier, Norristown, PA 19404) and the other mixes silver amalgam alloy powder with a Type II glass-ionomer cement (Miracle Mix, Fuji II + LumiAlloy, G-C Dental Industrial Corp, Scottsdale, AZ 85260). Although no longer tooth-colored, these silver-containing glass-ionomer cements were developed to enhance certain physical properties of the set cement.

The purpose of this study was to utilize scanning electron microscopy to visualize the integrity of margin interfaces between gold castings and glass-ionomer cements (one traditional and two silver-containing). In addition, these micrographs were compared to those previously obtained for margin interfaces between gold castings and composite resin, high-copper amalgam, and direct-filling gold (Carlson & others, 1986).

MATERIALS AND METHODS

Fifteen caries-free human canines were selected which had been stored in water immediately following their extraction. All teeth selected were visually free from fractures or craze lines, and were cleaned with a white webbed prophy cup and slurry of pumice.

A one-surface inlay preparation was cut on the facial of each tooth. A #56 bur was used in a high-speed handpiece with an air-water spray coolant. Burs were used for five teeth and then replaced. The preparations were cut 1.5 mm deep and 2 mm x 4 mm in outline. All margins were cut in enamel, and a 45° bevel was placed on the mesial, distal, and incisal margins. The preparations were lubricated, direct wax patterns made, and the teeth replaced in water. All patterns were cast with Type III gold.

Just prior to cementation of the inlays, the teeth were dried and cavity varnish was applied to each preparation. The inlays were cemented with zinc-phosphate cement, and following a 30-minute delay were again placed in water for storage.

At a subsequent time, preparations were cut at the cervical margin of each inlay to simulate a clinical margin repair. The instrumentation was similar to that of the initial preparation. All margins except those against the inlays were kept in enamel. Each preparation was scrubbed for 15 seconds with 30% polyacrylic acid to remove the smear layer, then washed with water for 20 seconds and dried with compressed air. Five of the specimens were restored with Ketac-fil (ESPE-Premier), five with Chelon Silver (ESPE-Premier), and five with Fuji II + LumiAlloy (Miracle Mix, G-C Dental). Each of the cements was manipulated using the same technique. After being mixed according to manufacturers' instructions, the cement was placed into the preparation, immediately covered with a preformed aluminum matrix (Cervical Matrix Form, ESPE-Premier), varnished, and allowed to set for 15 minutes. The matrix was then removed and the cement was flooded with water. Excess cement was removed, and the restoration was smoothed and contoured using aluminum oxide disks (Sof-Lex, 3M Dental Products, St Paul, MN 55144) and water coolant. After finishing, each specimen was immediately placed into water. Typical repaired castings in Figures 1-3 illustrate the different appearance of the three materials.

After being stored in water for at least 72 hours, the specimens were thermocycled for 2500 cycles at temperatures of 10 and 50 °C. Replicas were made and viewed under a scanning electron microscope at various magnifications to compare their micromorphology and margin adaptation.

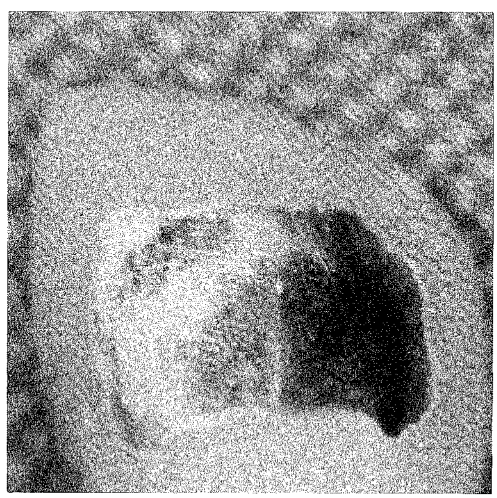

FIG 1. *Typical gold inlay used in this investigation. The cervical margin has been repaired with a traditional tooth-colored glass-ionomer cement (Ketac-fil).*

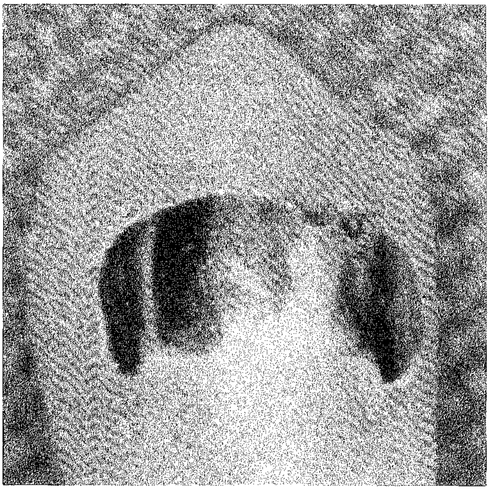

FIG 2. *Typical gold inlay repaired with a glass cermet glass-ionomer cement (Chelon Silver)*

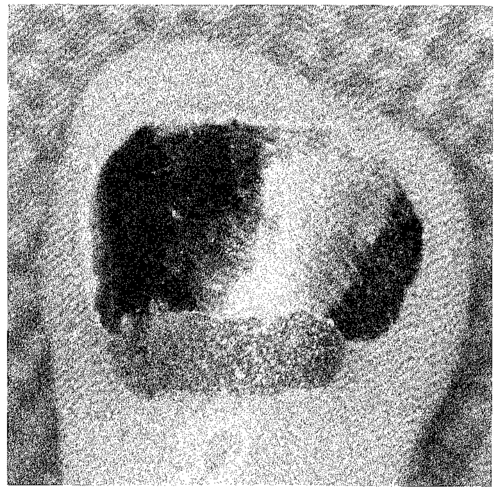

FIG 3. *Typical gold inlay repaired with a silver-alloy-filled glass-ionomer cement (Miracle Mix, Fuji II + LumiAlloy)*

RESULTS

The adaptation of the glass-ionomer repair to the gold casting appeared consistent regardless of the brand of cement. There were visible differences in the surface micromorphology of the different cements. Figure 4 shows a typical inlay/Ketac margin; Figure 5, inlay/Chelon Silver; and Figure 6, inlay/Fuji-LumiAlloy. These can be compared to similar repairs of inlay/resin, Figure 7; inlay/amalgam, Figure 8; and inlay/direct gold, Figure 9. In all photographs, the cast gold is at the top and the repair material is toward the bottom.

DISCUSSION

Adaptation

All of the glass-ionomer repairs appeared to remain well-adapted to the gold casting after thermocycling. This close adaptation was very consistent between specimens, both within groups and between different groups. The adaptation of all the glass-ionomer cements was superior to that seen for amalgam and resin in our previous study (Carlson & others, 1986). The adaptation of the direct gold was found to be equal to or better than that found for any other material.

Surface Characteristics

Without magnification the surface of the Ketac-fil repairs appeared even and uniform (Fig 1). Under the high magnification used with the SEM, the surface appeared quite rough and irregular. Clinical use of this material in cervical erosion lesions has shown that it is not prone to more stain or plaque accumulation than other tooth-colored materials, in spite of its microscopic roughness (Matis & others, 1988).

The silver-containing glass-ionomer cements were more variable in their surface micromorphology than the Ketac-fil. Typical surfaces are shown in Figures 5 and 6, although viewing adjacent locations revealed areas that were alternatively more rough or more smooth than those illustrated. Without magnification, the Chelon Silver repairs (Fig 2) appeared smooth and of a uniformly light silver color, much like a fresh amalgam. The Fuji-LumiAlloy repairs (Fig 3) appeared very dark gray and speckled. None of the cements appeared to change appreciably as a result of contact with the cast gold inlay during storage or thermocycling.

CONCLUSIONS

Based on SEM analysis of micromorphology and margin adaptation, three formulations of

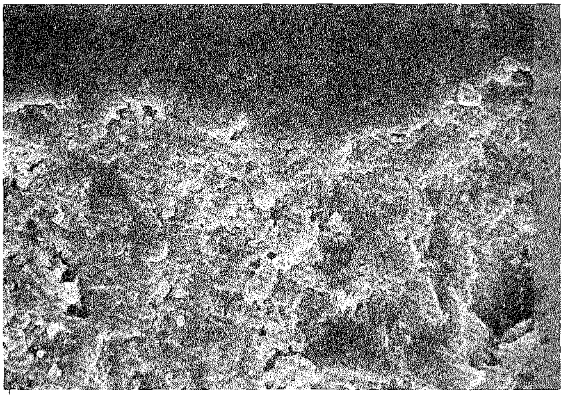

FIG 4. *Scanning electron micrograph of a typical interface between the casting (top) and Ketac-fil (magnification X800)*

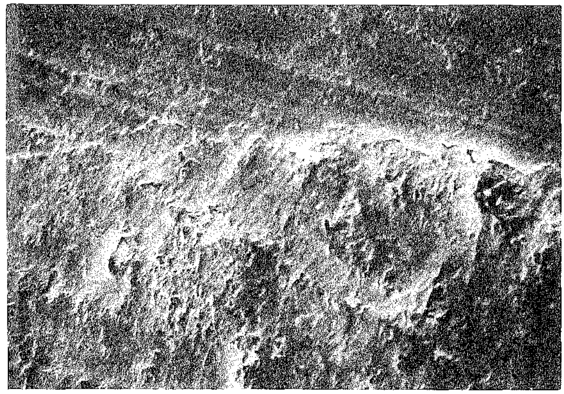

FIG 5. *Scanning electron micrograph of the casting/Chelon Silver interface (magnification X800)*

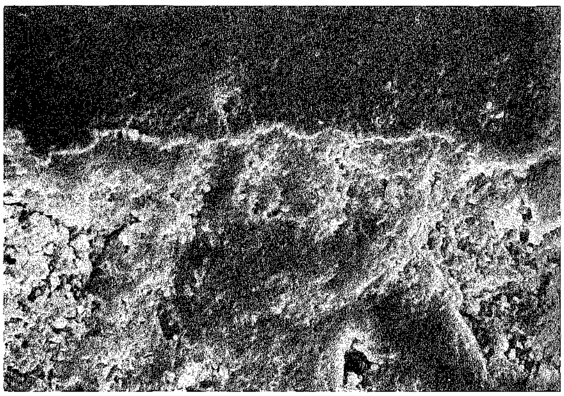

FIG 6. *Scanning electron micrograph of the casting/Fuji-LumiAlloy interface (magnification X800)*

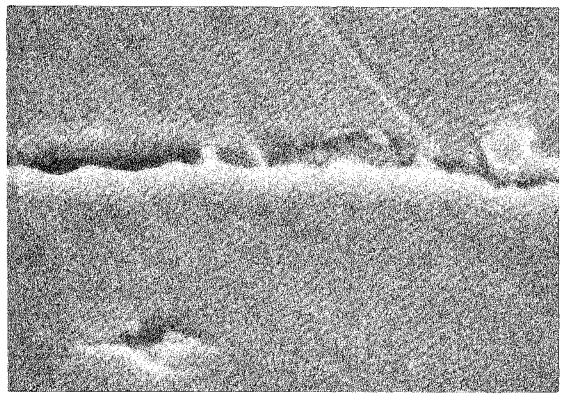

FIG 7. *Scanning electron micrograph of the typical gap formed between the casting and resin (magnification X800)*

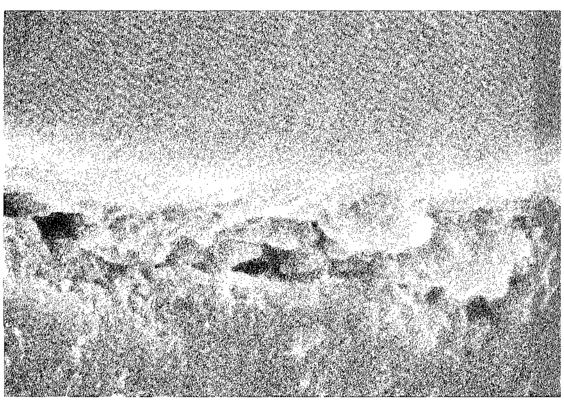

FIG 8. *Scanning electron micrograph of the casting/amalgam interface. A gap is formed, but is filled with corrosion products. (magnification X1000)*

