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GUEST EDITORIAL

Why Operative Dentistry?

JOHN W REINHARDT

Why should anyone be interested in the discipline of operative dentistry? Why read this journal or participate in the activities of the Academy of Operative Dentistry?

Not long ago, some people were ready to give operative dentistry last rites. In 1984, the dental director of the World Health Organization, Dr David Barmes, was quoted as predicting that by the year 2010, we would need only one dentist for every 20,000 people in the US. This prediction was based in part upon the declining caries rate among children, and the projected lack of need for operative dentistry among adults as those children grew up.

We have now reached the halfway marker from 1984 to 2010, and it's obvious that Dr Barmes's prediction was off target. Pediatric dentists (for which, theoretically, there would be very little need) are reportedly quite busy. The number of new dentists graduating from US dental schools is steady, at about one-third fewer than in the early 1980s. The demand for dental treatment is increasing. People are keeping their natural teeth, the US population is growing at a steady rate, and more patients are seeking not just restorative, but also elective esthetic treatment. Even more mature patients are interested in maintaining a natural esthetic smile. The days of elderly persons soaking their teeth in a glass on the nightstand are rapidly disappearing.

In addition to the increasing demand for treatment, advancements in technology are making operative dentistry more exciting and challenging. Improvements in bonding agents, composite resins, and ceramics give us opportunities to provide better treatment. Newer equipment (e g, kinetic cavity preparation devices and erbium-YAG lasers), although not complete replacements for traditional operative instruments, allows us conservative treatment options that cause less discomfort.

Even though new treatment options are available, the need for a sound set of foundation skills has not gone away. In fact, the same patients who expect more services from their dentists are also demanding proof that the treatment they are receiving is technically good. Hands-on training, either through continuing education courses or clinical study clubs, is the best way for practicing dentists to maintain and improve their psychomotor skills. The American Board of Operative Dentistry Certification Program provides an excellent mechanism for demonstrating and documenting a very high skill level in operative dentistry. Demonstrating proficiency through the three-part (written, clinical, and oral) board certification process challenges individuals to grow in knowledge and skill and attests to operative expertise.

As we approach the beginning of a new century, I have noticed a growing awareness among deans of leading US dental schools that the discipline of operative dentistry should not be minimized in the dental curriculum. This is in contrast to the 1980s, when there was a tendency to downplay the importance of the fundamental training upon which further clinical skills were built. In the future, operative dentistry educators will be those with specific advanced training (including graduate degrees) related to the clinical techniques and research methods that apply to both traditional and emerging treatment methods. The operative dentist and operative dental educator of the future need to be continually learning, and those dedicated to practicing the discipline of operative dentistry to its highest level must do the same.

So, why operative dentistry? The answers should be obvious: operative dentistry is needed and wanted by today's patients; operative dentistry is challenging and changing with exciting new treatment options; the fundamental excellence promoted by the Academy and journal, as well as demanded by today's patients, is more important than ever before. Enjoy yourself; it's a great time to be an operative dentist!

JOHN W REINHARDT
President
Academy of Operative Dentistry

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ORIGINAL ARTICLES

Shear Bond Strengths of One-Bottle Dentin Adhesives Using Multiple Applications

E J SWIFT, Jr • A D WILDER, Jr
K N MAY, Jr • S L WADDELL

Clinical Relevance
Multiple applications of one-bottle adhesives had little effect on composite shear bond strength to dentin.

SUMMARY

This study evaluated the effect of multiple applications of the one-bottle adhesives Prime & Bond, One-Step, and Tenure Quik on the shear bond strength of composite to dentin. In addition, the study examined the effects of surface moisture and dual-cure composite on bond strengths of One-Step and Tenure Quik respectively. The adhesive systems were bonded to the occlusal dentin of extracted human teeth. Control group specimens received only two applications of adhesive, as recommended by the manufacturers. Two experimental groups of each system received a greater number of adhesive applications. Additional experimental groups using only two adhesive applications were made to test modifications in surface moisture and composite type for One-Step and Tenure Quik. Shear bond strengths were determined using an Instron Universal Testing Machine. The mean shear bond strength of the Prime & Bond control group was significantly greater than that of the other two control groups. Multiple applications of adhesive decreased the bond strength of each system, but the difference was significant only for four applications of One-Step. The method of moisture removal (compressed air or blotting) had no effect on shear bond strength of One-Step. The shear bond strength of Tenure Quik was not affected by the type of composite used. Prime & Bond had significantly higher shear bond strengths to dentin than either One-Step or Tenure Quik. Both Prime & Bond and One-Step had significantly higher bond strengths than Tenure Quik.

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INTRODUCTION

Three new one-bottle dental adhesives have recently been introduced: Prime & Bond (L D Caulk/Dentsply, Milford, DE 19963), One-Step (Bisco, Inc, Itasca, IL 60143), and Tenure Quik (Den-Mat Corp, Santa Maria, CA 93456). These products are based on the chemistry of the adhesive systems ProBond,

All-Bond 2, and Tenure respectively.

Prime & Bond contains the proprietary adhesion promoter PENTA (dipentaerythritol penta acrylate phosphoric acid ester), a urethane-modified BIS-GMA resin, TEGDMA (triethylene glycol dimethacrylate), and a photoinitiator in acetone. One-Step contains BPDM (biphenyl dimethacrylate), BIS-GMA, HEMA (hydroxyethylmethacrylate), and a photoinitiator in acetone. Tenure Quik contains a dimethacrylate resin, HEMA, and NTG-GMA (adduct of N [p-tolyl] glycine and glycidyl methacrylate) in acetone.

The manufacturers of all three materials recommend two applications of adhesive before placement of composite restorative material. However, the One-Step directions also state that up to four coats may be used. The application of multiple layers of primer has always been recommended to ensure optimum performance of All-Bond 2 (Kanca, 1991a), and one study showed that multiple primer applications also improved the shear bond strength of another current-generation adhesive system, Scotchbond Multi-Purpose (3M Dental Products, St Paul, MN 55144) (Vargas, Fortin & Meckes, 1995).

The purpose of this study was to determine whether multiple applications of the new one-bottle adhesives would improve composite shear bond strength to dentin.

METHODS AND MATERIALS

A total of 110 human molars were obtained shortly after extraction. The teeth were debrided and examined to ensure that they were free of defects. They were stored in 0.5% chloramine solution for 1 week, and then were transferred to distilled water until used in the study. Each tooth was mounted in a 1-inch-in-diameter phenolic ring (Buehler, Ltd, Lake Bluff, IL 60044) using self-cure acrylic resin (Trayresin, Dentsply International Inc, York, PA 17405). The tooth was mounted so that its long axis was perpendicular to the base of the mold. The occlusal surface was ground on a water-cooled orthodontic model trimmer until all enamel was removed (except at the periphery). This procedure resulted in exposure of a flat dentin surface located slightly apical to the mid-coronal level and oriented perpendicular to the long axis of the mold. The dentin was hand-polished to 600-grit on a series of wet silicon carbide abrasive papers. The surface was examined after polishing to ensure that its orientation was not altered.

Table 1. Summary of Experimental Design: Number of Adhesive Applications in Each Treatment Group

	Prime & Bond	One-Step*	Tenure Quik
Control (instructions)	2	2	2
Experimental #1	3	4	3
Experimental #2	4	6	4
Experimental #3	---	2†	2‡

*Does not include the final, uncured adhesive layer applied just before composite resin.

†Excess moisture blotted with wet tissue paper, not removed by compressed air.

‡Tenure Quik used with dual-cure composite.

Specimens were randomly assigned to eleven groups (n = 10) as shown in Table 1. Three groups were treated with Prime & Bond, four groups were treated with One-Step, and four were treated with Tenure Quik. The main independent variables were type of adhesive and number of coats, with shear bond strength as the dependent or outcome variable. The additional groups of Tenure Quik and One-Step were included to evaluate aspects of the bonding procedure peculiar to those systems. Tenure Quik was tested with both a light-cure and a dual-cure composite, as use of a dual-cure composite is an option specifically mentioned by the manufacturer. The additional One-Step group was used to evaluate the effect of dentin surface moisture on shear bond strength.

In the Prime & Bond groups, dentin was etched for 15 seconds with 10% phosphoric acid gel. The etchant was rinsed off using air/water spray, and the dentin was gently dried, avoiding desiccation, with compressed air. Prime & Bond (lot # 950602) was applied liberally to dentin and was left undisturbed for 30 seconds. Excess solvent was removed with compressed air, and the agent was light-cured for 10 seconds. A second layer of Prime & Bond was applied, immediately air-dried, and light-cured for 10 seconds.

Specimens in the Prime & Bond control group received no further applications of adhesive. Specimens in the other groups received either one or two additional applications, each of which was immediately air-dried to remove solvent and light-cured for 10 seconds.

For One-Step specimens, dentin was etched for 15 seconds using 32% phosphoric acid gel. After rinsing, excess moisture was removed with a very brief (< 1 second) burst of compressed air; dentin was not desiccated. Two consecutive coats of One-Step adhesive (lot #079065) were applied using a saturated brush, with no waiting between coats. The

adhesive was thoroughly air-dried for 10 seconds using a compressed air syringe held at a distance of 1.5 inches from the surface. The adhesive was light-cured for 10 seconds.

The One-Step control group received only these two applications of adhesive. A second group also received two applications of adhesive, but excess moisture was removed by blotting on wet tissue paper, not by compressed air. The remaining groups received either two or four additional applications of adhesive. Each pair of applications was applied and cured as described in the previous paragraph. In all One-Step groups, an additional coat of the adhesive was applied to the surface, air-dried immediately, and not light-cured just before application of composite.

In the Tenure Quik groups, dentin was etched for 15 seconds using 37% phosphoric acid. The etchant was rinsed with air/water spray and the dentin was dried with compressed air, but not desiccated. Two consecutive coats of Tenure Quik (lot #226005) were applied using a saturated brush, and the surface was very lightly air-dried. Control specimens and specimens to be bonded with dual-cure composite received only these first two applications. The remaining specimens received additional applications for a total of either three or four. Tenure Quik was not separately light-cured, but was cured simultaneously with the composite restorative material, as directed by its manufacturer.

At the completion of the bonding procedure, composite was loaded into a #5 gelatin capsule (Eli Lilly and Co, Indianapolis, IN 46285) and applied to the treated dentin surface. The composites used were the A2 shades of Prisma TPH (lot # 9507241) with Prime & Bond, AELitefil (lot # 019195) with One-Step, and Marathon (lot # 246069) with Tenure Quik. For 10 of the Tenure Quik specimens, Marathon was mixed with initiator paste (lot #410827) for dual-curing. Composite-filled gelatin capsules were applied to the treated dentin surfaces, and excess composite was carefully removed from the periphery with an explorer. The composite was cured for 40 seconds from each of four directions at a 45° angle to the bonding interface.

Bonding agents were cured with an Elipar II curing light (ESPE America, Norristown, PA 19404) and the composites were cured with an Optilux 401 visible-light-activation unit (Demetron Research Corp, Danbury, CT 06810). The intensity of both lights was checked periodically with a radiometer to ensure that it exceeded 400 mW/cm2.

Specimens were stored for approximately 24 hours in distilled water at room temperature. For shear bond testing, they were mounted in a Universal Testing Machine (model 4411, Instron Corp, Canton, MA 02021). A chisel-shaped rod attached to a compression load cell and traveling at a crosshead speed of 5 mm/min was applied to each specimen until failure occurred. The maximum load (N) was divided by the cross-sectional area of the bonded composite posts to determine shear bond strength in MPa. Data were subjected to a two-way analysis of variance (ANOVA) and Tukey's multiple comparisons test using the Systat for Windows 5.0 statistical software package (Systat, Inc, Evanston, IL 60201). Comparisons between the One-Step and Tenure Quik control groups and the experimental groups peculiar to those adhesives were done using Student's *t*-test. All specimens were examined visually with magnification to determine whether failures were cohesive, adhesive, or mixed.

RESULTS

Data are summarized in Tables 2 and 3. Two-way ANOVA showed that the type of bonding system and the number of applications were statistically

Table 2. Mean Shear Bond Strength (MPa) of Adhesives with Different Numbers of Primer Applications. Standard Deviations Are Listed in Brackets.

	Prime & Bond	One-Step	Tenure Quik
Control (instructions)	12.3 [3.2]	7.3 [2.5]	2.9 [2.3]
Experimental #1	10.1 [3.4]	3.6 [2.5]*	1.8 [1.6]
Experimental #2	10.0 [3.3]	4.3 [1.8]	2.3 [1.8]
Experimental #3	---	7.0 [3.0]	2.0 [1.0]

*Significantly less than control ($P < 0.05$).

Table 3. Failure Modes of Each Group. A = Adhesive; C = Cohesive in Dentin or Composite; M = Mixed Adhesive/Cohesive.

	Prime & Bond			One-Step			Tenure Quik		
	C	A	M	C	A	M	C	A	M
Control (instructions)	1	2	7	1	6	3	0	10	0
Experimental #1	1	7	2	0	10	0	0	10	0
Experimental #2	2	5	3	0	9	1	0	10	0
Experimental #3	---	---	---	1	5	4	0	10	0

significant at $P < 0.0001$ and $P < 0.001$ respectively. The interaction of these two main effects was not significant ($P = 0.42$).

Tukey's test showed that the shear bond strength of the Prime & Bond control group was significantly greater than that of the other two control groups at $P < 0.05$. Both Prime & Bond and One-Step had significantly higher mean shear bond strength than Tenure Quik.