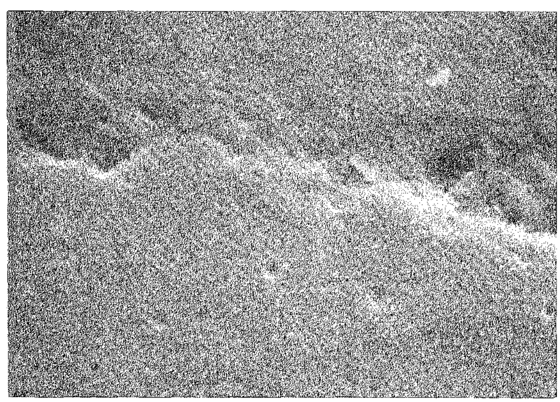

FIG 9. *Scanning electron micrograph of the casting/direct gold interface (magnification X1000)*

glass-ionomer cement were assessed for their usefulness as margin repair materials for cast restorations. This information was compared to that previously found for amalgam, resin, and direct gold. Recommendations on the selection of a direct repair material for cast gold restorations are:

1. All of the glass-ionomer cements investigated here appear to maintain tight adaptation to gold castings, and may be considered satisfactory repair materials in selected cases. Good access and isolation are important in order to maximize the adhesion of the cement to the tooth structure.
2. If esthetics are a concern, a tooth-colored glass-ionomer cement is appropriate, and is superior to a resin repair, which leaves a gap at the casting interface as a result of polymerization shrinkage.
3. Glass-ionomer cement is the material of choice if the margin defect is the result of abrasion/erosion and the operator desires a repair which does not necessitate preparing the tooth to provide retention for a traditional metallic restoration.
4. If the repair is located subgingivally, consideration should be given to using a polishable restoration such as direct gold or amalgam, rather than glass ionomer.
5. Based on a comparison of these data with that from our previous study (Carlson & others, 1986), the authors believe that direct gold is the material of choice for casting repair because of its adaptability, similar composition, polishability, and documented longevity. The exceptions to using direct gold are related to concerns for esthetics and the lack of convenience to make appropriate preparations. Access and isolation requirements are almost identical for direct gold and glass-ionomer cement when bonding to dentin is expected.

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Contraction Patterns in Cavities Tested with Two Dentin Bonding Agents

G SOH • L J HENDERSON

Summary

Differences in microleakage at occlusal and cervical margins have been attributed to variations in the microstructure of enamel. The lack of homogeneity in dentin may have similar influences on the effectiveness of composite bonding. This study examined marginal contraction gaps occurring at the occlusal, cervical, mesial, and distal margins of dentin cavities restored with a composite restorative material, with and without the use of dentin bonding agents. Results showed that marginal contraction gaps at the dentin-restoration interface among the four sites in both treated and untreated cavities are not statistically different in size. Adhesion of composite restorative materials to dentin is not affected by the location of the margins.

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Introduction

The advent of acid-etching opens up new possibilities for adhesive dentistry. The effectiveness of bonding resins to acid-etched enamel has long been recognized and practiced universally in composite restorations (Buonocore, 1955). Adequate adhesion between tooth structure and restorative materials not only enables conservative tooth preparations but also reduces microleakage at the tooth-restoration interface. While acid etching has resulted in significant reduction in microleakage at the interface between enamel and restoration, similar successes with dentin interface is not only inconsistent but also limited (Hembree & Andrews, 1978; Fuks, Hirschfeld & Grajower, 1985; Crim, 1989; Tjan, Dunn & Sanderson, 1989). Bonding of restorative materials to dentin has always posed a greater challenge because of the presence of a smear layer after tooth preparation, and the lower inorganic content of dentin compared to enamel (Munksgaard, Itoh & Jorgensen, 1985c).

Tests in vitro have shown that the use of dentin bonding agents improves adhesion of composite restorative materials to dentin (Munksgaard, Hansen & Asmussen, 1984; Munksgaard & Asmussen, 1984; Munksgaard & others, 1985c; Munksgaard & others, 1985b; Munksgaard & Irie, 1987). Two of the commonly used dentin bonding formulations are either halophosphorous esters of bisphenyl A glycidyl methacrylate (BISGMA) which bonds chemically with the calcium in dentin (Setcos, 1988), or aqueous solutions of glutaraldehyde and B hydroxyl-ethylmethacrylate (HEMA) which bond with the collagen in dentin (Asmussen, 1985; Setcos, 1988; Robinson & Moore, 1988). The most efficacious ratio of the mixture was found to be 5/35/60 (5% weight/volume of glutaraldehyde, 35% weight/volume of HEMA, and 60% weight/volume of water) (Munksgaard & Asmussen, 1984; Chantler, Bishop & Henderson, 1985). Attempts have been made to improve the bonding of dentin adhesives by pretreatment of dentin (Cooper & others, 1986; Asmussen & Bowen, 1987), by varying the types and ratios of aldehydes and monomers used (Asmussen & Munksgaard, 1985), and also by combining dentin adhesives of similar basic formulations (Munksgaard & others, 1985c).

Previous studies that assessed bonding of restorative materials to either enamel or dentin have shown that none of the bonding systems provided consistent, leak-free restorations (Hembree & Andrews, 1978; Hembree, 1984; Fuks & others, 1985; Finger & Ohsawa, 1987). Differences in bond strength and ability to inhibit microleakages have been attributed to variations in tooth structure. Microleakage studies involving cavities with margins on enamel showed that marginal leakage was more pronounced at the cervical margins than at the occlusal margins of restored cavities (Crim & Mattingly, 1980; Retief, Woods & Johnson, 1982). Structural differences in the thickness of enamel and orientation of enamel prisms have been postulated as being contributory to greater microleakage occurring at cervical margins (Retief & others, 1982; Tjan & others, 1989). Similarly, the structure and histochemical composition of dentin may also vary according to the type of tooth, location, and depth of dentin from the surface (Scott & Symons, 1974; Jansen van Rensburg, 1986).

The lack of homogeneity of dentin may also vary effectiveness of bonding restorative materials to dentin at different regions of a tooth. The increased emphasis on, and utilization of, esthetic techniques such as composite and porcelain veneers will invariably result in margins of tooth preparations on dentin. The purpose of this study in vitro was firstly to identify the contraction pattern of restored butt-joint cavities prepared in dentin at the cementoenamel junction and, secondly, to establish the influence of dentin bonding agents on the contraction pattern of such cavities.

Materials and Methods

The study was carried out using extracted human teeth. After extraction the teeth were stored in isotonic saline solution at 37±1 °C and kept moist at all times during surface and cavity preparations. The teeth were mechanically cleaned and flattened on the buccal surfaces using wet carborundum paper to a final coarseness grade of 600. A total of 150 cylindrical cavities each measuring approximately 2.0 mm in diameter and 1.5 mm in depth were prepared entirely in dentin at the region of the cementoenamel junction, and then randomly assigned to three groups of 50 cavities each. Cavities in the control group were restored with an intermediate resin (Heliobond, Vivadent, Schaan, Liechtenstein) and composite restorative material (Heliomolar, Vivadent) according to the manufacturer's instructions. The experimental HEMA-based dentin adhesive was applied to the air-dried cavities in the second group for five seconds prior to air drying and restoring with the intermediate resin and composite restorative material similar to those cavities in the control group (Experimental Adhesive/Heliobond/Heliomolar). In the third group, the cavities were treated with the BISGMA-based dentin adhesive (Prisma Universal Bond, L D Caulk Co, Milford, DE 19963) according to the manufacturer's instructions and restored with the composite restorative material (Prisma Universal Bond/Heliomolar). For all treatment groups, a plastic instrument was used to improve adaptation of the composite restorative material to the cavity walls. The slightly overfilled cavities were placed against a celluloid matrix strip on a thin glass slab and held in place with finger pressure. The composite restorative material was cured through the thin glass slab for 20 seconds by means of an Elipar Visio-light system (ESPE, Seefeld/Oberbay, West Germany). The slab was removed and the restorations cured for another 20 seconds through the celluloid matrix strip. After restoration, the specimens were placed back in normal saline and further preparation was not undertaken until at least 15 minutes after polymerization.

Excess composite restorative material was removed by wet grinding on carborundum paper (grade 220) followed by six 20-cm strokes each on carborundum paper grades 320, 400, and 600. The specimens were left in isotonic saline solution for 24 hours before being subjected to 200 thermocycles between 5 °C and 55 °C with a dwell-time of 30 seconds prior to the measurement of the contraction gaps. A Nikon Measurescope Model II (Nikon KK, Tokyo, Japan) was used to measure the vertical and horizontal diameters of each restored cavity. The largest contraction gaps occurring between the cavity wall and the composite material at the occlusal, cervical, mesial, and distal quadrants of each restored cavity were also measured (Figs 1-3). Measurement of contraction gaps was made by means of a Nikon Metaphot Series V microscope connected to a video camera and Colorado Video Micrometer 305 (Colorado Video Inc, Boulder, CO 80301), with the resulting image projected onto a high-resolution television monitor. The gaps between the cavity wall and the composite material were expressed as a percentage of the cavity diameter, thus giving four measurement values reflecting contraction gaps recorded at each of the quadrants for each restored cavity.

Results

The overall mean contraction gap was derived for each treatment group by averaging the total contraction values over the total number of measurements made. Generally, cavities treated with dentin bonding agents achieved lower overall mean contraction gaps than those in the control

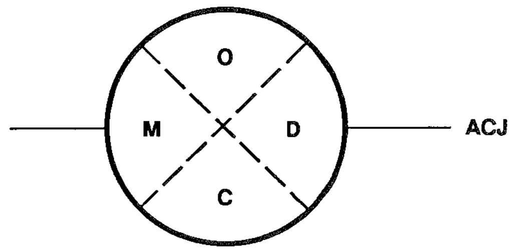

FIG 1. *Largest contraction gaps on the occlusal (O), distal (D), cervical (C), and mesial (M) quadrants were measured.*

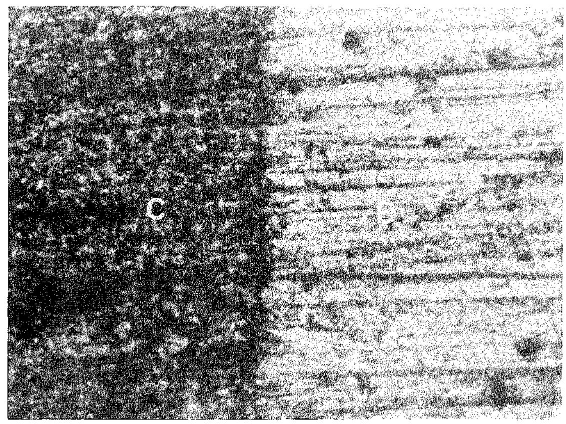

FIG 2. *Distal quadrant of a specimen with no contraction gap between composite restorative material (C) and dentin (D). (Magnification approximately X288)*

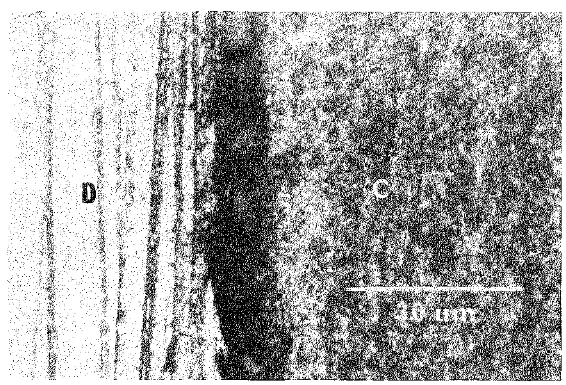

FIG 3. *Mesial quadrant of a specimen with a 10 μm contraction gap between composite restorative material (C) and dentin (D). (Magnification approximately X256)*

group (Table 1); however, only cavities treated with Prisma Universal Bond registered significantly lower overall mean contraction gaps ($P \leq .05$) compared to cavities in the control group as analyzed by Student's *t*-test. Between the two groups of cavities treated with dentin bonding agents, those treated with Prisma Universal Bond presented with lower overall mean contraction gaps than those in the experimental HEMA-based group, but the difference is not statistically significant (Table 1).The resultant contraction gaps at the tooth-restoration interface were also analyzed for each of the quadrants. Mean contraction gaps by quadrant were calculated by averaging the measurement values made for each of the quadrants (occlusal, cervical, mesial, and distal) in each of the treatment groups (Table 2). The mean contraction values for the quadrants in all the treatment groups neither varied markedly in size nor showed any consistent pattern. Tukey's studentized range test showed that differences in mean contraction gaps among quadrants (within treatment groups) were not statistically significant.

Table 1. Comparison of Overall Mean Contraction Gaps among Treatment Groups

Treatment	N	Mean Contraction Gap	SD	Test of Significance
Heliobond/Heliomolar	200	0.159	0.184	*
Prisma Universal Bond/ Heliomolar	200	0.117	0.154	*
Experimental Adhesive/ Heliobond/Heliomolar	200	0.151	0.158	

*Mean contraction gaps between Heliobond/Heliomolar and Prisma Universal Bond/Heliomolar tested statistically significant ($P < 0.05$) as analyzed by Student's *t*-test

Discussion

Studies in vitro testing the effectiveness of dentin bonding agents have used shear (Causton, 1984; Munksgaard, Irie & Asmussen, 1985a) and tensile bond strength (Asmussen & Bowen, 1986; Smith & Rose, 1986), and microleakage (Ebright, Duka & Norling, 1985; Fuks & others, 1985) as the basis of assessment. The measurement of marginal contraction gaps has also been used for this purpose (Jorgensen & others, 1985; Hansen, 1986). The results have been highly variable regardless of the method of assessment employed. This study found that dentin cavities treated with dentin bonding agents generally presented with smaller contraction gaps at the tooth-restoration interface. No consistent pattern in the size of contraction gaps was evident among quadrants in all treatment groups.

Experiments involving the use of restorative components applied in

Table 2. Comparison of Mean Contraction Gaps among Quadrants for Each Treatment Group

Treatment	Percent Mean Contraction Gap* (Mean + SD)			
	Occlusal	Cervical	Mesial	Distal
Heliobond/Heliomolar	0.171 (0.171)	0.140 (0.211)	0.170 (0.163)	0.153 (0.190)
Prisma Universal Bond/ Heliomolar	0.126 (0.186)	0.120 (0.162)	0.119 (0.146)	0.101 (0.120)
Experimental Adhesive/ Heliobond/Heliomolar	0.120 (0.133)	0.165 (0.185)	0.160 (0.166)	0.158 (0.142)

*Differences in mean contraction gaps among quadrants within each treatment group tested not statistically significant by Tukey's studentized range test.

multiple stages are prone to the influences of extraneous factors. In this study, only one composite restorative material was used because differences in the filler content (Asmussen, 1985), coefficient of thermal expansion (Hembree, 1984), and viscosity (Hansen, 1986; Crim, 1989) could influence the extent of microleakage. Similarly, possible influences from the volume of restorative material used (Hansen & Asmussen, 1985a; Hansen & Asmussen, 1985b) and cavosurface configuration (Crim & Mattingly, 1980) were minimized by limiting the investigation to only butt-joint dentin cavities of similar dimensions. Despite having taken such precautionary measures, variations in the size of contraction gaps among specimens belonging to the same subgroup were high. The high standard deviation values can be attributed to experimental variables such as time-interval differences between stages (Fuks & others, 1985; Fusayama & Kohno, 1989), storage time (Henderson, Chantler & Soh, 1989), dryness of cavity walls (Fusayama & Kohno, 1989), thickness of the dentin bonding agent (Fuks & others, 1985), and possibly to operator variability in preparation and measurement.

The structure and composition of enamel have been found to vary according to regions on the tooth (Gwinnett, 1967). Increased tendency for microleakage to occur on enamel cervical margins has been attributed to the dimension and orientation of the enamel prisms (Retief & others, 1982; Tjan & others, 1989). Deviations in the microstructure of dentin at various locations of the tooth have also been identified (Scott & Symons, 1974). The main feature distinguishing between various regions of dentin is the difference in fiber dimension and orientation. For instance, interglobular dentin is most common in coronal dentin while branching dentinal tubules present more commonly in the root dentin. Apparently, this study found that the possible lack of dentin homogeneity did not seem to affect the size and pattern of marginal contraction gaps occurring at the dentin-restoration interface.

Conclusions

The use of dentin bonding agents did not eliminate marginal contraction gaps in dentin cavities placed at the level of the cementoenamel junction. The contraction pattern of marginal contraction gaps as determined by size was quite uniform among occlusal, cervical, mesial, and distal margins of restored cavities in all treatment groups. Dentin bonding agents used in this study reduced the size of marginal contraction gaps but did not influence the contraction pattern. Adhesion of composite restorative materials to dentin is not affected by the location of the cavity margins.

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Effect of Dentinal Pretreatment on Bond Strength between Glass-Ionomer Cement and Dentin

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G WIECZKOWSKI, JR • L PIERCE

Summary

Removal of the dentinal smear layer prior to placement of glass-ionomer cement is thought to maximize the strength of glass-ionomer cement/dentin bonding. This study evaluated the effect of three polyacrylic acid pretreatments on bond shear strength between glass-ionomer cement and dentin. Extracted human molars were divided into four groups of 30 specimens each. One group (the control) received no pretreatment. Specimens in the remaining groups were pretreated with one of three commercially available polyacrylic acid conditioners, used according to the manufacturers' recommendations. The results indicated significant differences in shear strength among pretreatment conditions. Since the manufacturers' recommendations varied, it is not clear if these results were due to differences in polyacrylic acid concentration or to other factors, such as application time or placement procedure.

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INTRODUCTION

Glass-ionomer cements have come into widespread acceptance in dentistry, and interest has focused on their use in conjunction with composite resins. They are among the few materials that bond chemically to tooth structure (Wilson & Kent, 1972). In addition, after they have been allowed to set they can be acid-etched to provide an irregular surface to which a composite resin can be mechanically locked (McLean & others, 1985). This provides the clinician with an effective tool for dealing with two common problems in dentistry: root surface caries and reinforcement of weakened tooth structure.

One of the major problems in the restoration of root surface defects is obtaining sufficient retention. Because of tooth contour and the nature of these defects, it is frequently necessary to remove a considerable amount of sound tooth structure in order to develop the cavity form necessary to retain a restorative material mechanically. The use of glass-ionomer cement followed by acid-etching and placement of a composite resin makes possible the restoration of these problematic defects with minimal removal of tooth structure.

The chemical bonding of the restorative system to the entire dentinal surface of a class 2 cavity preparation provides for the potential to reinforce or strengthen tooth structure that has been weakened as a result of caries or trauma (Joynt & others, 1987; Morin, DeLong & Douglas, 1984). When used with a posterior composite resin, the potential exists to "tie together" weakened cusps, rendering the restored tooth more resistant to fracture.

Removal of the dentinal smear layer is considered a necessary first step prior to placement of a glass-ionomer cement, in order to maximize the strength of the glass-ionomer/dentin bond (Powis & others, 1982; Duke, Phillips & Blumershine, 1985). The first widely used product for this purpose was the liquid portion of Durelon cement (ESPE/Premier, Norristown, PA 19404), which is a 40% solution of polyacrylic acid.

Manufacturers are now marketing products specifically designed as smear layer removal agents. These are typically reduced concentrations (10% to 25%) of polyacrylic acid, which are intended to clean the dentinal surface without removing the smear layer debris that plugs the dentinal tubules. This is thought to provide an extra measure of protection by preventing direct contact of restorative materials with pulpal tissue. While glass-ionomer cements have generally been found to be biocompatible, there have been reports of postoperative sensitivity associated with their use as cementing agents (Council on Dental Materials, Instruments, and Equipment, 1984).

The need to remove the smear layer has been called into question recently with the introduction of a new glass-ionomer cement base material (3M Glass Ionomer, 3M Dental Products, St Paul, MN 55144). The manufacturer recommends that the smear layer be left in place, and reports higher bond strengths when no dentinal pretreatment is used.

The purpose of this study was to evaluate the effect of various dentinal pretreatments on the strength and durability of the bond formed between glass-ionomer cement bases and dentin.

MATERIALS AND METHODS

Three glass-ionomer cements (Ketac-Bond, ESPE/Premier; G-C Lining Cement, G-C International Corp, Scottsdale, AZ 85260; and 3M Glass Ionomer) used in conjunction with a posterior composite resin were studied. Four pretreatment conditions were included: no pretreatment, or pretreatment with Durelon liquid, Ketac-Conditioner (ESPE/Premier), or G-C Dentin Conditioner. Durelon liquid is a 40% solution of polyacrylic acid, whereas Ketac-Conditioner contains 25% and G-C Dentin Conditioner contains 10% polyacrylic acid. All materials were used according to manufacturers' recommendations when provided.

Preparation

Extracted molar teeth were immediately placed in a solution of phosphate buffered saline containing an antibiotic-antimycotic agent (Gibco Laboratories, Grand Island, NY 14072). They were pumiced and scaled and then stored in deionized water. Only those teeth that were free of caries were retained. Teeth were removed from water only long enough to complete required procedures.

The occlusal surfaces of 120 molar teeth were reduced on a dental model trimmer so that the occlusal enamel and all remnants of the occlusal groove pattern were removed. This created a flat surface of dentin perpendicular to the long axis of the tooth. The flattened dentinal surface was centered against the base of a cylindrical break-apart form (Sampl-Kup, Buehler Ltd, Evanston, IL 60204) and a bead of wax was placed against the base of the form and around the full periphery of the reduced occlusal surface. A loose mix of autopolymerizing tray resin was used to fill the mold, embedding the tooth (Fig 1). Following preliminary set of the resin, the mold was submerged in cool deionized water to dissipate the heat of reaction. After several hours in water, the specimens were separated from the molds and readied for glass-ionomer cement placement.

The dentinal portion of reduced surfaces of all specimens was further prepared to a uniform smoothness using the side of a #56 bur in a conventional-speed handpiece, thoroughly rinsed with water, and dried with a stream of oil-free air. Prior to placement of glass-ionomer cement, specimens were divided into four dentinal pretreatment groups of 30 specimens each: a) no pretreatment; b) Durelon liquid; c) Ketac-Conditioner; and d) G-C Dentin Conditioner. Ketac-Conditioner was placed with a cotton pellet, followed by 10 seconds of passive contact and a rinse with water. G-C Dentin Conditioner was applied with a cotton pellet using a scrubbing motion for 20 seconds, followed by a water rinse. Durelon liquid, which has no manufacturer's instructions for use as a dentinal pretreatment, was applied with a cotton pellet and allowed to remain in passive contact for 10 seconds before rinsing with water. All pretreatment group specimens were dried with a stream of oil-free air after rinsing.

All procedures involving the mixing and placement of glass-ionomer cement base were done in a controlled environment chamber maintained at 23 °C (±2 °C) and 50% humidity (±10%). A circular rubber mold, 4.3 mm in diameter, was used to retain the glass-ionomer cement on the prepared dentinal surface.

Specimens in each pretreatment group were further divided into three glass-ionomer groups of 10 specimens each: a) Ketac-Bond; b) G-C Lining Cement; and c) 3M Glass Ionomer. A single application of cement base was first placed in the mold, sufficient to cover the prepared dentinal surface. After four minutes, the surface of the set glass-ionomer cement base was acid-etched for 30 seconds with 37% phosphoric acid gel and rinsed thoroughly with water (Joynt & others, 1989). The surface was then carefully dried with an oil-free stream of compressed air. A layer of Scotchbond (3M) dentinal bonding agent was placed over the etched glass-ionomer base, followed by a layer of P30 posterior composite resin (3M), which was made flush with the superior surface of the mold. The resin was activated with a light-curing unit (PRISMA-LITE, LD Caulk Co, Milford, DE 19963) with an exposure time of 20 seconds. The rubber mold was removed from each specimen following polymerization of the resin. Forty specimens (10 from each pretreatment group) were prepared for each glass-ionomer material.