Multiple adhesive applications decreased the bond strength of each material somewhat. However, the only significant difference was between the One-Step control group and the experimental group that received four adhesive applications.

For two applications of One-Step, mean bond strength was similar regardless of whether excess moisture was removed with compressed air or blotted.

The shear bond strength provided by two applications of Tenure Quik was not affected by the type of composite used. The mean bond strength of specimens bonded with dual-cure composite was slightly less than those bonded with light-cure composite, but the difference was not significant.

DISCUSSION

Most current-generation dentin bonding systems involve three steps: etching with an acidic conditioner, priming with hydrophilic resin(s) in solvent, and bonding with an unfilled or lightly filled resin (Swift, Perdigao & Heymann, 1995). Although a wide range of bond strengths have been reported for these systems, shear bond strengths exceeding 20 MPa are not uncommon (Kanca, 1991b; Barkmeier & Erickson, 1994; Gwinnett & Yu, 1994; Triolo, Swift & Barkmeier, 1995).

The bond strengths determined in this study for the one-bottle adhesives were much less than 20 MPa. However, no conventional three-step system was included for direct comparison. Our laboratory recently acquired new testing equipment, so comparisons with data previously reported by the investigators may not be valid. However, in an ongoing study using similar bonding and testing methods, we have determined shear bond strengths of 7-10 MPa for resin-modified glass-ionomer restorative materials (unpublished data). These figures are very much in line with those reported by ourselves and other investigators (Bell & Barkmeier, 1994; Friedl, Powers & Hiller, 1995; Swift, Pawlus & Vargas, 1995), which supports the reliability of our methods. Although test methodology undoubtedly influences bond strength measurements, it is therefore unlikely that the methods used in the present study were the sole cause of the relatively low bond strengths recorded.

Because the one-bottle adhesives have been introduced very recently to the market, no published data were available at the time of writing. However, the manufacturers of these adhesives and some independent researchers have reported much higher bond strengths than those determined in the present study. For example, Bisco (1995) reported a shear bond strength of 27 MPa for One-Step to moist dentin, and independent tests by Barkmeier, Gwinnett, and Powers had mean shear bond strengths in the range of 20 MPa (Bisco, 1995). Bisco stated bonding to dry dentin reduced shear bond strength by approximately half, although Kanca (personal communication, 1995) had obtained bond strengths of 18-20 MPa to dry dentin. Studies by Powers and Barkmeier cited in the Prime & Bond technical manual reported bond strengths for that material in the range of 20-25 MPa (Caulk/Dentsply, 1994). Powers reported bond strengths of 14-18 MPa for Tenure Quik, depending upon the type of conditioner and etching time (Den-Mat, 1995).

In contrast to these relatively high bond strengths, other researchers in the field have obtained results remarkably similar to those reported in this study. For example, Vargas (personal communication, 1995) obtained shear bond strengths of 13.2 MPa for Prime & Bond, 9.8 MPa for One-Step, and 4.9 MPa for Tenure Quik to moist dentin. Bond strengths for the three materials to dry dentin were 8.8, 2.7, and 1.7 MPa respectively. Fundingsland (3M, personal communication, 1996) obtained shear bond strengths of 14.4, 9.2, and 6.1 MPa for Prime & Bond, One-Step, and Tenure Quik.

As Vargas's data indicate, these acetone-based bonding agents achieve higher bond strengths to moist dentin. Moisture is required to prevent collapse of collagen fibers in the etched dentin surface, ensuring adequate diffusion of the adhesive. Testing by Bisco (1995) showed dramatically lower bond strengths for both One-Step and Prime & Bond when surfaces were air-dried for 2-3 seconds rather than blotted before application of adhesives. All-Bond 2, which contains some water in its acetone-based primer, is less sensitive to dryness of the dentin surface than these systems, which contain only acetone (Kulton, Qian & Suh, 1996).

In this study, an air/water syringe was used very briefly (< 1 second) to remove excess water from the dentin surface before bonding to avoid desiccation of dentin. Nevertheless, it is possible that even this brief use of compressed air may have resulted in dentin that was drier than desired, although the mean shear bond strength of One-Step remained at 7 MPa when the surface was simply blotted dry. However, later work by one of the investigators resulted in much higher bond strengths (> 20 MPa) when One-Step was applied to surfaces that were deliberately left wetter than those in this study (unpublished data). It is very likely, therefore, that the lower shear

bond strengths reported here were caused by a lack of adequate surface moisture.

The extremely low values obtained for Tenure Quik might be related to inadequate resin penetration of the dentin surface. Later testing of this material indicated that numerous applications were required to produce a glossy, resin-coated surface. Its low bond strength might also be related to omission of the light-curing step, an omission that is directed by the manufacturer. Studies have shown that light activation of resin adhesives before placement of the restorative material is required to optimize their performance (Erickson, 1989; Hansen & Swift, 1989; Crim, 1990; McCabe & Rusby, 1994). Furthermore, the adequacy of that light curing affects shear bond strength and microleakage (Rozmajzl & others, 1994; Miyazaki & others, 1995; Tay & others, 1995). However, Fundingsland (personal communication, 1996) found very little improvement in shear bond strength when Tenure Quik was light activated before composite placement.

Application of a few additional coats of adhesive did not improve bond strengths for any of the materials. Rather, application of coats beyond the number recommended by the manufacturers actually decreased bond strengths, although the difference was significant in only one case. This finding does not imply that a single coat of any of these materials is sufficient, although the manufacturer of Prime & Bond recently changed its instructions to one application. Fundingsland (personal communication, 1995) found that a single coat of Prime & Bond resulted in a mean SBS of about 7 MPa, or approximately half of the SBS obtained with two applications. Bisco reported a similar reduction for One-Step when only one coat was applied. However, the idea that a specific number of coats is required for a specific material is somewhat erroneous. The most important point is that enough adhesive must penetrate the etched dentin surface to provide adequate mechanical interlocking.

Adequate bonding of adhesive materials to dentin depends not only on adequate penetration of the adhesive into dentin, but also on the mechanical properties of the resin itself (Amory & Yvon, 1994; Finger, Inoue & Asmussen, 1994). Therefore, the nature of the resin (degree of polymerization and mechanical properties) can influence shear bond strength. For example, the use of filled resin adhesives, which are stronger than conventional unfilled resin bonding agents, can improve bond strengths (Fanning & others, 1995). The one-bottle resins may have inferior mechanical properties, which could contribute to reduced bond strengths.

Finally, it should be noted that Prime & Bond and Tenure Quik have been re-formulated since this study was completed.

CONCLUSIONS

Prime & Bond had significantly higher shear bond strengths to dentin than either One-Step or Tenure Quik. Both Prime & Bond and One-Step had significantly higher bond strengths than Tenure Quik. Multiple applications of these adhesives did not improve their shear bond strength to dentin.

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Comparison of Retentiveness of Amalgam Bonding Agent Types

M M WINKLER • B K MOORE
J ALLEN • B RHODES

Clinical Relevance
Amalgam bonding agents with greater film thickness exhibited the greatest retention.

SUMMARY

Previous studies on amalgam bonded restorations indicated that amalgam bonding agents increased the bond strength of amalgam to tooth structure. This in vitro study was designed to compare how the mode of curing and the presence of filler in the resin would affect the bond strength of amalgam. The five test groups of lining agents for amalgam restorations included Chemical-cured, Unfilled resin (CU—Clearfil New Bond); Light-cured, Unfilled resin with a delayed chemical-cure property (LU*—Clearfil Photo Bond); Light-cured, Filled resin with a delayed chemical-cure property (LF*—Clearfil Photo Bond + Protect Liner); Dual-cured, Unfilled resin (DU—All-Bond 2); and Varnish (V—Copalite). For each group, 20 class 5 cavity preparations were cut on the facial, lingual, or proximal surfaces of human molars, which were embedded in acrylic resin. The preparations were 2.5 mm deep and 3 mm wide at the pulpal floor with a slightly divergent taper. After treating the preparation with the bonding agent, a ¾-inch, 18-gauge flat-headed wire nail was placed into the cavity with the head at the pulpal floor of the preparation, and Tytin amalgam was then condensed into the preparation around the nail. The restorations were stored for 24 hours in distilled water at 37 °C and then subjected to 2500 thermal cycles (8 °C to 48 °C). After 1 week, specimens were tested to failure in tension using an Instron Universal Testing Machine (crosshead speed = 2 mm/min) and peak load (kg) was recorded. The mean loads at failure (± SD) were LF* 26.4 (±7.0), DU 23.9 (±6.4), LU* 16.0 (±3.1), CU 14.3 (±8.0), and V 9.5 (±5.6). Significant differences were found using a one-way ANOVA and the Games and Howell post hoc test at a significance level of $\alpha = 0.05$. The LF* and DU groups were not significantly different from each other, but they were significantly higher in peak load than all other groups. LU* was significantly higher than the varnish (V) but not significantly higher than CU. CU was not significantly higher than the varnish (V). The adhesives forming a thicker resin interface (the light-cured resin with filled

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resin liner and the dual-cured unfilled resin) demonstrated significantly greater retention than the light-cured unfilled resin, chemical-cured unfilled resin, and the varnish control.

INTRODUCTION

As shown in several studies, amalgam bonding agents can help ameliorate some of the disadvantages of using amalgam as a restorative material, but few studies have attempted to illustrate the characteristics of bonding agents that are most effective in enhancing retention. Lack of adhesion and microleakage are two of the main disadvantages of using amalgam as a restorative material. The use of cavity varnishes under amalgam restorations does not inhibit microleakage (Mazer, Rehfeld & Leinfelder, 1988). Previous studies on amalgam-bonded restorations have indicated that amalgam bonding agents can increase the retention of amalgam restorations if no macroscopic undercuts are used (Staninec & Holt, 1988; Charlton, Moore & Swartz, 1992; Kawakami & others, 1994). In one study, an amalgam bonding agent was significantly more effective than proximal grooves or dovetails in improving the retention of the amalgam restoration (Staninec, 1989). This bond strength is modest when compared to the bond strength of resin composite restorations to tooth structure (Cooley, Tseng & Barkmeier, 1991). Filled bonding agents significantly increase the bond strength to tooth structure (Bagley, Wakefield & Robbins, 1994; Miyazaki & others, 1995). Some bonding agent studies have also found that microleakage is reduced when compared to cavity varnish, the typical amalgam liner (Cooley & others, 1991; Charlton & others, 1992; Hadavi & others, 1993; Saiku, St Germain & Meiers, 1993; Turner, St Germain & Meiers, 1995). Microleakage is also reduced at the interface between existing amalgam and freshly placed amalgam (Hadavi & others, 1993). With adhesion between the amalgam and tooth structure, the fracture resistance is also increased (Eakle, Staninec & Lacy, 1992; Ianzano, Mastrodomenico & Gwinnett, 1993). However, in one bonding agent study, no such increase in fracture resistance was found (Santos & Meiers, 1994).

While amalgam bonding agents generally significantly increase retention of amalgam to tooth structure, there are differences in retentive strength among the bonding agents. In fact, strengths recorded for any product can differ markedly among laboratories, and so a fair comparison of different types of amalgam bonding agents by comparing numbers from different laboratories is not possible. One study was unable to test one particular bonding agent due to the failure of all samples prior to testing (DeSchepper & others, 1991). However, other studies of this same bonding agent found it to be effective in significantly increasing retention and reducing microleakage (Cooley & others, 1991; Charlton & others, 1992). Also, occlusal function may significantly decrease the strength of any bond between the tooth and amalgam restoration (McComb, Brown & Forman, 1995).

The mechanism for bonding between the amalgam and the resin liner is by a mechanical intermingling of the amalgam with the setting resin liner during condensation of the amalgam (Scherer & others, 1992; Temple-Smithson, Causton & Marshall, 1992). For some bonding agents, this intermixing of the resin and amalgam may significantly reduce the compressive strength (Charlton, Murchison & Moore, 1991). Bonding afforded by the resin liner has also shown in vitro caries to have been inhibited along the cavity wall (Torii & others, 1989). Bonding of amalgam to tooth structure, including any advantageous side effects, is almost without exception a result of micromechanical interlocking of the resin liner between the amalgam and tooth structure.

This in vitro study was designed to compare how the mode of curing and the presence of filler in the resin may affect the bond strength of amalgam bonding agents when used in class 5 preparations.

METHODS AND MATERIALS

Sample Preparation

The test materials included a control group of cavity varnish and four adhesive resin systems that generally utilized a phosphoric acid conditioner, have resins based on BIS-GMA and HEMA, and possess at least some potential for chemical activation. The five test groups of lining agents for amalgam restorations included Varnish (V—Copalite, Cooley & Cooley, Ltd, Houston, TX 77041) as a control; Chemical-cured, Unfilled resin (CU—Clearfil New Bond, catalyst lot # 0796A, universal lot # 0900A, Kuraray Co, Ltd, Osaka, Japan); Light-cured (with a delayed chemical-cure property), Unfilled resin (LU*—Clearfil Photo Bond, lot # 61177, Kuraray Co); Light-cured (with a delayed chemical-cure property), Filled resin (LF*—Clearfil Liner Bond, lot # 61117, Kuraray Co); and Dual-cured, Unfilled resin (DU—All-Bond 2, all-etch lot # 079023, Primer A lot # 069243, Primer B lot # 69233, Dental/Enamel Bonding Resin lot # 0792123, Pre-bond Resin lot # 079073, Bisco Inc, Itasca, IL 60143). The chemical-curing modalities of LF* and LU* adhesives appear to be considerably slower than that for DU, since the manufacturer of these two adhesives stated in the instructions that they should be light-cured prior to placement of the restoration if the restorative material is greater than 2 mm thick.