All specimens were thermocycled to simulate the thermal stresses of the oral environment (Simmons, Barghi & Muscott, 1976; Guzman, Swartz & Phillips, 1969). Prior to thermocycling, a bead of silicone rubber caulk was placed around the periphery of the specimen to protect the dentin, glass ionomer, and resin junctions from moisture. The top surface of the posterior composite resin was left uncovered (Fig 2). Specimens were then stored for 24 hours in a 100%

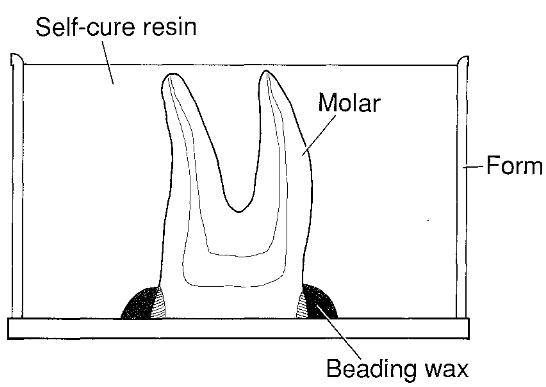

FIG 1. *Prepared molar tooth embedded in self-cure resin form*

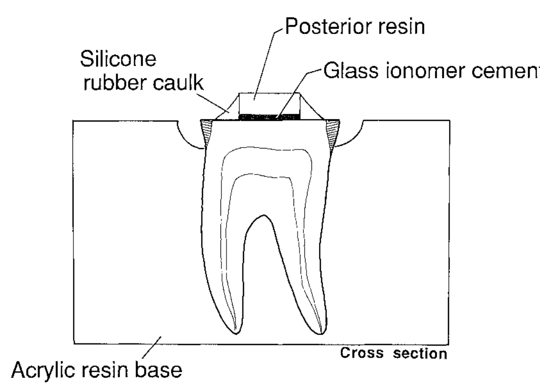

FIG 2. *Specimen prepared for thermal cycling*

humidity environment at 37 °C.

Specimens were subjected to thermal stress by means of three thermally controlled water streams maintained at 4-6 °C, 36-38 °C and 53-55 °C. A complete cycle lasted one minute and consisted of 15 seconds each at 36-38 °C, 53-55 °C, 36-38 °C, and 4-6 °C. All specimens were thermocycled 1800 times.

Testing

Specimens were tested for bond shear strength immediately following thermocycling. The protective silicone seal was removed and the specimen was placed in a positioning jig such that the prepared dentinal surface was parallel to the shearing instrument mounted on the crosshead of the Instron Universal Testing Machine (Instron Corp, Canton, MA 02021). The shearing instrument made contact at the junction of the glass-ionomer cement and prepared dentinal surface (Fig 3). The Instron Universal Testing Machine was operated at a crosshead speed of 0.01 cm/minute, and specimen failure was recorded in kg force to failure.

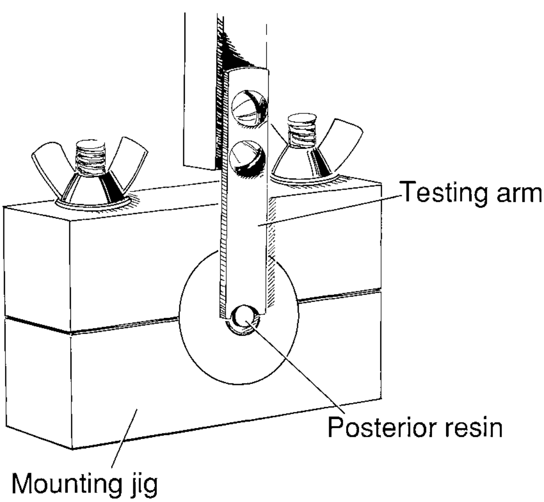

FIG 3. *Jig-mounted specimen before shear testing*

RESULTS

A two-way univariate analysis of variance was used to examine the effects of glass-ionomer material (Ketac-Bond, G-C Lining Cement, 3M Glass Ionomer) and pretreatment (no pretreatment, Durelon liquid, Ketac-Conditioner, G-C Dentin Conditioner) on shear strength of the bond between dentin and glass-ionomer cement. Results (Table 1) indicated significant differences in shear strength among pretreatment conditions ($F_{3,108}$=6.08, $P < .001$). Multiple comparisons among means (Table 2) indicated that G-C Dentin Conditioner provided significantly stronger bonds than both Durelon liquid and no pretreatment ($P < .05$). In addition, Ketac-Conditioner produced bond strengths significantly higher than no pretreatment ($P < .05$), but not significantly different from G-C or Durelon. There were no significant differences among glass-ionomer materials ($F_{2,108}$=1.27, $P > .05$) and no interaction between material and pretreatment ($F_{6,108}$=2.17, $P > .05$).

Table 1. Summary of Analysis of Variance Results

Source	SS	df	MS	F
Material	4.26	2	2.13	1.27
Pretreatment	30.51	3	10.17	6.08*
Material x Pretreatment	21.72	6	3.62	2.17
Residual		108	1.67	
Total		119		

*$P < .001$

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Lesions in Vitro Associated with a Fl-containing Amalgam and a Stannous Fluoride Solution

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Summary

Secondary caries is one of the most important factors leading to replacement of amalgam restorations. This investigation compared the anticariogenic effect of a fluoride-containing amalgam, a stannous fluoride application in the cavity prior to restoration with conventional amalgam, and the combination of the fluoride treatment with the well-recognized technique of cavity varnishing.

Class 5 cavities were prepared in the middle third of both buccal and lingual surfaces of 20 extracted premolars. Conventional amalgam was inserted in 10 cavities (control group). Fluoride-containing amalgam was inserted in 10 cavities (second group). The third group received a treatment of 8% SnF_2 and the fourth group received the SnF_2 and a cavity varnish application before insertion of the conventional amalgam. After 15 weeks in an acid-gel for caries-like lesion formation, the teeth were sectioned longitudinally and examined with polarized light.

The results showed that both fluoride-containing amalgam and conventional amalgam with prior treatment of the cavity with the stannous fluoride solution and varnish had an inhibitory effect on the development of artificial cavity wall caries in vitro.

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Introduction

Unvarnished, freshly packed amalgam restorations leak, and one consequence of this leakage may be the development of secondary caries (Kidd, 1976; Jodaikin, 1981). Fortunately, with time, there is a reduction in microleakage, but in a caries-prone mouth it would be an advantage to increase the resistance of the cavity

CONCLUSION

As indicated in Table 2, there were significant differences in the force required to fracture (shear strength) among the four pretreatment conditions evaluated. It is interesting to note the difference in bond strengths between G-C Dentin Conditioner and Durelon. For all glass-ionomer cement groups, G-C Dentin Conditioner produced significantly higher values. This may be due to differences in either application technique or polyacrylic acid concentration. The manufacturer's instructions call for using G-C Conditioner on dentin for 20 seconds with a scrubbing technique. Both Durelon liquid and Ketac-Conditioner are used passively for 10 seconds. It may be that an active application of dentinal pretreatments is a more efficient method of treating the smear layer. The results observed could also be due to the difference in polyacrylic acid concentration between G-C Dentin Conditioner (10%) and Durelon (40%). Future research will focus on determining the causal factor in these differences. Finally, with the exception of Durelon, pretreatment of the dentin resulted in greater dentinal bond strengths than no pretreatment.

*Table 2. Group and Marginal Mean Kg Force by Material and Pretreatment**

	MATERIAL						
	Ketac-Bond		G-C Lining Cement		3M Glass Ionomer		
PRETREATMENT	mean	sd	mean	sd	mean	sd	Marginal Means
none	1.10	1.43	.95	.64	2.00	1.35	1.35
Durelon liquid	1.57	1.12	2.17	1.08	1.71	1.58	1.82
Ketac-Conditioner	3.08	1.87	1.68	1.50	1.66	1.18	2.14
G-C Dentin Conditioner	3.27	1.13	2.38	1.00	2.55	1.20	2.73
Marginal means	2.25		1.80		1.98		

*n = 10 for each cell

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wall to carious attack.

Secondary carious lesions seem to be one of the most important factors leading to failure of amalgam restorations (Richardson & Boyd, 1973; Dahl & Eriksen, 1978). The considerably lower incidence of secondary caries associated with silicate cements compared to amalgam restorations has been explained by the release of fluoride from the filling material (Laswell, 1967; Forsten, 1976; Dionysopoulos & others, 1988). In order to simulate the anticariogenic properties of silicate cement, fluoride has been incorporated into amalgam (Hurst & von Fraunhoffer, 1978). It has been shown that addition of fluoride to silver amalgam reduces the enamel solubility of tooth structure adjacent to the restorations (Jerman, 1970); however, the addition of fluoride to amalgam has not received universal acceptance because of minor release and low diffusivity of fluoride from the material (Shannon & Miller, 1980; Dionysopoulos & others, 1988).

It has also been shown that stannous fluoride addition to silver amalgam reduced its physical properties (Jerman, 1970; Fazzi, Vieira & Zucas, 1977) and resulted in a notable deterioration of the corrosion-resistance of the amalgam (Stoner, Senti & Gileadi, 1971).

Treatment of the cavity with stannous fluoride solution has been proposed as an alternative to fluoride-containing amalgam. It has been shown that stannous fluoride solution application resulted in a significant reduction of enamel solubility (Lambert, 1970) and an inhibition of caries-like lesion formation (Shannon, Uribe & Wightman, 1973; Nixon, Hembree & McKnight, 1978).

The aim of this study was to compare the rate of caries-like lesion formation in vitro around fluoride-containing amalgam fillings and conventional amalgam fillings, when an 8% stannous fluoride solution was applied to the cavity before insertion of the amalgam restoration. In addition, such treatment was compared with the well-recognized technique of cavity varnishing after the fluoride treatment.

Materials and Methods

Twenty extracted human upper premolars, free of caries and other defects, which had been stored in 10% neutral formalin, were selected and randomly assigned to four groups. The teeth were not allowed to dry during any stage of the experiment. Before use, the teeth were washed in tap water to elute the formalin fixative, and were then cleaned with an aqueous slurry of pumice using a handpiece and rubber cup. For each tooth, one cavity preparation (class 5) was cut in the middle third of both buccal and lingual surfaces. The approximate dimensions of the formed cavity were: 3 mm mesiodistally, 1.5 mm occlusogingivally, and 1.5 mm in depth. A #557 straight fissure carbide bur was used in a high-speed handpiece with water cooling. The bur was always held at a right angle to the tooth surface to produce a cavosurface angle close to 90°. The cavity margins were finished with a flat fissure bur using a slow-speed handpiece. After rinsing with water, the cavities were dried with compressed air. The distribution of the tested restorative materials in the prepared teeth is shown in Table 1.

Table 1. Materials Used in Each Group

Materials	Group	Number of Cavities
Conventional amalgam (Amalcap)	1	10
Fluoride-containing amalgam (Fluor-Alloy)	2	10
Conventional amalgam & stannous fluoride 8%	3	10
Conventional amalgam & stannous fluoride 8% & varnish (Copalite)	4	10

The first group of teeth was used as the control group, and conventional amalgam (Amalcap, Vivadent, Schaan, Liechtenstein) was inserted in 10 cavities without any previous treatment. Fluoride-containing (2.4%) amalgam (Fluor-Alloy, Dentoria SA, Cachan, France) was inserted in 10 freshly prepared cavities of the second group with no other previous treatment. The third group received a topical application of 8% stannous fluoride for one minute, using a cotton pledget before insertion of the conventional amalgam. The fourth group received the same stannous fluoride treatment and an additional application of cavity varnish (Copalite, H J Bosworth Co, Skokie, IL 60076) before insertion of the conventional amalgam. Two layers of cavity varnish were applied to the walls of each cavity, each layer being gently dried with air. The manufacturers' instructions were followed, and the amalgams were condensed by hand instruments. All restored teeth were stored in a humid environment for 24 hours before finishing and polishing the restorations. Amalgam was polished with a bristle brush and aqueous slurry of pumice. The teeth were then subjected to thermal cycling for 400 cycles between 5 °C and 55 °C. Subsequently all the teeth were painted with an acid-resistant varnish except for a 1-mm rim of sound enamel surrounding the restorations. The teeth were then immersed in jars containing an acid-gel for caries-like lesion formation (Kotsanos & others, 1989). The gel contained 10% methylcellulose and 0.1 M lactic acid and the pH was adjusted to 4.5 with potassium.