The protocol for fabricating and testing the retention of the amalgam liners followed the procedure reported in an earlier study (Charlton & others, 1992). The main advantage of this method was that it utilized a clinically relevant preparation that included both enamel and dentin and minimized the typically large variations found in bond strength values by machining the preparations instead of cutting them by hand. For each group, 20 class 5 cavity preparations were cut with a crosscut fissure bur (#557) on the facial, lingual, or proximal surfaces of human molars with only one prep per tooth. In order to minimize variation both between and within preparations, they were prepared using a high-speed dental handpiece that was attached to a small machine lathe with a water spray. The preparations (Figure 1) were 2.5 mm deep and 3 mm wide at the pulpal floor with a slightly divergent taper (about 5% for one wall or 10% total taper). Prior to placement the preparations were stored in distilled water.

Immediately prior to restoration, the teeth were rinsed with a water spray for 20 seconds. For all adhesive bonding systems, the removal of the water, used to wash away the etchant, was accomplished using a brief blast of air sufficient only to remove visible standing water and not to desiccate the dentin. The adhesive resins were prepared and applied to the cavity walls as follows.

Adhesive Application Procedures

Varnish (V—Copalite): Two separate thin coats of cavity varnish were applied.

Chemical-cured, Unfilled resin (CU—Clearfil New Bond): 1) 40% phosphoric acid conditioner was applied to the tooth for 30 seconds and then rinsed and dried; 2) The first coat of adhesive (New Bond) solutions was mixed for 5 seconds and applied to the tooth and air-dried; 3) The second coat of adhesive (New Bond) solutions was mixed for 5 seconds and applied to the tooth; 4) The amalgam was condensed within 30 seconds of mixing the adhesive.

Light-cured, Unfilled resin (with a delayed chemical-cure property) (LU*—Clearfil Photo Bond): 1) 40% phosphoric acid conditioner was applied for 30 seconds, rinsed, and dried; 2) The first coat of adhesive (Photo Bond) solutions was mixed for 5 seconds, applied to the tooth, and air-dried; 3) The liner was light-cured for 10 seconds; 4) The second coat of adhesive (Photo Bond) solution was mixed for 5 seconds and applied to the tooth; 5) The amalgam was condensed within 2 minutes of mixing the adhesive.

Light-cured, Filled resin (with a delayed chemical-cure property) (LF*—Clearfil Liner Bond): 1) Citric acid conditioner (CA) was applied to the tooth for 40 seconds and then rinsed and air dried; 2) Salicylic acid derivative (SA) primer was applied to the tooth and then evaporated with air; 3) One coat of adhesive (Photo Bond) solution was mixed for 5 seconds, applied to the tooth, and then air-dried; 4) Microfilled composite (Protect Liner) was applied to the tooth, thinned with a brush, and light cured for 20 seconds; 5) Amalgam was condensed immediately. (Note: A prior pilot study indicated that the substitution of this CA conditioner and SA primer for phosphoric acid did not increase the retention of amalgam in the test procedure utilized in this study. So, Clearfil Liner Bond as packaged and sold by the manufacturer was used to increase this study's clinical relevance.)

Dual-cured, Unfilled resin (DU—All-Bond 2): 1) 10% phosphoric acid conditioner was applied for 15 seconds and then rinsed, and excess water was removed with air; 2) Primer solutions A & B were mixed, five coats of the mixture applied to the tooth, and then air-dried; 3) Adhesive resin solutions (Dentin/Enamel Bonding resin and Pre-Bond resin) were mixed and the resulting mixture applied to the tooth in a thin coat; 4) The amalgam was condensed 30 seconds later.

A 3/4-inch, 18-gauge flat-headed wire nail was placed into the cavity preparation with the head at the pulpal floor of the preparation (Figure 1). The diameter of the head of the nail was matched to the diameter of the preparation at the pulpal floor, so that bonding between amalgam and tooth was limited to the tapered walls of the preparation.

A spherical silver amalgam (Tytin, lot # 31148, Kerr Mfg Co, Romulus, MI 48174) was triturated for 8 seconds at the M2 setting on a mechanical amalgamator (Vari-Mix II, L D Caulk/Dentsply, Milford, DE 19963) and condensed into the preparation around the nail. After carving the amalgam surface flush with the cavosurface margin, the

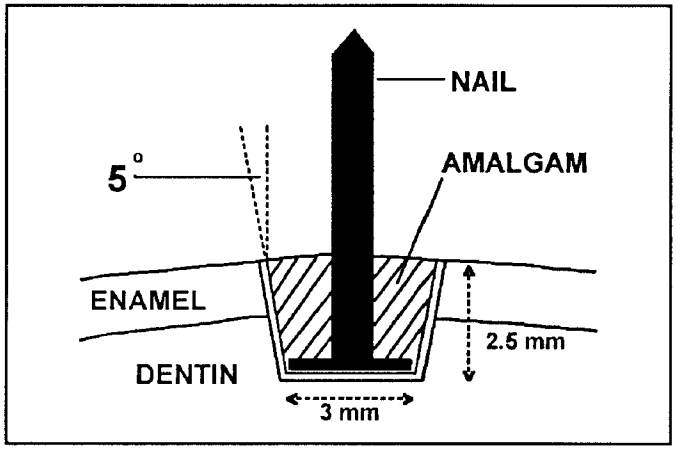

Figure 1. *Diagram of cross section of sample restored class 5 preparation*

Table 1. Mean Loads at Failure

Liners	Mean Load at failure (kg)	Standard Deviation
Liner Bond* (light-cured, filled resin)	26.4	7
All-Bond 2 (dual-cured, unfilled resin)	23.9	6.4
Photo Bond* (light-cured, unfilled resin)	16	3.1
New Bond (chemical-cured, unfilled resin)	14.3	8
Copalite (varnish--control)	9.5	5.6

*These adhesives contain a delayed chemical-cure property.
Mean loads connected by vertical lines are not significantly different at $P = 0.05$.
N = 20 per group.

restoration was stored in distilled water at 37 °C. One day later, all samples were subjected to 2500 thermal cycles (8 °C to 48 °C) with a dwell time of 30 seconds. One week after placement of the amalgam restoration, specimens were tested in tension using an Instron Universal Testing Machine (Instron Corp, Canton, MA 02021) at a crosshead speed of 2 mm/min. Connected to the upper grip was a metal swivel-assembly holding the embedded tooth, and connected to the lower grip was a drill chuck fastened to the nail protruding from the amalgam. Samples were tested to failure and peak load (kg) was recorded. Any fracture of tooth structure was noted. The failed amalgam samples were examined for failure mode using a light stereomicroscope at a magnification of X40. The failure mode was determined for each sample by noting on which side of the tooth-amalgam interface the lining agent remained.

Statistical Analysis

The peak loads at failure for the five groups were analyzed using a one-way ANOVA ($P = 0.05$). Because the variation among groups was not uniform, a Games and Howell post hoc test was utilized (Kirk, 1982). Data were also submitted to Weibull analysis (Johnson, 1964) by plotting the data points on a distribution grid using custom computer software. The strength of the correlation between the number of failures involving tooth structure and mean retentive strength was determined using the Pearson correlation coefficient (Olson, 1987).

Confocal Microscopy

In order to assess the thickness of the amalgam liner and its incorporation into the amalgam, cross sections of completed restorations were examined

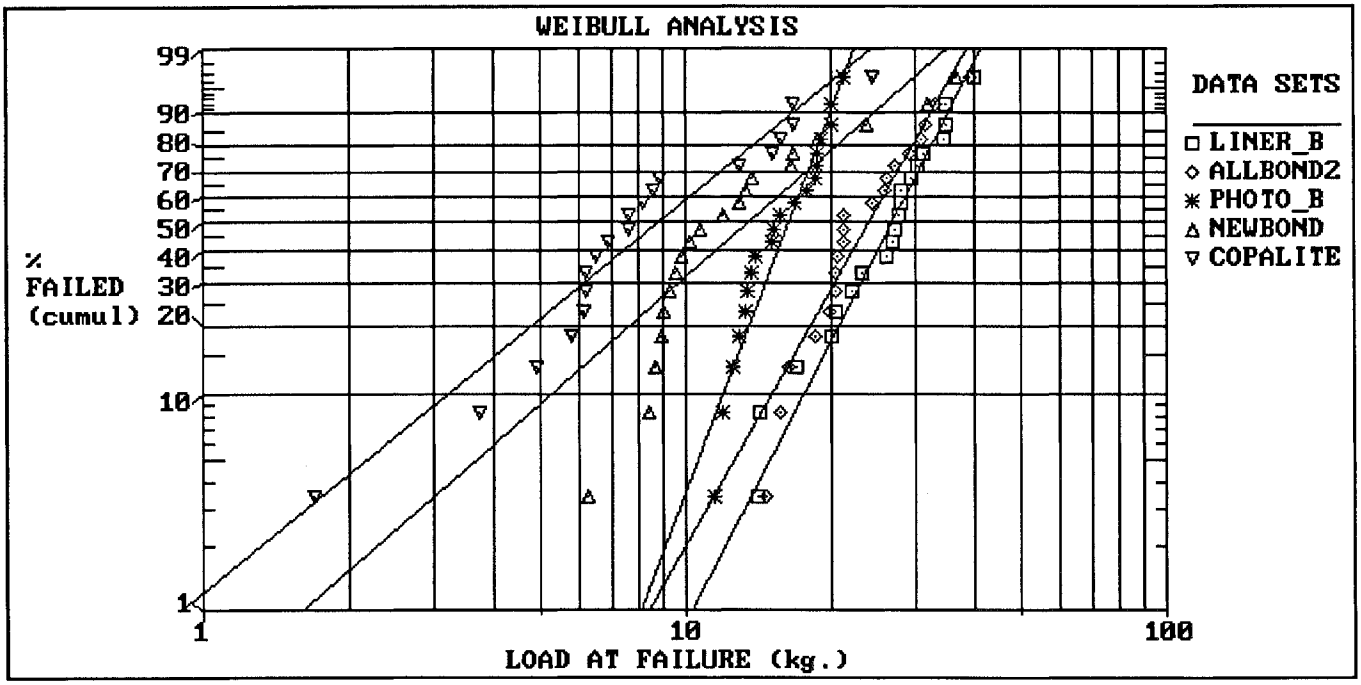

Figure 2. *Plot of logarithm of mean load (kg) at failure (horizontal axis) according to a Weibull cumulative distribution (vertical axis)*

using a confocal microscope at X400. Buccolingual sections of a completed restoration were cut with a high-speed diamond saw using water spray. The cut surfaces were finished using 2000-grit silicon carbide paper and then were treated with 32% phosphoric acid for 10 seconds. After rinsing with water and air drying, the samples were mounted on glass slides for viewing under the confocal microscope (Noran Odyssey, Noran Instruments, Middleton, WI 53562). The microscope was operated in the reflected mode using an argon laser as the light source with a wavelength of 488 nm. Images were obtained by capturing and averaging video frames using computer software (Image I Image Analysis software ver. 4.14c, Universal Imaging, West Chester, PA 19380).

Scanning Electron Microscopy

Representative samples of each group were prepared for examination using a scanning electron microscope (Hitachi S450, Hitachi Scientific Instruments, Mountain View, CA 94043) in order to examine the mechanical interaction of the bonding agent with the amalgam and tooth at the interface. Samples were sectioned in a similar manner to those prepared for the confocal microscope. They were then mounted on aluminum stubs and coated with gold-palladium (40:60) using a sputter-coater (Hummer V, Anatech Ltd, Alexandria, VA 22151). The microscope was operated in the secondary electron mode at 20 kV at a magnification of X400.

RESULTS

Retentive Strength

The mean values and standard deviations of peak load at failure for the five groups are presented in Table 1. The Liner Bond (LF*) and All-Bond 2 (DU) groups were not significantly different from each other, but they were significantly higher in peak load at failure than all other groups. Photo Bond (LU*) was significantly higher than Copalite but not significantly higher than New Bond (CU). New Bond (CU) was not significantly higher than Copalite.

Plots of the load at failure according to the Weibull distribution (Figure 2) showed the same ranking of the five groups. The deviation of the Copalite (varnish) and New Bond (CU) data from the line fitted to them according to maximum likelihood statistical methods suggested that either the Weibull distribution was not appropriate for these data or that different modes of failure may have been present. While not shown here, the fit of these two data sets to a normal distribution was similar to the fit of the data to the Weibull distribution.

Mode of Bond Failure

Almost all failures were adhesive, but there were several instances of cohesive failure in tooth structure especially for Liner Bond (LF*) and All-Bond 2 (DU) (Table 2). The cavity varnish typically remained with the amalgam after failure, and the bonding agents New Bond (CU), Photo Bond (LU*), and Liner Bond (LF*) typically remained with the tooth structure after failure. While adhesive failure was also the most common mode of failure for All-Bond 2 (DU), this bonding agent was found to cover more than 50% of the area on both amalgam and tooth structure after failure, suggesting some cohesive failure in the bonding resin. A significant correlation ($r = 0.92$) was found between the number of fractures involving tooth structure and mean retentive strength.

Microscopic Examination

The confocal photomicrographs revealed the relative thickness and uniformity of the amalgam liners. The mean thicknesses (calculated from five locations along the interface on these photomicrographs) of the liners were 9 μm for Copalite (varnish), 8 μm for New Bond (CU), 14 μm for Photo Bond (LU*), 26 μm for All-Bond 2 (DU), and 53 μm for Liner Bond (LF*). Both the Copalite cavity varnish (Figure 3A) and the New Bond (CU) resin (Figure 3B) exhibited very thin layers, but some of the New Bond (CU) resin was found incorporated in the amalgam. The Photo Bond (LU*) (Figure 3C) presented a layer that was thicker than that for New Bond (CU) but was relatively uniform in thickness. Regions of Photo Bond (LU*) were also found

Table 2. Frequency of Failures in Tooth Structure

Liners	Number of Failures Involving Tooth Structure
Liner Bond (light-cured, filled resin)*	9
All-Bond 2 (dual-cured, unfilled resin)	12
Photo Bond (light-cured, unfilled resin)*	3
New Bond (chemical-cured, unfilled resin)	2
Copalite (varnish--control)	1

*These adhesives also contain a delayed chemical-cure property.

Figure 3. *Confocal photomicrographs of cross sections of untested samples at amalgam/dentin interface (Note: Amalgam and dentin are on the left and right respectively.)*

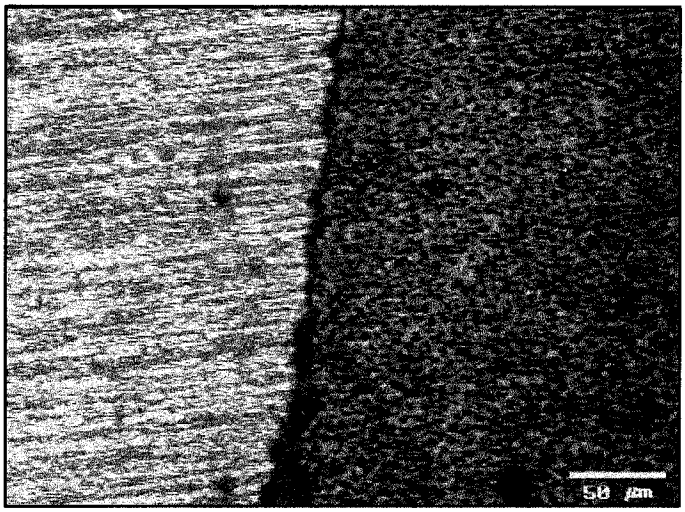

Figure 3A. *Copalite varnish*

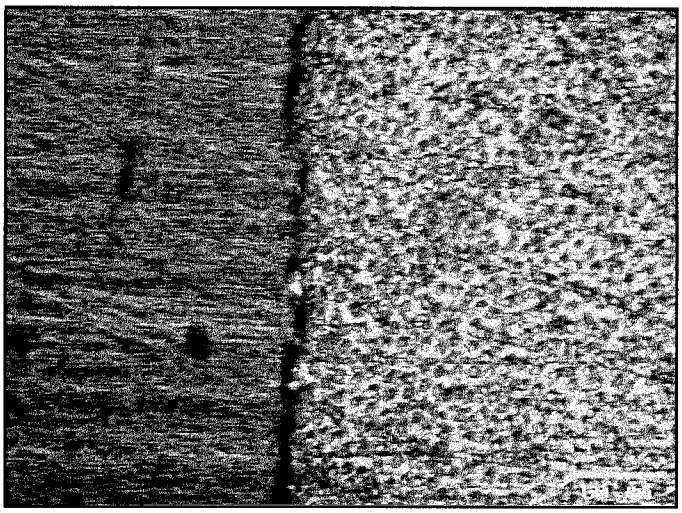

Figure 3B. *New Bond (CU)*

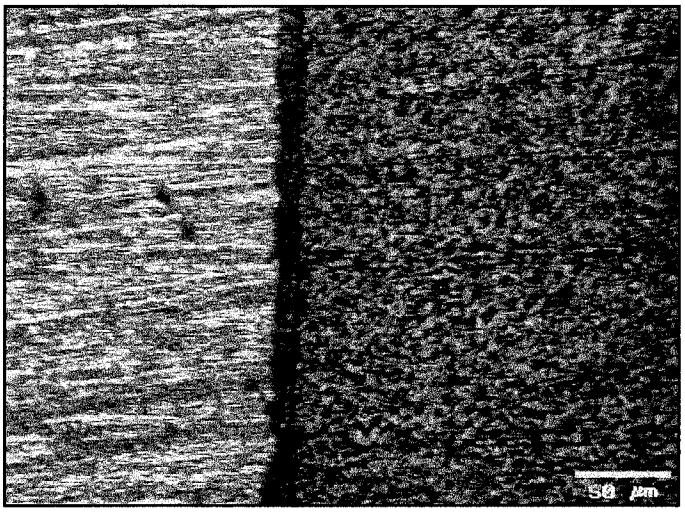

Figure 3C. *Photo Bond (LU*)*

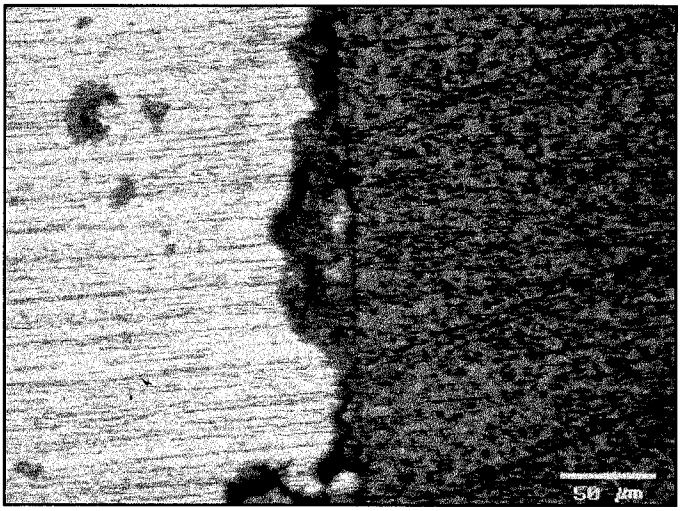

Figure 3D. *All-Bond 2 (DU)*

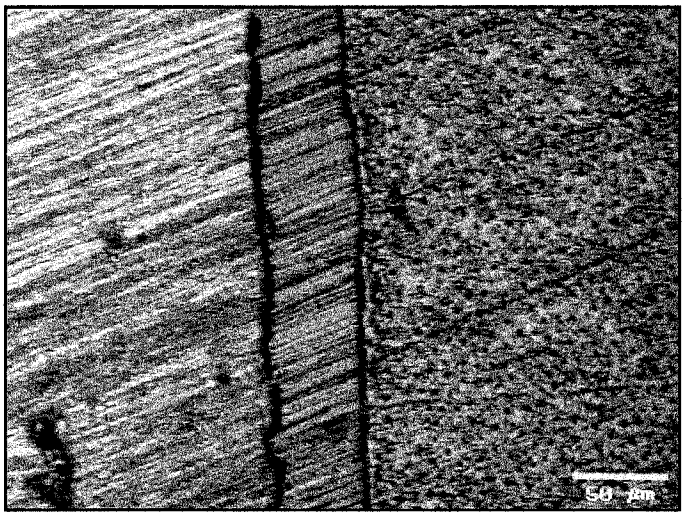

Figure 3E. *Liner Bond (LF*)*

within the amalgam. The All-Bond 2 (DU) resin (Figure 3D) exhibited a thicker layer than the Photo Bond (LU*) liner and a layer that varied in thickness to a much greater degree. Several regions of the All-Bond 2 (DU) liner were found within the amalgam. The Liner Bond (LF*) (Figure 3E) liner revealed a thicker layer that was very uniform. Very few regions of this liner could be found within the amalgam.

The scanning photomicrographs were similar to the confocal photomicrographs, except that the demarcations between the materials (resin bonding agent, enamel or dentin, and amalgam) were not as clear, especially for samples presenting with thin layers of bonding agent, and that gaps were present at the interface and were probably due to the desiccation of the samples during the sputtering process. The gap

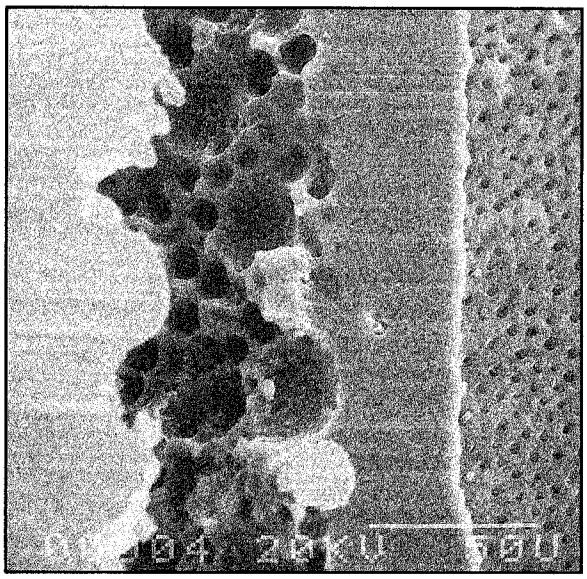

Figure 4. *Scanning electron micrograph of cross section of untested sample at amalgam/dentin interface for Liner Bond (LF*). (Note: Amalgam and dentin are on the left and right of the figure respectively.)*

present in the Liner Bond (LF*) group (Figure 4) revealed that the resin surface contained craters that appeared to correspond with the spherical particles of the amalgam. The depth of these craters was approximately one-third to one-half of the diameter of the alloy particles.

DISCUSSION

The bonding agents with the thicker adhesive layers, Liner Bond (LF*) and All-Bond 2 (DU), exhibited the higher load at failure. Since New Bond (CU), with only chemical activation, was not significantly different from Photo Bond (LU*), with both light activation and delayed chemical curing, the mode of curing did not seem to affect the retention. However, the addition of filler to Photo Bond (LU*), resulting in group Liner Bond (LF*), did significantly increase retention over group Photo Bond (LU*). Except for New Bond (CU), all of the adhesive liners had significantly greater retention than Copalite cavity varnish.

All of the adhesive liners have some chemical activators; however, their dependence on these activators differs. Since no light was used to activate All-Bond 2 (DU) or the second layer of Photo Bond (LU*), these two liners, except for limited curing due to exposure to ambient light, depend entirely on chemical activation. Clinically, All-Bond 2 (DU) hardens at a significantly faster rate than does Photo Bond (LU*). This, in concert with the manufacturer's recommendation (Clearfil Photo Bond product manual, Kuraray Co) to light cure if overlying composite restorative is greater than 2 mm, suggests that the amount of chemical activation is certainly less in Photo Bond (LU*).

The only adhesive that has no potential for light curing is New Bond (CU). For the filled adhesive resin liner Liner Bond (LF*), the first layer of adhesive was the same as Photo Bond (LU*), which had the potential for curing by either light or chemical means. This layer was not exposed to light until after the placement of the filled layer. Placement of the filled layer, which contained no chemical activator, over the uncured adhesive of Photo Bond (LU*), may have allowed some of the Photo Bond (LU*) adhesive to be incorporated into the filled resin and even on the surface exposed to the amalgam during condensation. In this way, chemical activators may have been present within and on the surface of this layer of filled resin and allowed a delayed hardening of the air-inhibited layer of the filled resin layer after being covered with the amalgam. The extent to which this may have happened is not known. Microscopic examination of the interface of the Liner Bond (LF*) resin with the amalgam did not demonstrate macroscopic undercuts that theoretically could occur as a result of using light to cure a relatively viscous filled resin prior to condensation of amalgam. As evidenced by the relatively high number of failures involving tooth structure and the continuing successful bond of the fractured portion of tooth to the amalgam after failure, the Liner Bond (LF*) resin did attach firmly to tooth structure.

The number of fractures involving failure in tooth structure (Table 2) generally parallelled the mean bond strengths, as demonstrated by the high correlation coefficient. The two groups with the highest number of failures involving fracture of tooth structure, Liner Bond (LF*) and All-Bond 2 (DU), were also the same groups with significantly higher mean loads at failure.

The rather high standard deviation and low Weibull modulus, represented by the shallow slope of the best fit line for the Weibull distribution, for the New Bond (CU) may be due to the variation inherent in handling the material. First, the time needed to mix, place one coat of New Bond (CU), dry, and place another coat, and then start condensing amalgam was extremely short. If bond strength changed drastically as the 1-minute limit was approached, this would certainly explain the high variation. The light-cured version, Photo Bond (LU*),was not as retentive as the most retentive agents, but its retentive bond strength was very consistent from sample to sample as evidenced by its relatively low standard deviation and higher Weibull modulus, represented by a steeper slope for the best fit line for the Weibull

distribution. The main difference between New Bond (CU) and Photo Bond (LU*) in procedure was that the first layer of adhesive for Photo Bond (LU*) was light cured. It is speculated that the better consistency in retentive strength may be due to the longer working time, 2 minutes for Photo Bond (LU*) as opposed to 30 seconds for New Bond (CU). This difference in working time suggested that the chemical activation of Photo Bond (LU*) may be slower than that of New Bond (CU). Also, if there is no activation by light, the hardening rate of the Photo Bond (LU*) adhesive was considerably longer than that for All-Bond 2 (DU).