After 15 weeks the teeth were removed from the acid-gel, rinsed thoroughly with water and sectioned longitudinally through the restorations using a diamond-sectioning saw. The sections were then ground to a thickness of about 80 μm. Three sections were obtained through the middle part of each restoration. After 24 hours of imbibition in water, the sections were examined and photographed in polarized light.

The lesions formed consisted of two parts, outer surface lesion and cavity wall lesion (Fig 1). Measurements were made on the two parts of the lesion using a calibrated eyepiece reticule. The measurements included the depth of the outer lesion as the largest distance between the enamel surface and the inner border of the lesion in water, the depth of the wall lesion as the largest distance between the amalgam restoration and the inner border of the lesion, and the wall lesion extent from the enamel surface to the axial wall of the cavity.

All relative measurements from the three sections of each lesion were averaged, and the data from each group were compared statistically using Student's *t*-test. One examiner did the scoring and was "blind" to the extent of not knowing which were test and which were control specimens.

Results

Figures 2, 3, and 4 show typical lesions produced after a 15-week immersion in acid-gel, consisting of outer surface lesion and cavity wall lesion. Mean thickness of the depth of the body of the lesion for the outer and wall lesions and the wall lesion length are shown in Figure 5 and Table 2.

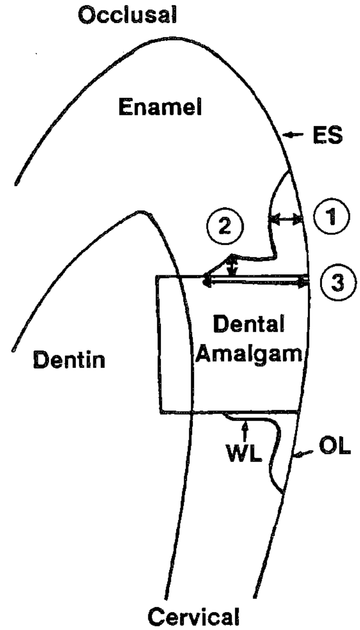

FIG 1. *Schematic representation of various parts of caries-like lesions formed around dental amalgam. The carious lesion consists of a primary outer surface lesion (OL) and a secondary cavity wall lesion (WL). The measurements made on each lesion are: (1) the body depth of the outer surface lesion is measured as the largest distance between the enamel surface (ES) and the inner border of the lesion; (2) the body depth of the wall lesion is measured as the largest distance between the amalgam restoration and the inner border of the lesion; (3) the wall lesion length is measured from the enamel surface to the innermost extended portion of the WL towards the axial wall of the cavity.*

The mean depth of the body of the outer lesion ranged from 181 μm for the fluoride-containing amalgam restorations to 277 μm for the conventional amalgam restorations with stannous fluoride and varnish.

The depth of the body of the outer lesion for teeth restored with fluoride-containing amalgam was significantly smaller ($P < .05$) than the depth of the teeth restored with conventional amalgam and stannous fluoride and with conventional amalgam with stannous fluoride and varnish. There was no significant difference in the depth of the body of the outer lesion among the other

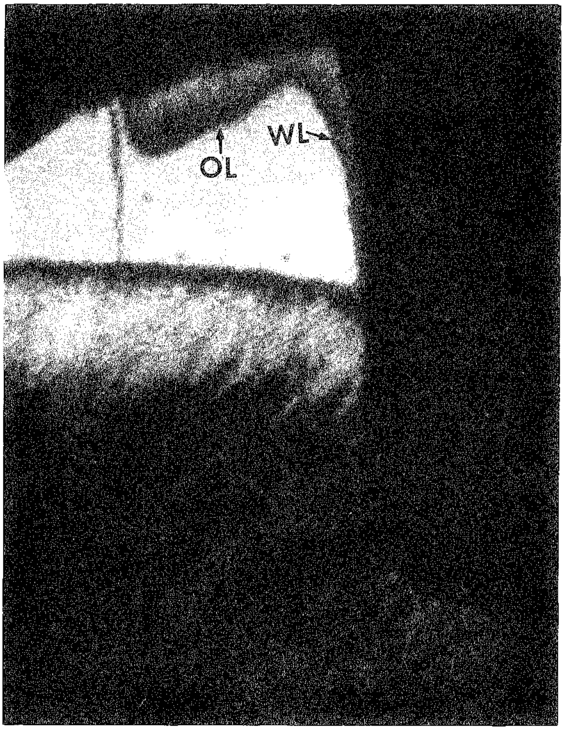

FIG 2. *A typical caries-like lesion formed around a conventional amalgam-restored cavity. It consists of an outer surface lesion (OL) and a cavity wall lesion (WL).*

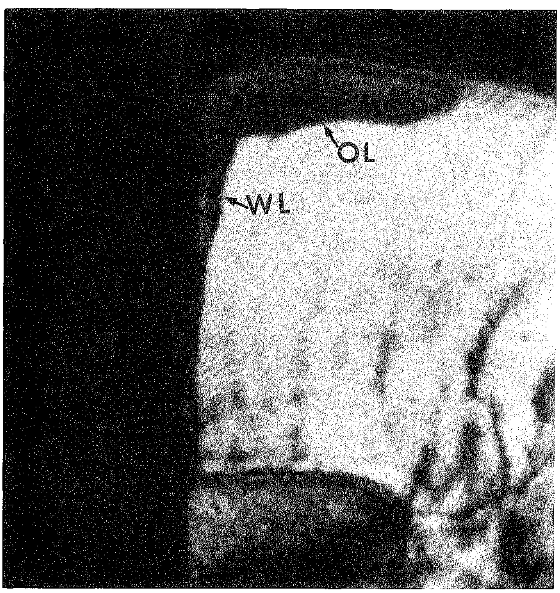

FIG 3. *A typical caries-like lesion formed around a cavity that received a topical application of 8% stannous fluoride before insertion of the conventional amalgam. It consists of an outer surface lesion (OL) and a cavity wall lesion (WL).*

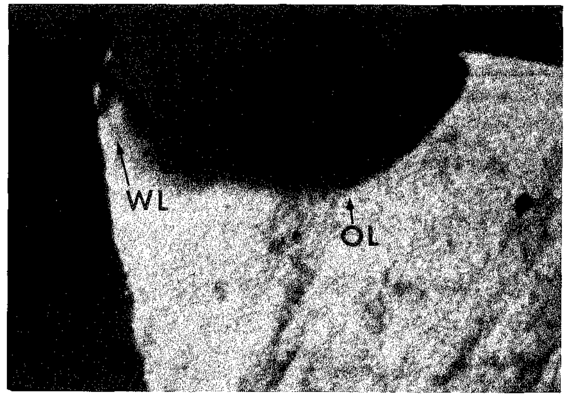

FIG 4. *A typical caries-like lesion formed around a fluoride-containing amalgam-restored cavity. It consists of an outer surface lesion (OL) and a cavity wall lesion (WL).*

groups of teeth.

The mean wall lesion length ranged from 234 μm for the fluoride-containing amalgam restorations to 797 μm for conventional amalgam restorations. The wall lesion length for teeth restored with fluoride-containing amalgams was significantly smaller ($P < .001$) than the teeth restored with conventional amalgam and the teeth restored with conventional amalgam and stannous fluoride. There was no significant difference in wall lesion length among the other groups of teeth.

The mean depth of the body of the wall lesion ranged from 20 μm for the fluoride-containing amalgam to 81 μm for conventional amalgam restorations.

The depth of the body of the wall lesion for the teeth restored with fluoride-containing amalgam was significantly smaller ($P < .001$) than that for the teeth restored with conventional amalgam. It was also significantly smaller ($P < .01$) than the depth for the teeth restored with conventional amalgam and stannous fluoride, and significantly smaller ($P < .001$) than the teeth restored with conventional amalgam, stannous fluoride, and varnish. There was no significant difference in the depth of the body of wall lesions among teeth restored with fluoride-containing amalgam, conventional amalgam with stannous fluoride, and conventional amalgam with stannous fluoride and varnish.

Discussion

The development of secondary caries around restorative materials is determined by the

FIG 5A & B. *Mean measurements in µm of lesions around amalgam restorations of the four test groups. 1. conventional amalgam 2. fluoride-containing amalgam 3. conventional amalgam and stannous flouride 4. conventional amalgam and stannous fluoride and varnish*

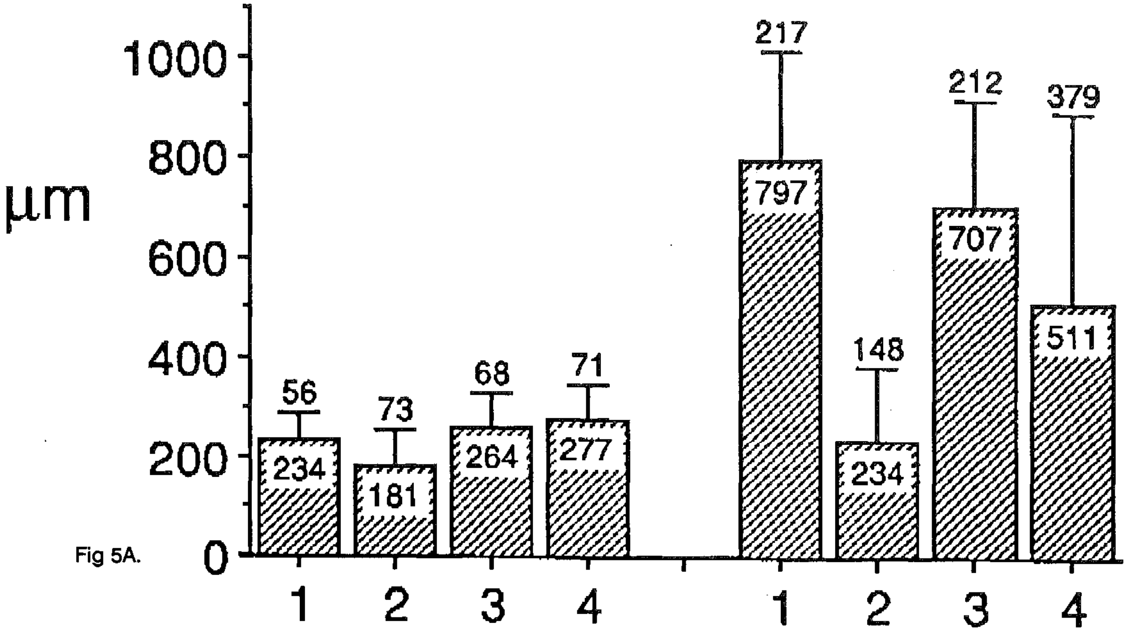

Fig 5A.

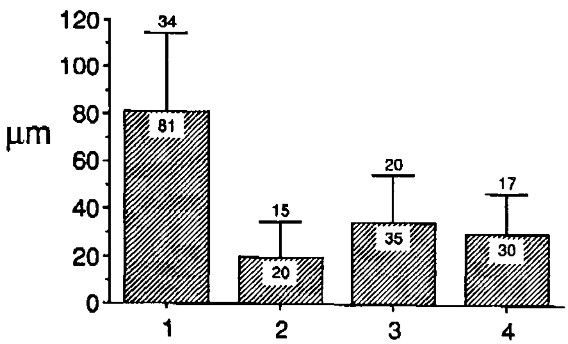

Fig 5B.

physicochemical properties of the materials (for example, shrinkage, corrosion, solubility, fluoride content, and permeability) and their clinical performance (that is, cavity-sealing ability, microleakage of bacteria, fluids, and acidic products, and cavity preparation).

The acidified gel technique is a valuable method for the production of caries-like lesions around restorations, and its histopathology is similar to early secondary natural caries (Hals & Nernaes, 1971; Hals, Hoyer & Bie,1974; Kidd & Silverstone, 1978; Hicks & Silverstone, 1982; Kidd, 1983). The lesion consists of two parts, an outer surface lesion showing the features of primary attack on the enamel surface, and the cavity wall lesion forming as a consequence of microleakage of acidic products from dental plaque or acidified gelatin gel along the enamel-restoration interface.