Confocal photomicrographs of cross sections of lined amalgam preparations revealed that the more retentive liners, Liner Bond (LF*) and All-Bond 2 (DU), also had the thickest layers. However, the uniformity of the liner's thickness differed greatly. The consistent thickness of the Liner Bond (LF*) resin was probably due to the fact that this liner was light cured prior to condensation, and the great variability in thickness of the All-Bond 2 (DU) liner was probably enhanced during condensation, which occurred prior to complete curing of the chemically cured resin liner. The All-Bond 2 (DU) liner was intermixed with the amalgam at the interface, while the retention for the Liner Bond (LF*) liners relied less on intermixing and more on a rough surface filled with craters. The cratering of the resin increased surface area and allowed for mechanical undercuts on a microscopic level, which increased the retentive force. While the interfaces of the All-Bond 2 (DU) and Liner Bond (LF*) differed greatly, the failed samples, which exhibited cohesive failures of the tooth, typically exhibited similar failures with enamel remaining attached to the amalgam. Also, the bond strengths of Liner Bond (LF*) and All-Bond 2 (DU) were similar and were in agreement with another study (Vargas, Denehy & Ratananakin, 1994). The filled resin liner in this study, Liner Bond (LF*), exhibited the highest retentive strength as did a filled resin liner in another study of amalgam bonding agents (Kawakami & others, 1994).

The New Bond (CU) and Photo Bond (LU*) adhesives are not very viscous. The relatively thin and relatively smooth layer of New Bond (CU) is similar to that reported by others (Leelawat & others, 1992). This lack of viscosity may not be sufficient to maintain a sufficiently thick layer that can be incorporated into the amalgam during condensation, since the general mode of attachment of the resin liner to the amalgam is by the mixing together of the unset resin and amalgam (McComb & others, 1995). The interface of these two bonding agents and the Copalite cavity varnish is rather thin and very smooth with little evidence of mechanical interlocking. This contrasted with photomicrographs of All-Bond 2 (DU) and Photo Bond (LU*) and with a scanning electron microscope study of three amalgam bonding agents (Scherer & others, 1992), which revealed that the typical interface between the amalgam and resin was very irregular with close mechanical interlocking of the two materials. Technique sensitivity may be related to the thickness of the layer available for mechanical bonding, which for liners with initially viscous layers would still depend on the extent of polymerization that took place prior to condensation of the amalgam (Temple-Smithson & others, 1992). If polymerization proceeded too far, the layer may be too viscous and not allow optimum interlocking between the amalgam and the resin. The trend of higher bond strengths for adhesives with thicker interfaces should be further investigated in hopes of determining an optimum thickness and degree of intermixing of adhesive with freshly packed amalgam.

CONCLUSIONS

No significant difference in retention was found between the light-cured (with delayed chemical-cure) adhesive, Photo Bond, and the chemical-cured bonding agent, New Bond. A layer of light-cured microfilled composite significantly increased retention for the light-cured bonding agent (with delayed chemical-cure), Photo Bond. The amalgam bonding agents with the thicker liners, the light-cured resin with filled resin liner (Liner Bond) and the dual-cured unfilled resin with relatively fast chemical-curing mode (All-Bond 2), demonstrated significantly greater retention than the liners with considerably thinner layers: light-cured unfilled resin with a delayed chemical-curing mode (Photo Bond), chemical-cured resin adhesive (New Bond), and varnish liner (Copalite). These two liners also exhibited the most failures involving tooth structure. Most other failures were adhesive with residual liner generally remaining on the tooth structure, but some cohesive failure in the liner was noted for the dual-cured liner, All-Bond 2.

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In Vitro Corrosion Behavior and Microstructure Examination of a Gallium-based Restorative

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Clinical Relevance
The gallium-based restorative material tested is more corrosion prone than a high-copper amalgam and may undergo accelerated corrosion when placed adjacent to a high-copper amalgam.

SUMMARY

Concerns of mercury toxicity have led to the development of gallium-based restorative materials to replace dental amalgam. A new gallium-based dental restorative, Galloy, was compared with a high-copper amalgam, Permite, for anodic polarization behavior in deoxygenated Ringer's solution and by immersion testing in normal Ringer's solution at 37 °C. Corrosion products were analyzed using energy dispersive X-ray spectrometry and transmission electron diffraction. The data from both sources were consistent with the presence of α-Ga_2O_3 and SnO_2 as the primary corrosion products of Galloy. Anodic polarization behavior of Galloy- and Permite-coupled specimens suggests that coupling Galloy with the more noble Permite amalgam may cause accelerated electrochemical corrosion and that Galloy is more corrosion prone than Permite.

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INTRODUCTION

Introduced to dentistry over 150 years ago, silver amalgam remains the most inexpensive, reliable, and popular restorative material for the repair of posterior teeth. However, recent controversy surrounding mercury has renewed interest in developing a mercury-free restorative with physical properties comparable to dental amalgam (Flanders, 1992). Mercury-free metallic restorative materials proposed as substitutes for mercury-containing amalgams may include gallium-containing materials (Horibe & others, 1991; Miller and others, 1994) and pure silver and/or silver-based alloys (Dariel & others, 1995).

The use of gallium as a replacement for mercury with dental alloys is not new. Its use was partially based on the remarkable ability of liquid gallium to wet the surfaces of many solids, including human teeth (Smith & Caul, 1956; Smith, Caul & Sweeney, 1956). Like mercury, gallium is a liquid at room

temperatures. However, attempts to develop satisfactory gallium restorative materials were unsuccessful until Smith and others (1956) showed that improved palladium-gallium and gold-gallium materials had physical and mechanical properties that were similar to or even better than those of silver amalgam.

Liquid gallium with silver alloy powder was developed as a substitute for amalgam (Horibe & others, 1991) and is currently marketed in Japan as Gallium Alloy GF (Tokuriki Honten Co, Tokyo 101, Japan). It is composed of a liquid phase consisting of 65 wt% Ga, 18.95 wt% In, 16 wt% Sn, and 0.05 wt% Ag and Pd, and a powder consisting of 50 wt% Ag, 25.70 wt% Sn, 15 wt% Cu, 9 wt% Pd, and 0.3 wt% Zn. Studies of biocompatibility, allergic reaction (Eakle & others, 1992), and cytotoxicity (Psarras, Wennberg & Dérand, 1992) of the gallium restorative material indicate that it is not significantly different from amalgam and composite resin. In addition, the much lower vapor pressure of liquid gallium (2.06×10^{-40} mm Hg at 30 °C), calculated from Brandes (1983), as compared to mercury (0.00278 mm Hg at 30 °C) should result in fewer occupational and environmental safety risks.

However, a significant shortcoming of gallium restorative materials is their relatively low resistance to corrosion (Endo, Ohno & Okabe, 1991; Nakajima, Horasawa & Okabe, 1994; Henson & others, 1994). Clinical studies of gallium-based dental restoratives have indicated that there are breakdowns of marginal integrity and surface texture within 1 year after placement (Yamashita, Itoh & Wakumoto, 1989; Navarro & others, 1996). Oshida and Moore (1993), investigating the corrosion behavior of Gallium Alloy GF, found it to be more anodic or "corrosion prone" than Valiant (L D Caulk/Dentsply, Milford, DE 19963), a high-copper dental amalgam. The corrosion products of this gallium-based restorative material consisted of α-Ga_2O_3 and SnO_2, when exposed to 37 °C Ringer's solution.

SDI (Southern Dental Industries, Ltd, Bayswater, Victoria, Australia 3153) has recently marketed a gallium-based dental restorative (Galloy) that differs slightly in composition from Gallium Alloy GF. It consists of a liquid phase composed of 61.98 wt% Ga, 24.99 wt% In, 12.98 wt% Sn, and 0.05 wt% Bi, and a powder phase of 60.10 wt% Ag, 28.05 wt% Sn, 11.80 wt% Cu, and 0.05 wt% Pt. Miller and others (1994) found Galloy to have significantly higher 7-day compressive strength and less dimensional change during setting than Gallium Alloy GF. Corrosion studies of the new Galloy material are lacking. The purpose of this study was to investigate the electrochemical corrosion behavior of Galloy compared to a representative high-copper amalgam, to identify corrosion products, and to examine Galloy's microstructure.

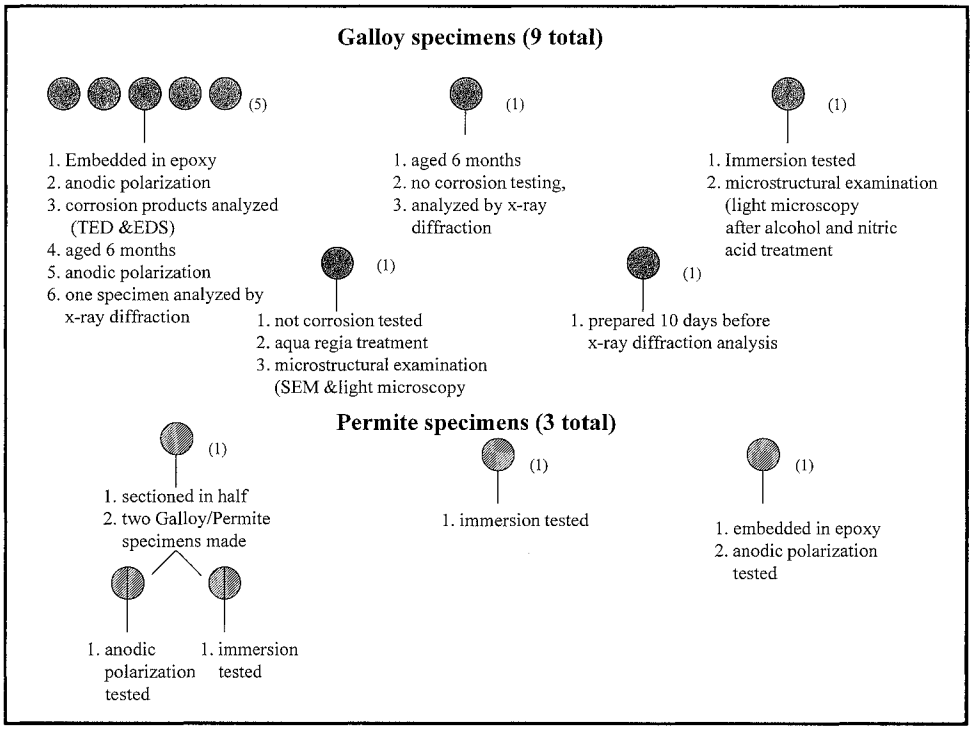

Figure 1. *Procedures performed on various specimens used*

METHODS AND MATERIALS

Two different materials were compared in this study: a gallium-based restorative (Galloy, Batch #931117, SDI Ltd) and a representative high-copper amalgam (Permite, Batch #100893 SDI Ltd). The Permite alloy composition included a liquid phase of mercury and a powder phase of 56% Ag, 27.9% Sn, 15.4% Cu, 0.5% In, and 0.2% Zn by weight.

A total of nine disk-shaped specimens of Galloy and three disk-shaped specimens of Permite approximately 11.3 mm in diameter and 2 mm thick were fabricated in PTFE molds of the same dimensions. Both materials were mixed according to recommended times on the triturator supplied by the manufacturer at powder/liquid ratios of 1.0:0.49 for Galloy and 1:0.92 for Permite. All specimens were hand-condensed by one operator using standard clinical amalgam condensation techniques and instruments. Due to the variety of test conditions, a flow diagram (Figure 1) is provided to clarify procedures. In preparation for anodic polarization, five of the condensed Galloy specimens and one of the Permite specimens were embedded in an epoxide resin (Buehler, Lake Bluff, IL 60044). The exposed surface on these specimens was approximately 1 cm^2. To create Galloy/Permite coupled specimens, one of the remaining two Permite specimens was sectioned across its diameter using a saw under water spray conditions. Each of these sectioned halves was returned to a separate PTFE mold, and freshly triturated Galloy was condensed against the Permite halves. One of these coupled specimens was embedded in an epoxide resin in the same manner, as previously described, and the other was immersion tested, as described below. After the resin had hardened around the embedded specimens, holes were drilled and tapped in the resin that allowed contact of the specimens with the electrode used for anodic polarization tests.

One Galloy specimen, one Permite specimen, and one Galloy/Permite coupled specimen were reserved for immersion corrosion testing and were not embedded in epoxide resin. Following fabrication, the previously described specimens were stored dry at 37 °C for at least 1 week before testing. One Galloy specimen was not corrosion tested, but aged at 37 °C for approximately 6 months and one specimen was fabricated, aged 10 days, and subjected to X-ray diffraction.

Anodic Polarization Tests and Corrosion Product Analysis

Anodic polarization tests were conducted using a scanning potentiostat (EG & G Model 362, Princeton Applied Research, Princeton, NJ 08540). In preparation, exposed surfaces of the resin-embedded specimens were polished with a SiC metallographic paper (600 grit) under wet conditions immediately prior to polarization tests. One each of the Permite, Galloy, and Permite/Galloy-coupled specimens were scanned through complete anodic polarization curves from 100 mV cathodic to the open circuit potential to as high as +1200 mV (vs Standard Calomel Electrode) in Ringer's solution held at 37 °C. The pH of the Ringer's solution at 37 °C was 6.95. The scanning rate was 0.5 mV/s. The electrolyte was bubbled with nitrogen gas at a flow rate of 1 liter/minute for approximately 15 minutes prior to and throughout the scanning process. Scanning was begun after the stabilization of open-circuit potential, which took approximately 15-20 minutes.

The anodic scans of the remaining four embedded Galloy specimens were terminated, one at each of the four peaks previously observed on the complete anodic polarization curve. Each peak on this curve was believed to correspond to different anodic reactions. After scanning, the specimens were removed, ambient air-dried, and stored in a desiccator until corrosion products were subjected to analysis. Typical corrosion-tested specimens were examined under optical and scanning electron microscopy (20 kV with a working distance of 15-25 mm).

The corrosion products were subjected to transmission electron diffraction (TED) (Phillips CM-10, Phillips, Einthoven, Netherlands) for phase identifications. The amount of collected corrosion products was not large enough for conducting the powder method of X-ray diffraction in order to identify the chemical compounds. Elemental analysis and identification of the crystalline structures of these corrosion products were conducted using TED technique. Platinum foil was used as a reference sample. By maintaining the same accelerating voltage (i e, 100 kV) for the electron diffraction, the d-spacings of each corrosion product could be calculated. The formula used was $2r_{sample}\, d_{sample} = 2r_{Pt}\, d_{Pt} = \text{constant}$, where r was the measured radius of diffracted rings for the sample and Pt foil, and d_{sample} was the lattice spacings of each crystalline index with d_{Pt} (d-spacings of Pt foil) being known (Oshida, Sachdeva & Miyazaki, 1992).

The corroded specimens were also subjected to energy dispersive X-ray spectrometry (EDS) analysis. Typical EDS conditions included an accelerating voltage of 20 KeV, a beam incidence angle of 70°, an X-ray emergence angle of 28°, an X-ray window incidence angle of 8.9°, and a data acquisition preset time of 100 seconds.

After analyses of the corrosion products, these same Galloy specimens were aged 6 months at 37 °C. The aged specimens were then resurfaced with 600-grit SiC paper and subjected to previously

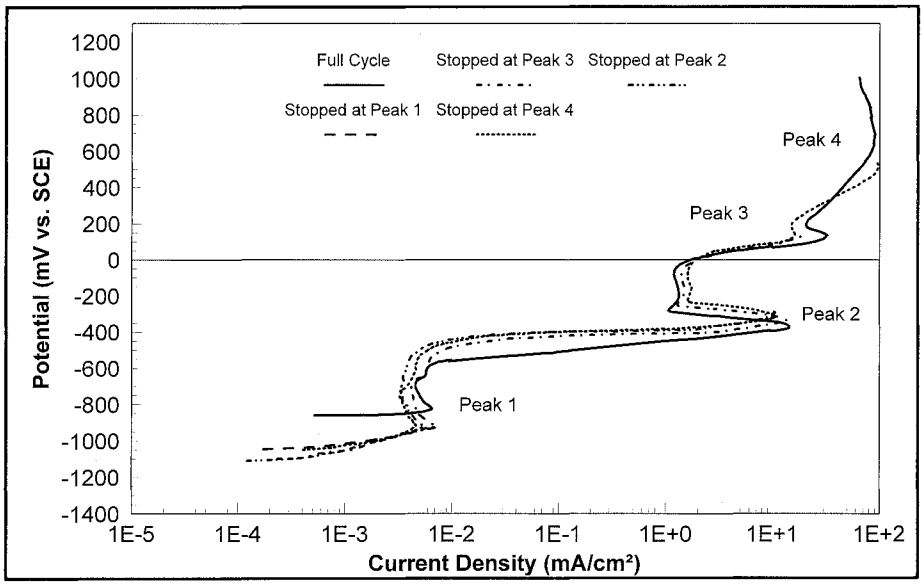

Figure 2. *Full cycle and interrupted anodic polarization curves of Galloy specimens*

described anodic polarization testing. This was done to determine if aging caused changes in corrosion behavior in Galloy.

To determine if age-related phase changes occurred in Galloy, three different Galloy specimens were analyzed using an X-ray diffractometer (Siemens Diffraktometer, Model D-500, Siemens Analytical X-Ray Systems, Inc, Madison, WI 53719) using the CuKα line, with a single channel analyzer that required no filter. The specimens consisted of one 6-month-old specimen that had undergone polarization testing, a 6-month-old specimen that had not undergone polarization testing, and a newly fabricated 10-day-old specimen that had not undergone polarization testing.

Immersion Test and Corrosion Product Analysis

One Galloy, one Permite, and one Galloy/Permite coupled specimen, none of which had been previously corrosion tested, were polished dry using a slow-speed hand rotor and separate Shofu (Shofu, Inc, Kyoto 605, Japan) amalgam polishing points until a mirror surface was obtained. These specimens were then stored separately in glass beakers containing 80 ml of Ringer's solution at 37 °C for approximately 1 week. At the completion of this immersion test, corrosion products from the specimen were analyzed using TED, as described previously.

Microstructural Observations

Microstructural characteristics of two typical gallium specimens were examined. One of these specimens had not undergone corrosion testing, while the other sample had undergone immersion testing. The surface of the untested gallium sample was polished with 600-grit SiC paper and etched for 5 seconds with Aqua Regia (H20:HCl:HNO3 = 1:3:1 by vol). This specimen was examined and photographed using the SEM and light microscopy. The SEM examination was conducted at 20kV with a working distance between 15 and 25 mm. The immersion-tested sample was cleaned and slightly etched with ethyl alcohol containing 2 vol% of nitric acid. Microstructure was observed with an optical microscope and photographed.

RESULTS

Anodic Polarization Tests and Corrosion Product Analysis

Figure 2 illustrates the first anodic polarization curves of five identical Galloy specimens. The curves

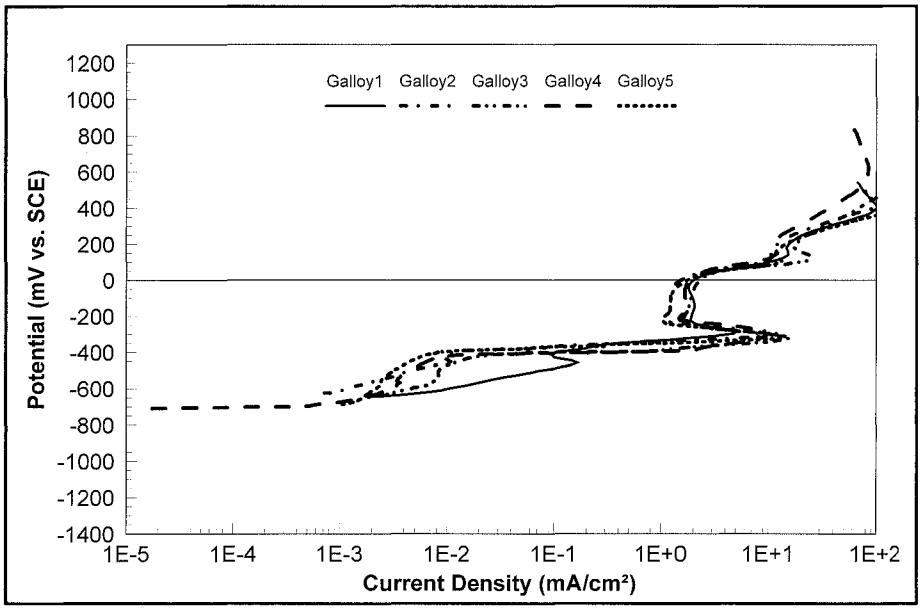

Figure 3. *Full cycle polarization curves of previously corroded, 6-month-old Galloy specimens*

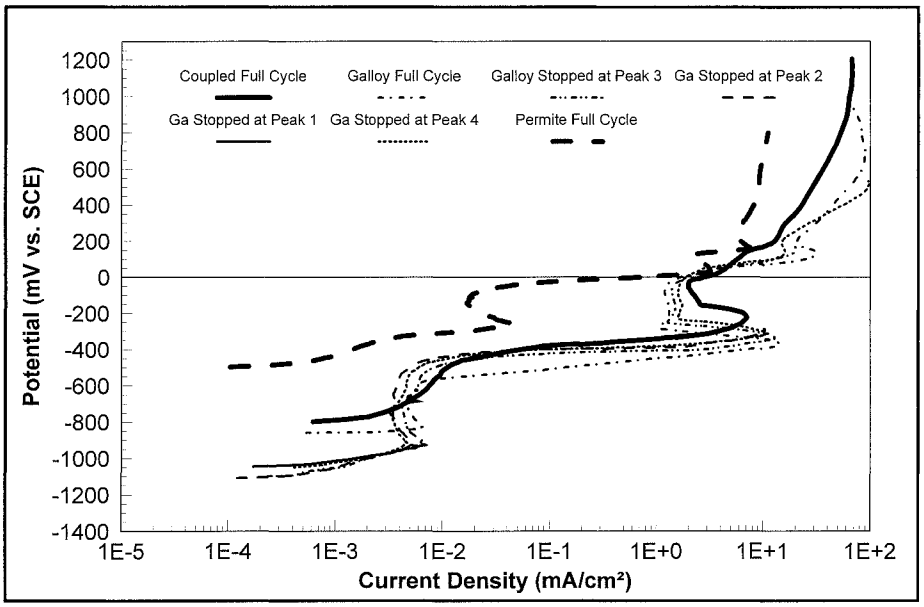

Figure 4. *Comparison of anodic polarization curves for nonaged Galloy specimens and Permite*

represent specimens 1-5, which include one complete scan and four partial scans corresponding to each of the four observed current density peaks. The first anodic polarization peak was found between -940 mV and -860 mV, followed by a slight decrease in current density and a sharp increase between -575 mV and -435 mV. The second peak occurred between -400 mV and -350 mV, followed by a slight decrease in current density and a sharp increase between 0 mV and 50 mV. The third peak occurred at about +125 mV, and the fourth peak occurred between +400 mV and +600 mV. A small region of quasi-passivation was evident between -260 mV and -10 mV potential.

The plotted anodic polarization curves from the same specimens after aging 6 months were depicted in Figure 3. In both Figures 2 and 3, the anodic polarization curves are in close proximity to each other, indicating the reliability of the methodology. Comparing the original polarization curves (Figure 2) with those made at 6 months (Figure 3), the following observations can be made: (1) The general shapes of the curves are the same, except the first anodic peak is much less pronounced or nonexistent in the aged specimens, and (2) the curves are shifted in the aged data to slightly higher potentials.

Comparison of X-ray diffraction patterns of new and aged Galloy specimens, that had not undergone polarization testing, revealed that aging resulted in: (1) increased diffracted integrated intensities of In_4Ag_9 and $CuGa_2$, (2) sharpened diffracted lines corresponding to these phases, (3) decreased line broadening of these phases, and (4) the presence of unconsumed γ-Ag_3Sn, although the diffracted integrated intensities remained unchanged.

Figure 4 compares the anodic polarization curves obtained from Galloy, Permite, and Permite/Galloy-coupled specimens. As seen from the figure, the polarization curve of the Permite specimen exhibited relative cathodic behavior when compared with the Galloy specimens.

The coupled Galloy/Permite specimen when compared with the uncoupled Galloy specimens exhibited similar behavior in terms of the onset of the second and third anodic dissolution peaks. In both cases, however, the peaks occurred at slightly higher potentials and lower current densities (Figure 4).

Due to similarities of atomic structures of silver and tin elements, it was difficult to distinguish between these elements using the semi-quantitative EDS analysis. Elemental analysis of the corrosion products of the uncoupled specimen (Full Cycle) indicated that Ag predominated, while Sn predominated in the corrosion products on the coupled specimens.

During polarization tests of Galloy, two different visible corrosion products formed. At the first current peak (Figure 2), no corrosion was apparent to the naked eye. At the second anodic dissolution peak, a distinct gray or blackened surface was evident. As determined by TED, each diffraction line from the corrosion product at peak 2 was consistent with α-Ga_2O_3, and its lattice spacing was checked against the ASTM X-ray Powder Data File No 6-503 (1967). At the third anodic dissolution peak, distinct white corrosion products became evident. TED indicated that all diffraction lines from this corrosion product were also consistent with α-Ga_2O_3.

After the onset of the third anodic peak, white precipitates began to form on the specimen. SEM analysis of Galloy specimens subjected to full cycle anodic polarization testing revealed cubic-shaped crystals consisting primarily of Ag and Sn, as determined by EDS. TED analysis revealed every diffracted line as SnO_2 (ASTM X-ray Powder Data File No 5-467, 1967).

For comparison, SEM analysis of Permite revealed a globular aggregation of small angular crystals (Figure 5, arrow) both of which consisted primarily of Cu as determined by EDS.

The general appearance of anodic polarization-tested Galloy coupled with Permite was found to be very similar to the previous case, which was not coupled with Permite. EDS analysis identified the corrosion product collected from the Galloy side as SnO_2.