The technique used in this study is efficient in creating caries-like lesions at rates comparable to those occurring in vivo, and utilizes a gel-medium with organic and inorganic elements which acts as a substitute for the plaque occurring in vivo (Kotsanos & others, 1989).

The results showed that, when compared with a conventional amalgam, the fluoride-containing amalgam had an inhibiting effect on the development of experimental cavity wall lesions in vitro, while the effect on outer lesions was insignificant.

A reduction of the development of lesions in vitro around fluoride-containing fillings as compared to conventional amalgam fillings has also been reported (Heintze & Mornstad, 1980; Tveit & Hals, 1980).

The inhibiting effect on the development of experimental cavity wall lesions around fluoride-containing amalgam fillings reported in this study may be due to fluoride present in the material and/or less marginal leakage around the fillings. The fluoride-containing amalgam in question releases fluoride (Forsten, 1976; Dionysopoulos & others, 1988) and fluoride uptake into enamel and dentin from this material has been measured (Forsten & others, 1976; Le Quang & others, 1976; Tveit & Tötbal, 1981; Tveit & others, 1987). It has been claimed that the incorporation of fluoride into amalgam will have adverse effects on the mechanical properties of the material. The general opinion, however, seems to be that small amounts of fluoride added to amalgams will affect their physical and chemical properties, but not to the extent that it prohibits their use (Tveit & others, 1987). There seems to be no difference in amalgam leakage between conventional amalgams with and without stannous fluoride (Buonocore & Tani, 1968). Consequently, the inhibitory effect observed must be due to the fluoride in the material.

Table 2. Mean (±SD) Measurements (μm) of Lesions around Amalgam Restorations of the Four Test Groups

	Outer Lesion	Wall Lesion	
Restorative Materials	Body Depth	Lesion Length	Body Depth
Conventional amalgam	234 (±56)	797 (±217)***	81 (±34) *** ** ***
Fluoride-containing amalgam	181 (±73) *	234 (±148)***	20 (±15)
Conventional amalgam & stannous fluoride 8%	264 (±68)	707 (±212)	35 (±20)
Conventional amalgam & stannous fluoride 8% & varnish	277° (±71)	511 (±379)	39 (±17)

Number of sections = 40; number of measurements = 80.

* Significant difference by *t*-test $P < .05$

** Significant difference by *t*-test $P < .01$

*** Significant difference by *t*-test $P < .001$

The results also showed that, using a conventional amalgam, treatment of the cavity preparation with the 8% stannous fluoride solution resulted in significantly smaller experimental cavity wall lesions. This finding is in accordance with previous reports by Shannon and others (1973) and Nixon and others (1978).

When the treatment with stannous fluoride was supplemented with the additional treatment with the well-recognized technique of cavity varnishing prior to packing with amalgam, the cavity varnishing did not have any additional statistically significant inhibitory effect to that expected by the stannous fluoride itself on experimental cavity wall lesion development. The inhibitory effect of the stannous fluoride treatment on the development of wall lesions in vitro can be explained by the finding of Tveit and others (1987), that fluoride concentration of adjusted enamel and dentin increases and this is expected to result in reduced solubility and inhibition of caries-like lesion-formation (Lambert, 1970; Shannon & others, 1973).

It is apparent from this study that both fluoride-containing amalgam and stannous fluoride application had an inhibitory effect on the development of lesions in vitro around amalgam fillings; however, more clinical studies are necessary to test whether fluoride-containing amalgam and stannous fluoride application have a significant effect on development of secondary caries and, thus, on the durability of the restoration.

Conclusions

Both fluoride-containing amalgam and conventional amalgam with treatment of the cavity preparation with the 8% stannous fluoride solution had an inhibitory effect on the development of experimental cavity wall lesions in vitro.

There was no significant difference between the fluoride-containing amalgam and the conventional amalgam with treatment of the cavity preparation with the 8% stannous fluoride solution on the inhibitory effect on the development of experimental cavity wall lesions in vitro.

The application of two coats of copalite to the preparation after treatment with fluoride did not significantly alter the inhibitory effect of the fluoride on the development of experimental cavity wall lesions.

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Reducing Microleakage with the Glass-Ionomer/Resin Sandwich Technique

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Summary

The effect on microleakage of two glass-ionomer/resin "sandwich" restorations and an incrementally placed microfilled resin restoration was tested in class 5 preparations extending apical to the cementoenamel junction. There was significantly less leakage detected in the sandwich restorations with microfilled resin placed in one or two increments. These results indicate that a glass-ionomer/microfilled resin sandwich restoration may significantly reduce microleakage in restorations extending below the cementoenamel junction.

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Introduction

Cervical caries and abrasive lesions in anterior teeth often require cosmetic restorations. Filled resins are usually the preferred restorative material. However, when the gingival margin extends beyond the cementoenamel junction, these restorations are susceptible to early failure due to a deficient marginal seal.

Polymerization shrinkage is a problem with filled resin materials (Craig, 1980; Rupp, 1979). Using a three-dimensional model, Davidson, deGee and Feilzer (1984) showed that contraction-stress values can exceed the bond strength of composite resin to dentin. The result is a separation from the cavity wall and marginal microleakage. This problem is evident at gingival margins of class 5 restorations located apical to the cementoenamel junction. Attempts to remedy this situation have met with limited success (Amsberry & others, 1984; Crim, Esposito & Chapman, 1985; Crim & Chapman, 1986b). Theoretically, apical marginal separation is due to the superior resin bond obtained at the occlusal margin when the enamel is acid-etched. Enamel, when present at the cervical margin, is usually thin, aprismatic, and less amenable to bonding. When there is no enamel at the apical margin, a much weaker bond to dentin occurs. When polymerized, the composite resin shrinks

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toward the superior bond at the occlusal margin and away from the weaker bond at the gingival margin (Asmussen, 1975). A cervical gap is thus created with the potential for leakage and fluid percolation. The gap permits the diffusion of ions and molecules such as enzymes and acids, and migration of bacteria along the cavity walls. Previous studies (Heys, Heys & Fitzgerald, 1985) have examined bacterial leakage around filled resin restorations and its potential to cause pulpal inflammation. Bergenholtz and others (1982) found bacteria in the dentinal tubules of monkey teeth restored with composite resins. This leakage can lead to pulpal inflammation, sensitivity, staining, recurrent caries, and eventual failure of the restoration (Crim & Mattingly, 1980; Brännström, 1987; Triadan, 1987).

With the advent of dentinal bonding agents there is new hope that the dentin cervical margin can be sealed. Theoretically, dentinal bonding seals margins below the cementoenamel junction by bonding resin to dentin in the absence of enamel (Crim & others, 1985; Gillette & others, 1984; Braem, Lambrechts & Vanherle, 1986). Limited success has been reported in stopping leakage at the gingival margin.

Attempts have been made to limit the marginal gap by incrementally placing filled resins. The theory of incremental layering is that increments of material built on each other will distribute the polymerization shrinkage throughout the layers. A strong bond between layers of filled resin has been reported (Gordon, von der Lehr & Herrin, 1986). As each increment is placed, it fills in the space lost by shrinkage of the previous increment. The small final increment results in a diminished final force of contraction. A smaller dimensional area and corresponding force is available to pull resin away from the gingival margin. Studies have shown limited success in using the incremental fill technique (Crim & Chapman, 1986a; Leclaire & others, 1988).

Glass-ionomer cements have shown a direct bond to dentin (Chan, Reinhardt & Schulein, 1985; Powis & others, 1982; Coury & others, 1982) and have been used in class 5 restorations (Brandau, Ziemiecki & Charbeneau, 1984; Charbeneau & Bozell, 1979). Decreased leakage at the gingival margin has been reported (Welsh & Hembree, 1985; Cooley & Robbins, 1988). The unesthetic appearance and difficult handling properties of ionomers led to an early lack of popularity. Ionomer's properties of dentinal bonding and fluoride leaching, with subsequent potential for a cariostatic effect, continue to be of interest to restorative dentistry (Mount, 1984).

Recent studies have demonstrated good bond strength between resin systems and glass ionomers (Chin & Tyas, 1986; McLean & others, 1985; Gordon & others, 1986). The successful bonding of ionomer to dentin and of resin to ionomer may reduce gingival margin leakage in a two-layer system, with microfilled resin placed over a glass-ionomer base (Sneed & Looper, 1985). Such systems have been tested with some success (Gordon & others, 1985; Roulet, Rosansky & Berlin, 1986). With proper material manipulation, a microfilled resin-ionomer restoration may significantly decrease gingival margin leakage in class 5 restorations. The microfilled resin improves the surface characteristics found with simple glass-ionomer restorations.

The purpose of this study was to compare leakage at the gingival margin of two glass-ionomer/microfilled resin (sandwich) restorations and an incrementally layered microfilled restoration technique control, as tested by Leclaire & others (1988).

Materials and Methods

Forty-four noncarious, nonfractured extracted human molar teeth were stored in normal saline with 0.2% sodium azide (bactericidal agent). The teeth were rinsed in running distilled water for 15 minutes to remove residual sodium azide. Class 5 cavity preparations were placed on the buccal and lingual surfaces of the teeth with a #37 high-speed friction-grip bur with air-water spray. The preparations were about 1.5 mm deep by 3 x 3 mm square, simulating an ideal cavity preparation. Each preparation was placed so that half was coronal and half apical to the cementoenamel junction. The enamel margins were beveled 1 mm. (The bevel was made after placement of ionomer in the sandwich restorations.) The gingival wall was prepared as a butt joint. A retentive groove was placed at half the depth of the gingival wall with a #33 1/2 high-speed bur. A notch was placed outside the preparation site, alternately across either the buccal or lingual surface, to identify the control side of the tooth.

The dentin of the preparations for the sandwich restorations was conditioned with Durelon liquid (ESPE, Seefeld, West Germany) for 10 seconds and then rinsed with water from an air-water spray for 60 seconds (Gordon & others, 1985). Twenty-two teeth were used for the first group of preparations. In the first experiment, a simple ionomer (Ketac-Bond, ESPE) sandwich was prepared according to the manufacturer's instructions, loaded to the gingival margin, and tapered to the dentinoenamel junction of the occlusal margin (Fig 1A). It was lightly condensed with a plugger to form a slightly concave surface. The ionomer was allowed to set for four minutes free of moisture contamination. The occlusal bevel was placed with a #7803 bur and the enamel etched with 37% phosphoric acid for one minute. The ionomer was etched with the same solution for 15 seconds (Smith, 1988). The

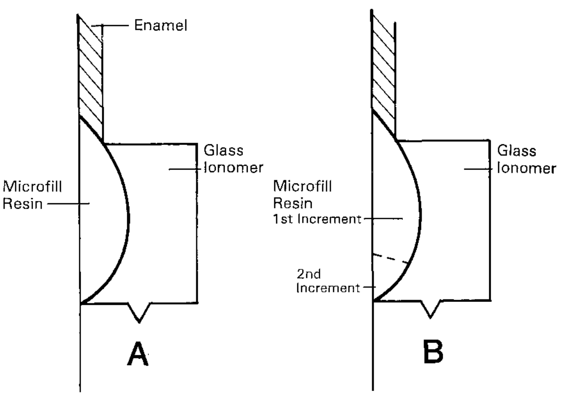

FIG 1. *First (A) and second (B) sandwich preparation techniques*

etched surfaces were rinsed for 40 seconds with water from an air-water syringe and dried for five seconds (Schulein, Chan & Reinhardt, 1986). Visible-light-cured Scotchbond (3M Dental Products, St Paul, MN 55144) was painted on and reduced to minimal thickness with a clean, dry stream of air. The surface was cured with a Command visible-light source (Kerr/Sybron, Romulus, MI 48174) for 20 seconds. Silux (3M) was filled to the remaining margins, and the restoration was light-cured for 60 seconds.

For the second group of sandwich restorations, an incremental resin-ionomer sandwich restoration (Fig 1B) was placed in 22 teeth. The glass ionomer was placed as it was in the first experiment. Silux was placed in two increments (Fig 1B). The first increment was placed at the enamel margin. The second increment filled the cavity preparation to the gingival margin. Each increment of microfilled resin was light-cured for 30 seconds.