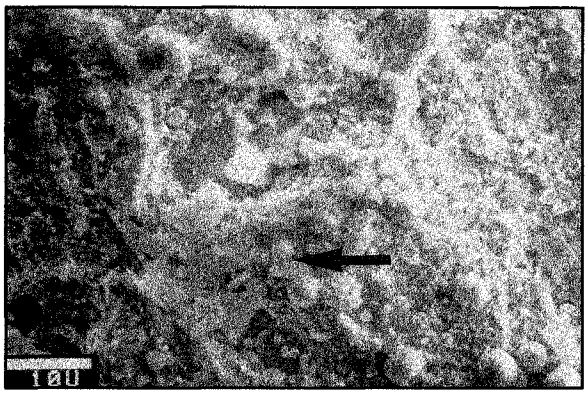

Figure 5. *SEM analysis of Permite, a globular aggregation of small angular crystals (arrow) consisting primarily of Cu as determined by EDS (original magnification X700)*

Immersion Test and Corrosion Product Analysis

The gross appearance of the Galloy and Galloy/Permite-coupled specimens after 1 week of immersion in Ringer's solution at 37 °C revealed gray and white corrosion precipitates that were very similar to the appearance of those specimens that had undergone complete anodic polarization testing. Figure 6 illustrates the appearance of a Galloy/Permite coupled specimen that had been immersion tested. The corrosion products found at the bottom of the beaker containing the Galloy specimen show crystalline configurations very similar to those observed on Galloy of the Galloy/Permite-coupled

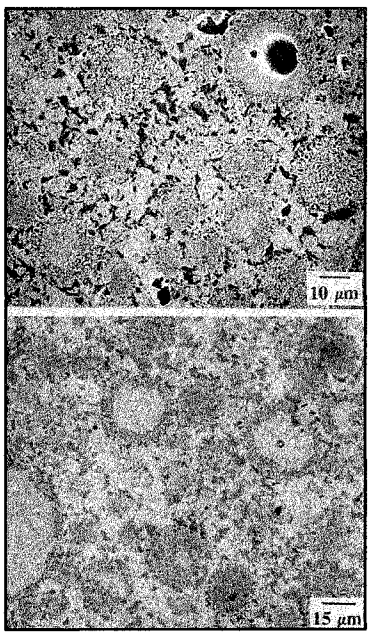

Figure 7. *(Top): Microstructure of Galloy specimen before corrosion testing, etched with Aqua Regia SEM, original magnification X400; (Bottom): light microscopy, original magnification X333.5*

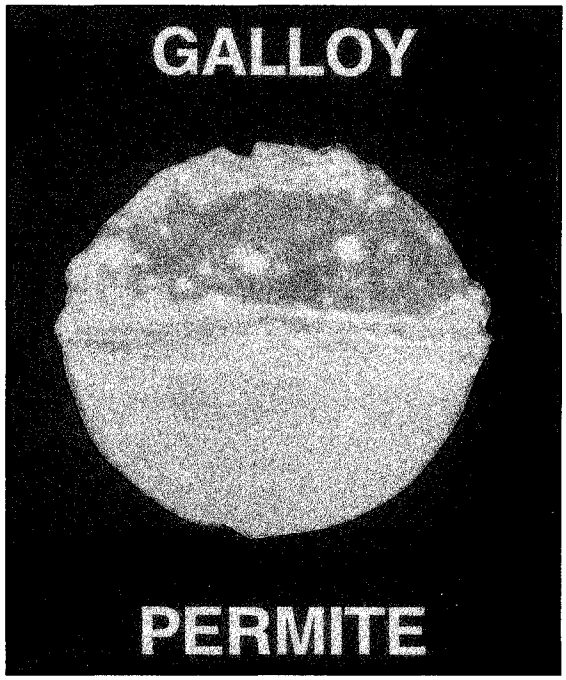

Figure 6. *Permite/Galloy-coupled specimen after immersion testing in Ringer's at 37 °C*

specimen. All lines diffracted from the corrosion products collected from the Galloy surface of the Galloy/Permite couple were identified as SnO_2. SEM and EDS examination of the Galloy side of this same immersion-tested specimen revealed a peripheral zone of the particles that were surrounded with cubic crystals that was identified as SnO_2. As in the immersed Galloy specimen, the corrosion product consisted primarily of Ag and Sn, but traces of Hg were also present, no doubt due to the sampled location's proximity to the Permite half.

Microstructural Observations

The result of cleaning the representative Galloy specimen with Aqua Regia is depicted in Figure 7 (SEM, top; light microscopy, bottom). The result of cleaning the postcorroded Galloy specimen is depicted in Figure 8 (light microscopy). The structure appeared to be a mix of unconsumed spherical alloy particles within a reaction matrix. The examination also revealed that the periphery of the unconsumed particles was selectively attacked.

DISCUSSION

Endo and others (1992), while conducting tests on a gallium-based restorative, observed sharp increases in current densities at approximately -400 mV in 1 wt% NaCl solution vs Ag/AgCl electrode. Oshida and Moore (1993), also testing a gallium-

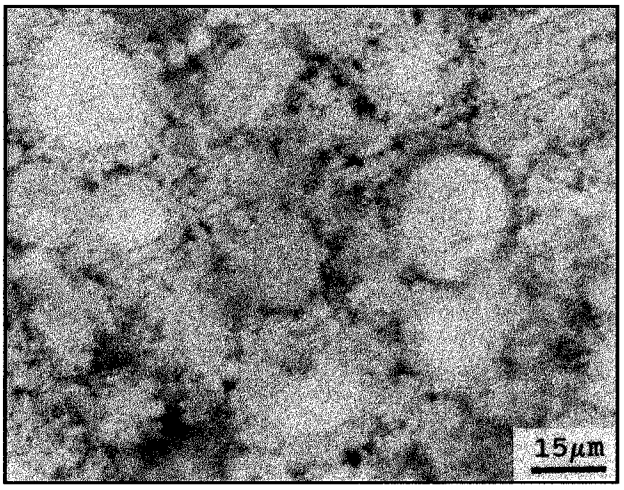

Figure 8. *Microstructure of Galloy specimen after corrosion testing, nonetched and cleaned with ethyl alcohol containing 2 vol% nitric acid (light microscopy, original magnification X667.03*

based restorative, observed a rapid increase in current densities in the region of -300 to -350 mV. However, in each of these previous studies, there was no evidence of a peak in the region between -940 mV and -860 mV, as observed in the present study. Furthermore, no corrosion products associated with this peak were identified using TED analysis. In efforts to determine if this peak was the result of the corrosion of a transitory phase, anodic polarization tests were repeated on Galloy specimens 1-5 after aging for approximately 6 months, and it was discovered that changes in the polarization curves did occur. These observations suggested that some type of phase change may have been occurring in the alloy as a result of aging. To test this hypothesis, three Galloy specimens were analyzed using X-ray diffraction. Observations of sharpened and decreased broadening of diffracted lines of In_4Ag_9 and $CuGa_2$ from this analysis suggested that aging resulted in: 1) a nonuniform compositional gradient being changed to a more uniform one, 2) internal stresses within each phase being relieved, and 3) an increase in the amount of crystalline particles of each phase contributing to the diffraction. Observation of increased diffracted integrated intensities of the same two phases (In_4Ag_9 and $CuGa_2$) and the presence of unconsumed γ-Ag_3Sn suggested that aging may promote further dissolution of solid ε-Cu_3Sn phase to form $CuGa_2$, and the increase in In_4Ag_9 may be the result of the reaction: solid γ-Ag_3Sn + liquid (Ga + In) $\rightarrow$ (Ag-Ga) + (Ag-In) + free Sn.

All of these observations suggest that phase changes occur in the alloy over time and may explain the variations in the anodic polarization curves observed in the aged specimens (Figures 2 and 3).

When comparing polarization curves of Galloy, Permite, and the Galloy/Permite-coupled specimens, one notices that the Permite curve exhibits cathodic behavior in comparison to Galloy (Figure 4).

This result suggests that if Galloy and Permite (high-copper amalgam) are placed in contact with each other, dissimilar galvanic corrosion is possible in the oral cavity with preferential corrosion of the Galloy material. The EDS analysis indicated that Ag predominated in the corrosion products of the uncoupled specimen, while Sn predominated in the corrosion products of the coupled specimens. This suggests that the corrosion reaction that occurs when Galloy and Permite are adjacent to each other is controlled primarily by the dissolution of tin. Similar in vitro results were observed by Oshida and Moore (1993).

The TED analysis of the gray or black corrosion products collected at peak 2 was consistent with α-Ga_2O_3. A blackening of a Ga-Pd-Sn alloy was described by Waterstrat (1969) in which the formation of white crystals that formed on the surface were identified as GaO(OH). In the present study, preparation of the specimen for TED analysis may have dehydrated the GaO(OH), producing α-Ga_2O_3.

Elemental analysis was not conducted in this study on the specimens that underwent microstructural examination. However, it is possible that the composition of the unconsumed particles retained their premixed composition of Ag, Sn, Cu, and Pt with a Ga-enriched area at the periphery of the particle that was dispersed within a Sn-rich matrix. Similar compositions were determined with Gallium GF in a previous study (Oshida & Moore, 1993).

In summary, the corrosive response of the gallium-based restorative in deoxygenated Ringer's solution held at 37 °C resulted in the formation of corrosive products rich in Ga and Sn as determined by EDS. Following the initial age-related peak (Peak 1, Figure 2), there were three distinct current density peaks in the anodic polarization curve. The first and second of these peaks (Peak 2 and 3, Figure 2) occurred between -400 mV and -350 mV and current density 1.5×10 mA/cm^2, and 100 mV and 125 mV and current density 2.5-3.1 x 10 mA/cm^2 respectively. The primary corrosive product identified at both of these peaks consisted of α-Ga_2O_3 as determined by TED. The corrosion product associated with the third of these peaks (Peak 4), which occurred at 725 mV and current density 9.1×10 mA/cm^2, consisted primarily of SnO_2 as determined by TED. When the gallium-based restorative was coupled with the high-copper amalgam alloy, the first and second anodic peaks occurred at similar, but higher potentials and at lower current densities than the uncoupled specimens. This

suggested that coupling the gallium-based restorative with the more noble high-copper amalgam may cause accelerated electrochemical corrosion. The immersion-tested coupled specimen lends support to this hypothesis (Figure 6).

CONCLUSION

From a clinical standpoint, a new gallium-based restorative material could be considered more corrosion prone than a representative high-copper amalgam, based upon this laboratory corrosion study. Furthermore, placing a gallium-based restorative material in direct contact with a high-copper amalgam may cause preferential and accelerated corrosion of the gallium-based restorative. Two laboratory corrosion products predominated, namely, α-Ga_2O_3 and SnO_2. Prolonged aging of the Galloy material may result in stress relief and phase changes that may affect corrosion behavior over time.

Acknowledgment

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The Effect of Internal Bevel on Marginal Leakage at the Approximal Surface of Class 2 Composite Restorations

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Clinical Relevance
An internal bevel of the cervical margins of class 2 composite restorations reduces marginal leakage compared to a conventional butt-joint cavity preparation.

SUMMARY

The aim of this study was to assess the effect of intentionally leaving undermined enamel (internal bevel) along the cervical margins of class 2 composites on marginal leakage. Conventional MO and DO cavity preparations were prepared in 25 extracted permanent premolars. In each tooth the cervical margin was a butt-joint for the control group and an internal bevel for the experimental group. A transparent celluloid matrix was adapted and the teeth were restored with Scotchbond Multi-Purpose and increments of Z100. A U-shaped increment was attached to the buccal and lingual walls and cervical floor of the box, leaving a gap for a middle increment. A third increment filled the occlusal part of the cavity. Following thermocycling the teeth were immersed in basic fuchsin for 24 hours, and 0.5 mm-wide sections were cut in a mesiodistal direction. Dye penetration was scored: 0 = no penetration; 1 = dye along enamel tooth interface; 2 = dye along the gingival floor; 3 = dye along pulpal wall; 4 = dye penetration into dentinal tubules. The experimental group showed 17 teeth (68%) with no dye penetration, compared to eight (32%) in the control group. Severe dye penetration (score 4) was found in only four teeth (16%) of the experimental group and 12 (48%) of the controls. The difference between the groups was statistically significant (Wilcoxon matched-pairs signed-rank test; $P < 0.01$). This study showed that an internal bevel at the cervical margins of class 2 composite restorations reduces marginal leakage when compared to a conventional butt-joint cavity preparation.

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INTRODUCTION

The traditional retention form of cavity preparations lost its relevance when the acid-etch technique was found to bind composite materials effectively to enamel. The surface size and pattern of etched enamel surrounding cavity preparations (and recently dentin) became dominant factors influencing

retention of restorative composite materials, rather than convergence of cavity walls. As a result, new conservative cavity preparations were designed preserving sound tooth structure (Simonsen, 1985; Kreulen & others, 1995) and involving a wide area of beveled enamel, intending to reduce marginal leakage (Wilder, 1985; Hinoura, Setcos & Phillips, 1988; Marzouk & Bhaiji, 1989; Porte & others, 1984).

Several studies have evaluated the sealing efficacy of beveled enamel of class 5 cavity preparations (Eriksen & Buonocore, 1976; Marzouk & Bhaiji, 1989; Porte & others, 1984; Retief, Woods & Jamison, 1982) and at the occlusal and buccal surfaces of class 2 cavity preparations (Moore & Vann, 1988; Derhami, Coli & Brännström, 1995; Wilder, 1985). However, the cavosurface finish of the enamel wall at the cervical margins of class 2 cavity preparations gained only little attention (Lutz & others, 1985; Suzuki, Jordan & Broksman, 1985; Hinoura & others, 1988). Lutz and others (1985) and Hinoura and others (1988) reported high percentages of excellent margins for class 2 cavity preparations in which the cervical enamel was beveled and etched prior to restoration. Suzuki and others (1985), on the other hand, claimed that "bevels often obscure a well-delineated cavosurface finish line, thereby commonly resulting in a thin fin of marginal excess material which is prone to fracture under occlusal loading, leaving a ledge type defect."

Beveling the enamel and restoring the tooth with a composite material may present excellent results in vitro (Eriksen & Buonocore, 1976; Porte & others, 1984; Lutz & others, 1985; Moore & Vann, 1988; Hinoura & others, 1988). However, several difficulties may arise when trying to prepare a bevel at the cervical margin of the approximal box and restore the tooth in the clinical setting: the interdental papilla may become injured by the high-speed bur and bleed; the etching agent may leak and harm the gingiva; the gingival fluid may contaminate and dilute the acid, thereby reducing its chelating effect; the cervical sulcular fluids and blood may contaminate the etched enamel, compromising the retention of the composite and increasing marginal leakage; tight adaptation of the matrix band to the etched enamel may damage the tags; and, in addition, the attached matrix band may interfere with application of the bonding agent and composite material.