The control cavity preparations (notched side of each tooth) were prepared in the same manner as the sandwich preparations. The occlusal bevel was placed, and the enamel was acid-etched for 60 seconds. The etch was rinsed for 40 seconds with water from an air-water syringe and dried for five seconds with compressed air. Visible-light-cured Scotchbond was applied and polymerized in the same manner as for the sandwich restorations. The coronal increment of Silux was placed as shown in Figure 2, and cured for 30 seconds with the Command visible-light source. The remainder of the preparation was filled and light-cured for 30 seconds.

After restoration, the teeth were stored in normal saline at 37 °C for 24 hours. The restorations were finished with graduated Sof-Lex discs (3M) and again stored in normal saline at 37 °C for an additional 14 days.

To simulate clinical aging, the teeth were alternately thermocycled in water for 30 seconds at 5 °C and 55 °C for a total of 400 cycles. Modeling compound was placed at the root apices. With the exception of the restoration and a surrounding 1 mm halo, the teeth were sealed with two

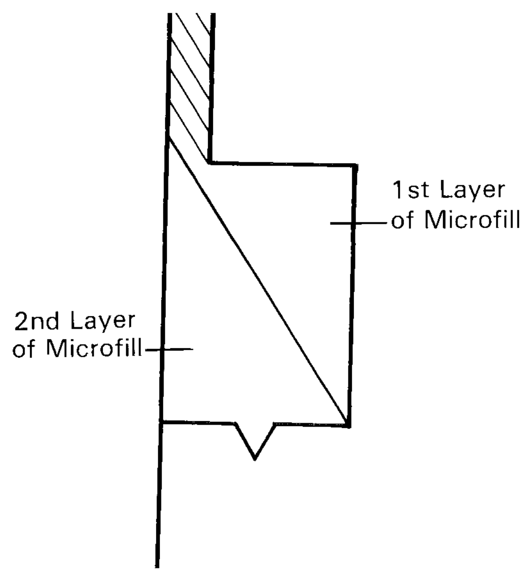

FIG 2. *Control fill technique*

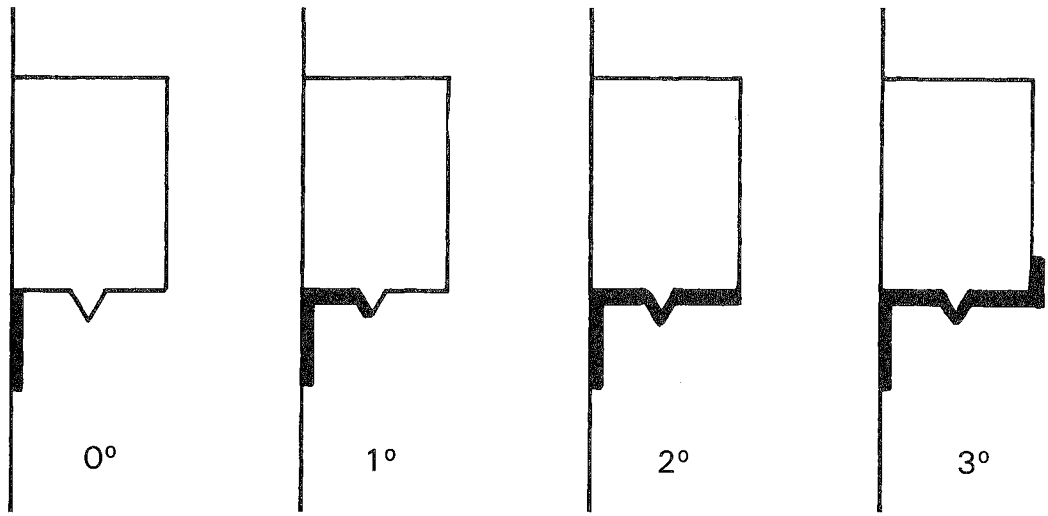

FIG 3. *The degree of microleakage as determined by the extent of penetration of silver nitrate. 0° = no leakage; 1° = penetration of silver nitrate up to the deepest part of the gingival groove; 2° = penetration of silver nitrate beyond the deepest part of the gingival groove, but not to the axial wall; 3° = any penetration of silver nitrate reaching the axial wall.*

coats of fingernail polish. In a dark room, the specimens were immersed in a 50% aqueous solution (by weight) of silver nitrate at 7 °C for two hours. After being rinsed under distilled water for one minute, the teeth were immersed in a petri dish of developing solution (Kodak Mix, Eastman Kodak Co, Rochester, NY 14650). The dish was placed on a lighted view box for one hour to facilitate the precipitation of silver ions. The teeth were rinsed again with distilled water for one minute. Each tooth was placed in an autopolymerizing resin block for sectioning with a diamond saw cutting machine (Bronwill TSM-77, VWR Scientific, San Francisco, CA 94119). The teeth were longitudinally sectioned so that both restorations in each tooth were sectioned with the same cut. Each section was viewed under a dissecting microscope (Bausch & Lomb, Rochester, NY 14604) at X30 magnification, and the sections were scored by two examiners. The degree of microleakage was based on the extent of dye penetration, as shown in Figure 3. If the interexaminer scores were different for the same restoration, the score of greatest die penetration was recorded for that restoration. Statistical comparisons of microleakage results of the control and the experimental groups were made using a 2 x 4 chi-square analysis ($P = .05$).

Results

Microleakage results are shown in the table. The simple and incremental sandwich restorations leaked significantly less ($P < .01$) than the control restorations. There was no significant difference ($P > .05$) between leakage results of the two sandwich techniques.

Microleakage Scores of the Restorative Techniques

Restorative Technique	Degrees of Leakage 0 (# of samples)	1	2	3	Total # of Tooth Sites
Control (no ionomer)	0	12	3	29	44
Simple ionomer sandwich	3	16	1	2	22
Incremental ionomer sandwich	5	16	1	0	22

Bar = statistically equivalent ($P > .05$, chi-square analysis). All comparisons with the control were significant ($P < .05$).

Three of the simple ionomer sandwiches and five of the incremental ionomer sandwiches showed no leakage. There seemed to be a strong distinction in leakage patterns between the sandwich restorations and the controls at the 1° level of leakage. Note that 19 (86%) of the simple ionomer sandwiches and 21 (95%) of the incremental sandwich restorations showed leakage of 0° or 1°. Only 12 (30%) of the microfilled controls showed 0° or 1° leakage and 32 (70%) showed 2° or 3° leakage. Twenty-nine (66%) of the controls showed the most severe leakage of 3°, reaching the axial wall.

Discussion

Although microleakage at the gingival margin was not completely eliminated, it was significantly decreased by both sandwich techniques. These restorations may be more clinically effective than incrementally placed microfilled resins. Leakage in the sandwich restorations generally occurred just beyond the cavosurface margin on the gingival wall (1°). The bond of the resin to the glass ionomer may have been strong enough to separate the ionomer from the dentinal wall at this area. This separation may have been caused by polymerization shrinkage or thermal stress. Leakage probably occurred up to an intact ionomer-dentin bond.

Our findings showed that there is no difference between placing the microfilled portion of the sandwich in one or two increments. Initially, we thought that the incremental layering of resin over glass ionomer might reduce leakage in a manner similar to the reduction of leakage by incremental filling of microfilled resin found by Leclaire & others (1988). There may not have been a great enough difference in surface area of microfilled resin polymerized per cure between the simple sandwich and incremental sandwich to yield a significant difference in microleakage patterns. Although incremental layering is the theoretically preferred technique for filled resin placement, the lack of significant improvement suggests that the additional steps may not be necessary in the sandwich technique.

Since microleakage was not completely eliminated in most of the test restorations, it is also important to consider the anticariogenic properties of the restorative material. Swartz, Phillips and Clark (1984) found continuous fluoride release from the fluorosilica glass of glass ionomers during their one-year study. Wesenberg and Hals (1980) used microradiographic techniques to measure fluoride uptake in dentin up to 80 microns from the restoration-tooth surface. The release of fluoride and its uptake by tooth structure could significantly decrease the potential for secondary caries. In several studies on artificial lesion formation, glass ionomers were found to diminish secondary lesion formation around the cavity walls of restorations (Kidd, 1978; Hicks, 1986; Hicks, Flaitz & Silverstone, 1986). Moline, Chan and Jensen (1988) studied wall-lesion formation in an artificial caries system and discussed the relationship of microleakage to caries formation. They found a significant decrease in lesion formation at the gingival margin in glass-ionomer restorations as compared to filled resins. Filled resins decreased the potential for wall lesions at the enamel margin. These findings may support the use of the sandwich restoration with an enamel margin in filled resin and the bulk of the gingival margin in glass ionomer.

As important as the fluoride activity is, prevention of marginal separation and subsequent microleakage is still a goal of restorative dentistry. Glass-ionomer cements chemically and mechanically bond to dentin. The coefficient of thermal expansion for glass ionomers is similar to that of dentin, which helps to keep the ionomer-dentin bond intact despite thermal stresses. The coefficient of thermal expansion of microfilled resins is quite dissimilar to that of dentin. Thermocycling is used in most studies to test the bond of the filled resin to cavity walls. Hinoura, Moore and Phillips (1986) found a decrease in bond strength of microfilled resin after thermocycling. They found that glass ionomer treated with polyacrylic acid and thermocycled did not have a similar decrease in bond strength. Staninec and others (1986) reported in scanning electron micrograph studies that the gingival margins of class 5 filled resin restorations showed increased gap widths when subjected to colder temperatures. Torstenson and Brännström (1988) looked at the cervical margin of filled composite resin restorations exposed to frozen ice cream. The effect of cold, even for a short time period, showed an increase in cervical marginal gap width when compared to a control at room temperature. Our study tested the limits of the restoration beyond normal temperature exposure. The prolonged exposure to cold evaluated in our research is unlikely to occur intraorally, but is a useful test model of extremes.

Conclusions

The results of this study suggest that:

1. Glass-ionomer/filled resin sandwich restorations decrease the microleakage at the dentin/restoration interface when compared with incremental placement of a filled resin.
2. Thermal cycling, even at extreme temperatures, did not appear to adversely affect the microleakage of the glass ionomer.
3. The reduced microleakage, cariostatic potential, and esthetic benefit of the glass-ionomer/filled resin sandwich technique make it a positive restorative option for the gingival lesion extending below the cementoenamel junction.

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A Sensitivity Study in Vivo: Glass-Ionomer versus Zinc-Phosphate Bases beneath Amalgam Restorations

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Summary

This study in vivo evaluated the sensitivity of class 1 and 2 amalgam restorations which had bases of either zinc phosphate or an admix, silver-reinforced glass ionomer. The evaluation of sensitivity was done by providing the patient with five postcard questionnaires to be mailed to the clinic over a period of time from one to 28 days. Teeth restored with amalgam and silver-reinforced glass ionomer were significantly less sensitive to cold than those restored with amalgam and zinc phosphate.

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Introduction

Silver-reinforced glass-ionomer cements have been developed to improve flexural strength and resistance to abrasion. Formed by the addition of alloy powders or the fusion of silver ions to glass-ionomer powder, these materials have been used clinically for: 1) post-core buildup, 2) restoration of minimal class 1 and class 2 lesions, and 3) base materials under castings, composite, or amalgam restorations (McLean & Gasser, 1985; Simmons, 1983; Swift, 1988). The silver-reinforced glass-ionomer cements also exhibit the same advantages as other non-reinforced glass-ionomer cements, including adhesiveness to tooth structure, fluoride release, and biocompatibility with tooth structure (Mount, 1986).

The purpose of this study was to evaluate and compare patient sensitivity after the insertion of class 1 or 2 amalgam restorations using two different base materials: an ad-mix, silver-reinforced glass-ionomer cement material (Miracle Mix, G-C International Corp, Scottsdale, AZ 85260), and zinc-phosphate cement (Mizzy, Inc, Clifton Forge, VA 24422).

Methods and Materials

Fifty-seven volunteer male and female subjects participated in this study. All subjects were healthy ambulatory individuals with no history of allergies or drug sensitivities. Each subject presented a minimum of two similar unrestored carious class 1 or class 2 lesions located in different quadrants. Only permanent teeth were used; lesions were selected by radiographic examination.

Both lesions were restored under a rubber dam at the same visit; one tooth received the glass-ionomer cement as a base while the other received zinc-phosphate cement as a base. Lesions were randomly assigned to the different base groups prior to excavation. In addition, the sequence of treatment was also randomly assigned. The amalgam Dispersalloy (Johnson & Johnson Dental Products Co, East Windsor, NJ 08520) was used as the final restorative material.

Treatment was performed by one faculty member of the Department of Comprehensive Care and Behavioral Science at New York University College of Dentistry. In all patient treatments, local anesthesia was used only if the patient requested it.

Conventional amalgam preparations were prepared using a #556 carbide bur in a friction-grip high-speed handpiece with water coolant. Decay was removed using round carbide burs at slow speed and spoon excavators. Cavity depth measured a minimum of 3.5 mm pulpally and 2.0 mm to 2.5 mm axially; base thickness measured a minimum of 0.5 mm.

After the removal of decay, the dentin of excavations receiving the glass-ionomer cement base was conditioned (G-C Dentin Conditioner, G-C International Corp) for 15 seconds, and the glass-ionomer cement mixed and placed as recommended by the manufacturer. If a calcium hydroxide liner (L D Caulk, Milford, DE 19963) was used for either base material, it was limited only to the deepest aspect of the preparation. In all cases where zinc-phosphate cement was used as a base, the material was mixed following manufacturer specifications and cavity varnish (Copalite, H J Bosworth Co, Skokie, IL 60076) was placed on dentin surfaces prior to the placement of the material.

After the insertion of the amalgam, the restorations were carved, burnished, and checked for occlusion. Each patient was given five postcard questionnaires (Table 1) to be completed and mailed to the Dental Center after 24 hours, three days, seven days, 14 days, and 28 days.

Results

Two of the 57 patients treated had carious exposures and were not included in the study. Therefore, the study was limited to 55 patients with each patient serving as his or her own control. The results of this study indicate that patients experienced no discomfort on biting with either base material. In all but two patients, where heat caused sensitivity reactions on day 28, sensitivity was limited only to cold stimuli. After day three, restorations utilizing the zinc-phosphate cement as a base were significantly more sensitive to cold than those utilizing the silver-reinforced glass-ionomer cement as a base ($P < .01$, chi-square test) when controlling for

Table 1. Postcard Questionnaire

Date postcard should be mailed ____________

Patient's Name ____________________ Chart # ________

Thank you for participating in this study. Your assistance is greatly appreciated.

	Material Tooth YES	Material Tooth NO	Used Number YES	Used Number NO
1. Do you have any discomfort when biting?	___	___	___	___
2. Do you have any discomfort to cold stimuli?	___	___	___	___
3. Do you have any discomfort to hot stimuli?	___	___	___	___

Comments: ________________________________

individual differences. By day 28, teeth restored with zinc-phosphate cement were still significantly more sensitive compared to those restored with the silver-reinforced glass-ionomer cement ($P < .05$, chi-square test) (Table 2).

No reversals in sensitivity were noted with zinc-phosphate cement. Two patients experienced sensitivity reversals with the silver-reinforced glass-ionomer cement. One patient who was not sensitive on day one noted sensitivity in a tooth restored with this material by day three. This tooth was no longer sensitive by day seven.

The other patient became aware of sensitivity in the tooth restored with the silver-reinforced glass-ionomer cement on day seven. This sensitivity lasted through day 14, and was not noted by day 28.

Discussion

A base material used beneath a permanent restoration should exhibit good compressive strength to withstand the forces of mastication and condensation in placing a restorative material. It should also act as a thermal insulator and protect the pulp from mechanical, chemical, and galvanic stimuli (Draheim, 1988). Over the years, zinc-phosphate cement has become accepted as a standard base material. In recent years, glass-ionomer cements have been formulated to meet these same criteria, with some investigators reporting that these materials cause less inflammatory pulpal response than do the zinc-phosphate cements (Pameijer, Segal & Richardson, 1981; Tobias & others, 1978).

Significant reductions in sensivity to cold were apparent with both materials over the 28 days. The results of this study indicated that restorations placed with the silver-reinforced glass-ionomer cement as a base appear to be significantly less sensitive to cold compared to those restorations utilizing zinc-phosphate cement as a base. Furthermore, sensitivity reactions with restorations using the silver-reinforced glass-ionomer cement as a base decreased at a much faster rate than restorations exhibiting sensitivity with the zinc-phosphate cement base.

It appears that reactions to cold on days one through three may be due to pulpal inflammation, which can result from the trauma of tooth preparation. However, sensitivity to cold from days seven through 28 may be due to a combination of effects: tooth preparation and the base material itself. By day 28, seven patients still exhibited sensitivity to cold in teeth restored using zinc-phosphate cement as a base material. The teeth of two of these patients developed reactions to heat as well. As a result, it appears that by day 28, the zinc-phosphate cement itself may be contributing to pulpal sensitivity. Two patients exhibited delayed sensitivity reactions with the silver-reinforced glass-ionomer cement: one at day three, and the other at day seven. These reversals may have been in response to cavity preparation, and disappeared in both subjects by day 14. No reversals were noted with the zinc-phosphate cement material.

The results of this study indicate that glass-ionomer cements may exhibit improved thermal insulating properties when compared to zinc-phosphate cement. In addition, the known

Table 2. Results of Study from Day 1 to Day 28

Patients Exhibiting Sensitivity to Cold

	Day 1	Day 3	Day 7	Day 14	Day 28
Patients exhibiting sensitivity with both zinc-phosphate cement and silver-reinforced glass-ionomer cement	19	10	2	1	0
Patients exhibiting sensitivity with zinc-phosphate cement but not to silver-reinforced glass-ionomer cement	11	13	16	9	7*
Patients exhibiting sensitivity with silver-reinforced glass-ionomer cement but not to zinc-phosphate cement	3	0	0	0	0
Patients exhibiting no sensitivity with either base material	22	32	37	45	48

*two of the seven patients developed sensitivity to heat biocompatible properties of glass-ionomer cements may also contribute to decreasing pulpal reactions as the material functions as a base under amalgam restorations. However, very few clinical studies of this type have been reported, and continued clinical research is necessary to determine the long-term clinical effects of these newer base materials.

Conclusions

1. Teeth restored with amalgam and zinc-phosphate cement were significantly more sensitive to cold than teeth restored with amalgam and silver-reinforced glass-ionomer cement over the 28 days of this study.
2. Patients experienced no discomfort on biting with either base material.

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DEPARTMENTS

Press Digest

The editor wishes to thank the second year General Dentistry Residents at Wilford Hall USAF Medical Center, Lackland AFB, Texas, for their assistance in the preparation of the following abstracts.

Effect of glass-ionomer base on composite resin hardness. *Berrong, J M, Cooley, R L & Duke, E S (1989) *Dental Materials* 5 38-40.

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The purpose of this investigation was to examine the effect of the glass ionomer/composite resin laminate technique on the hardness of the external composite resin surface. Test specimens were made by curing Silux against Ketac Bond. Teflon rings were fabricated to create specimens of 1 mm, 2 mm, and 3 mm thick. The glass-ionomer base was etched, rinsed, covered with Scotchbond Light Cured Dental Adhesive and then, in turn, with the resin. Control samples of composite resin were made by curing the resin against a plastic block. There was a significant difference in surface hardness between the 1 mm control and the 1 mm test specimens. However, surface hardness values for the 2 mm and 3 mm samples were not significantly different from their controls.

Effect of cigarette smoking on periodontal healing following surgical therapy. *Preber, H & Bergstrom, J (1990) *Journal of Clinical Periodontology* 17 324-328.

(*Department of Periodontology, School of Dentistry, Karolinska Institutet, Box 4064, S-141 04 Huddinge, Sweden)

The influence of cigarette smoking on the reduction of pocket probing depth after periodontal surgical therapy was investigated in 54 patients, 24 of whom smoked. All patients had moderate to severe periodontitis with persisting diseased pockets following nonsurgical therapy. Surgery was performed using the modified Widman flap procedure without osseous resection. Pockets had initial probing depths of 4-6 mm and were reevaluated at 12 months postsurgery. At this evaluation a probing depth reduction of 0.76 mm ± 0.36 mm was seen in smokers and 1.27 mm ± 0.43 mm in nonsmokers. This difference was statistically significant and remained so after multiple regression analysis to account for the effect of plaque. These results suggest that smoking may impair the favorable outcome of surgical periodontal therapy.

Properties of a glass ionomer/resin-composite hybrid material. Mathis, R S & *Ferracane, J L (1989) *Dental Materials* 5 355-358.

(*Baylor College of Dentistry, Department of Dental Materials, 3302 Gaston Avenue, Dallas, TX 75246)

A hybrid glass-ionomer/composite resin restorative material was made by mixing the liquid (87% wt) from a commercial glass-ionomer restorative material (Fuji II) with an experimental resin (13% wt) composed of BISGMA, triethyleneglycol dimethacrylate, camphoroquinone, and dimethylaminoethylmethacrylate and combining this with glass-ionomer powder according to the manufacturer's instructions. Specimens were dual-cured and compared to control specimens of 100% glass ionomer. Results showed good early mechanical properties for the hybrid with significant increases in compressive strength, yield strength, elastic modulus, and fracture toughness, and no difference in tensile strength compared to the glass ionomer at one hour. At 24 hours, the hybrid showed significant increases in tensile strength and elastic modulus, no differences in yield strength and fracture toughness, but a significant decrease in compressive strength compared to the glass ionomer. Adhesion to dentin was similar for both the hybrid and the glass ionomer. Specimens allowed to dry revealed extensive cracking of the pure glass ionomer but no cracking was observed in the hybrid material.

Cracked tooth syndrome: Diagnosis, treatment and correlation between symptoms and post extraction findings. *Ehrmann, E H & Tyas, M J (1990) *Australian Dental Journal* 35 105-112.

(*20 Collins Street, Melbourne, Victoria, 3000)

Cracked tooth syndrome has been defined as an incomplete fracture of the dentin in a vital posterior tooth, and must be distinguished from a split tooth. A diagnosis can often be made by means of the history, and must be confirmed by reproducing the patient's symptoms. The ideal treatment consists of applying a stainless steel band to the tooth, with cessation of symptoms confirming the diagnosis, followed by a full-coverage restoration. Several case histories illustrating the syndrome are presented in this article. There is also one case reported where a cracked tooth syndrome diagnosis was made, the tooth extracted, sectioned, and stained to show the nature of the cracks and their relationship to the pulp.

Clinical considerations of microleakage. *Pashley, D H (1990) *Journal of Endodontics* 16 70-77.

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The purpose of this excellent manuscript was to review the clinical considerations of microleakage concentrating on the anatomical variations of dentin and the potential risks to the pulp from oral fluids via the dentin. There is a section on dentin permeability and a discussion of the regional differences in access to the pulp. The presence or absence of a smear layer can play a significant role in dentin permeability and the increasing number of commercial products designed to remove the smear layer may not be advantageous to the tooth in the long run. There is also a discussion on the clinical measurement of microleakage, including suggested techniques for ruling out microleakage as the source of postoperative discomfort. Even in the chronic presence of microleakage, there is a clinical balance between the rate of infusion of toxic products and the pulp's ability to neutralize them. This, of course, is affected by the health and age of the pulp. Microleakage is a complex phenomenon and this review simply reinforces that fact.

In vivo fractures of endodontically treated posterior teeth restored with amalgam. *Hansen, E K, Asmussen, E & Christiansen, N C (1990) *Endodontics & Dental Traumatology* 6 49-55.

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This retrospective study evaluated the fracture pattern of 1639 endodontically treated posterior teeth. All teeth had MO/DO or MOD amalgam restorations without cuspal coverage. The 20-year survival rate of teeth with MO/DO restorations was markedly higher than those with MOD restorations. The lowest survival rate was found in maxillary premolars with an MOD restoration; 28% of these teeth fractured within three years of endodontic therapy, 57% were lost after 10 years, and 73% after 20 years. The most serious failures, irrespective of restoration type, occurred with the maxillary second molar where 10 of 29 fractures led to extraction. The authors concluded that amalgam, especially in MOD restorations, was an unacceptable material for restoration of endodontically treated posterior teeth if used without cuspal overlays.

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