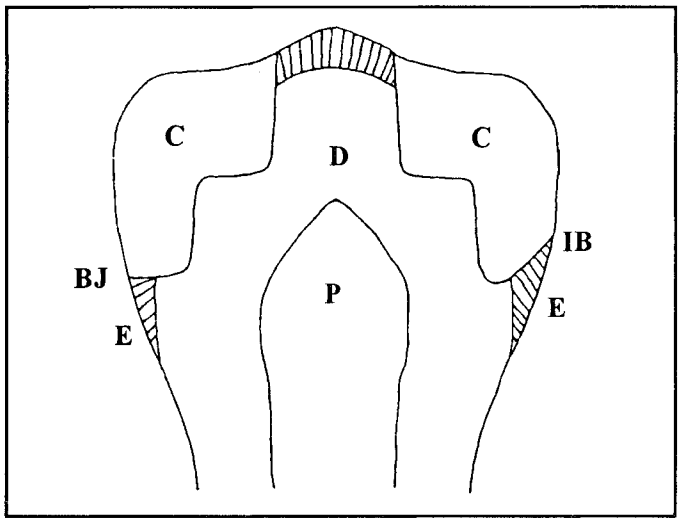

Figure 1. *Design of cavity preparations. BJ = butt joint; IB = internal bevel cavosurface preparation at the cervical margins of the approximal box; C = composite; D = dentin; E = enamel; P = pulp.*

It may be possible to cope with the aforementioned problems by creating an internal bevel. The internal bevel is a modification of the conventional class 2 cavity preparation (Figure 1). It is prepared by intentionally leaving undermined enamel at the margins of the approximal box. The undermined enamel has an inner surface ready to be etched that serves as an additional barrier to marginal leakage.

The purpose of the present in vitro study was to compare the microleakage between the tooth and the composite restoration for internal bevel and butt-joint cavosurface preparations at the cervical margin of class 2 restorations.

METHODS AND MATERIALS

Twenty-five permanent premolars extracted for orthodontic purposes were included in the study. The teeth were either intact or had a small carious lesion. The collected teeth were stored in tap water at room temperature until the beginning of the study procedures and during the study itself.

Cavity Preparations

Conventional MO and DO preparations were prepared in each tooth, using a #330 tungsten high-speed bur with water-spray coolant, locating the cervical margins of the approximal box in the enamel. In each tooth the cervical margin of one preparation was prepared as a butt-joint for the control group (Group BJ = Butt-Joint). The approximal cavosurface of the other preparation in each tooth was modified to create an internal bevel (experimental Group IB = Internal Bevel). This was prepared by removal of dentin along the approximal dentin enamel junction, intentionally leaving undermined intact enamel.

Restorative Procedure

A transparent celluloid matrix band was adapted to the teeth, and the preparations of both groups were filled using the same restorative procedure as

follows:

Scotchbond Multi-Purpose (3M Dental Products, St Paul, MN 55144) was applied to the enamel and dentin according to the manufacturer's instructions using 37% phosphoric acid as the etching agent. The preparations were filled with Z100 (3M Dental Products) in increments. A U-shaped increment was attached to the buccal and lingual walls and cervical floor of the approximal box, leaving a gap for a middle increment. A third increment filled the occlusal part. The composite was trimmed and each increment cured separately for 20 seconds. The restored teeth were kept at room temperature and at 100% humidity for 10 days to prevent dehydration and allow hygroscopic expansion.

The following steps were carried out to prepare the teeth for evaluation of marginal leakage: The teeth were thermocycled for 1500 cycles between 4 °C±2 and 60 °C±2, with dwell time of 1 minute in each bath, and 20-second intervals between the baths in ambient atmosphere. The surfaces of the teeth, apart from the restoration and 1 mm of the surrounding enamel, were coated with utility wax and nail varnish. The coated teeth were immersed in a 2% solution of basic fuchsin for 24 hours. The coatings were then peeled off by grinding and the teeth were then embedded in acrylic resin. The teeth were then sectioned from the buccal or lingual surface in a vertical plane parallel to the mesiodistal axis of the tooth. One-half millimeter-thick sections were obtained using an Isomet low-speed saw (Buehler Ltd, Lake Bluff, IL 60044) with a 0.3 mm-thick diamond wafering blade #11-4254 (Buehler Ltd). This allowed evaluation of dye penetration of each restoration in four to five different planes. Two examiners (GH and EE) scored the sections independently under a binocular microscope to evaluate dye penetration between the restoration and the tooth at the cervical margins. Dye penetration was rated according to the following scores established by previous studies (Eidelman & others, 1990; Holan & others, 1992): Degree 0 = no dye penetration; Degree 1 = penetration of dye between the restoration and the tooth along the composite-enamel interface only; Degree 2 = penetration of dye along the entire length of the cervical floor of the filling, but not along the pulpal wall; Degree 3 = penetration of dye along the entire length of the cervical floor of the filling, including the pulpal wall; Degree 4 = penetration of dye along the composite-tooth interface and into the dentinal tubules.

Always the most severe degree of dye penetration observed on any section of each tooth was recorded. Sections were reevaluated in cases of disagreement between the examiners and discussed until consensus was achieved.

The results of the two groups were compared using a two-tailed Wilcoxon matched-pairs signed-ranks test.

RESULTS

The results of dye penetration evaluation in both groups are presented in the table. The experimental (IB) group showed 17 teeth with no dye penetration (score 0), compared to eight in the control (BJ) group. Severe dye penetration (score 4) was found in only four teeth of the experimental group and 11 of the controls (Figure 2). The differences between

Distribution of Restorations by Type of Approximal Cavosurface Preparation and Degree of Dye Penetration

Degree of Dye Penetration	Type of Approximal Cavosurface Preparation			
	Internal Bevel		Butt-Joint	
	n	%	n	%
0	17	68	8	32
1	2	8	2	8
2	2	8	3	12
3	0	0	0	0
4	4	16	12	48
Total	25	100	25	100

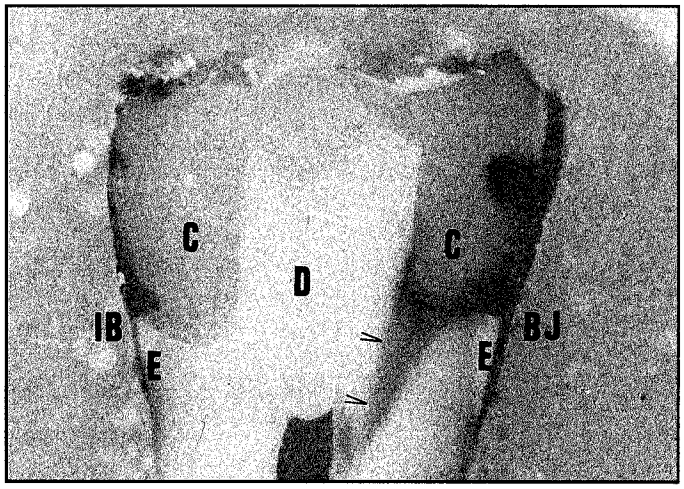

Figure 2. *Section of a restored tooth showing severe dye penetration (arrow) in the butt-joint preparation (B) and no leakage in the internal bevel cavosurface (IB). C = composite; D = dentin; E = enamel.*

the results of the two groups were found to be statistically significant ($P < 0.01$).

DISCUSSION

The present study showed that preparation of an internal bevel at the approximal cervical margin significantly reduced microleakage compared to the conventional butt-joint cavosurface. The finding is in agreement with a study by Eriksen and Buonocore (1976), who found little or no leakage in beveled restorations while a high degree of marginal leakage occurred in butt-joint restorations. This finding can be attributed to two main factors: the width of the etched enamel and the direction of the enamel prisms.

Past research has demonstrated that etched and bonded enamel reduces microleakage (Buonocore, Sheykholeslam & Glena, 1973; Crim & Shay, 1987). It seems logical, therefore, that larger areas of etched enamel would minimize or prevent marginal leakage. Enamel surface area is wider when it is cut diagonally (in the internal bevel cavosurface) than when it is cut in a cross-sectional direction (in the butt-joint cavosurface). Furthermore, as enamel becomes narrow close to the cementoenamel junction, preparation of a butt-joint cavosurface angle leaves a very narrow enamel surface to etch and bond.

In permanent teeth enamel prisms located in the cervical region are oriented apically (Sicher & Bhaskar, 1972). The internal bevel design exposes the enamel prisms in a cross section (Boyde, 1985). It has been suggested that bonding to the surface of longitudinally cut enamel prisms is not as strong as to cross-cut enamel prisms (Gwinnett & Matsui, 1967; Buonocore, Matsui & Gwinnett, 1968). The butt-joint and the traditional external bevel, on the contrary, are directed almost parallel to the enamel prisms, resulting in a poor etching pattern (Lutz & others, 1985). Lutz and others (1985) discussed the failure of a gingivo-proximal bevel to improve the quality of marginal adaptation. They claimed that forces generated by polymerization shrinkage in the restorative material exceeded the cohesive forces between the enamel prisms. It remains to be proven whether this argument is also relevant to the internal bevel restoration. Preserving sound tooth structure while preparing the internal bevel fits the general concept of cavity preparation that changed after the introduction of the acid-etch technique and composite materials (Leinfelder, 1996).

CONCLUSION

This in vitro study showed that an internal bevel at the cervical margin of class 2 composite restorations reduced marginal leakage as compared to a conventional butt-joint cavity preparation.

Acknowledgment

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Progression of Dental Demineralization with and without Modified Tunnel Restorations in Vitro

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Clinical Relevance
Modified tunnel restorations utilizing glass-ionomer cement may inhibit the progression of demineralization.

SUMMARY

This study evaluated the caries-inhibitory effects of a glass-ionomer cement restoration. As a model to assess these effects, a Ketac-Fil restoration was placed beneath the mesial or distal enamel layer in 14 extracted human molars by means of access from the occlusal fossa. The teeth were insulated in all but two areas on the approximal surfaces. The prepared teeth were mounted on a hollow cylinder and a localized progressing demineralization of the approximal surfaces was induced by storage of the samples in an acidified gel. Immediately before and 14, 21, 28, 35, and 42 days after initiation of demineralization, standardized radiographs were obtained to assess the progression of demineralization. On each radiograph, the demineralized lesions were assessed by measurement of the coronoapical extension (CA) and the central depth (CD). At 28, 35, and 42 days after initiation of the demineralization, the CD of the lesions of the glass-ionomer cement group was revealed to be statistically significantly smaller than the lesions of the control group (no tunnel restoration) ($P < 0.1$). A multiple linear regression analysis identified CA and time as factors correlated to CD positively and the glass-ionomer restoration as a factor related to CD negatively ($P < 0.001$). It seems that modified tunnel restorations utilizing glass-ionomer cement inhibit progression of dental demineralization in vitro.

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INTRODUCTION

A favorable property of glass ionomers is their release of fluoride when exposed to the oral environment (Tveit & Gjerdet, 1981; van de Voorde, Gerdts & Murchison, 1988; Swift, 1988, 1989; Mount, 1991). Fluoride from glass-ionomer restorations can be taken up by the surrounding dental hard tissues (Wesenberg & Hals, 1980; Retief & others, 1984) and may inhibit recurrent caries (Swift, 1988). This leads to the hypothesis that glass-ionomer cement may inhibit or reduce the progression of demineralization even in a very aggressive caries model.

The purpose of the present study was to evaluate to what degree a glass-ionomer cement restoration

might influence the progression of dental demineralization, as related to time in vitro, and thereby represent a caries-inhibitory fluoride depot.

METHODS AND MATERIALS

Specimens

After extraction in the Department of Dento-maxillofacial Surgery at the University of Heidelberg and storage in distilled water containing thymol (Silverstone & Poole, 1969), 14 human molars were selected as clinically caries-free. On each tooth, a modified tunnel preparation was performed on either the mesial or distal side of the tooth. Therefore, from access in the occlusal fossa, the dentin beneath the enamel of the interproximal surface could be removed (Figure 1) (McLean, 1988). This modification of the tunnel restoration has been used in this study as a model to study the influence of glass-ionomer cement on the demineralization of enamel. The tooth surface was insulated by nail varnish, so the only way fluoride released from the glass-ionomer cement could reach the demineralization area was through sound dentin and enamel. Fluoride could not be released into the acidified gel and thereby influence the lesions on either side, test or control. These tunnel preparations were restored with a glass-ionomer cement (Ketac-Fil, ESPE, Seefeld/Oberbay, Germany). The remaining interproximal surface of each tooth was left untreated and served as a control. Random assignment determined which interproximal surface of each tooth (mesial or distal) served as the test side. The preparation of the specimen was carried out according to Lenhard and others (1996). The teeth were covered with a layer of varnish, leaving a varnish-free window (2.2 mm in diameter) on each approximal surface. The teeth were attached to the open end of a hollow, methacrylate resin cylinder (Technovit 4071, Haereus Kulzer, Wehrheim, Germany) using a fixing agent of self-curing, methacrylate resin (Trim, Bosworth Company, Skokie, IL 60076). A metal ball was fixed onto the Trim material such that it was sitting at a level approximately adjacent to the nonvarnished window. Thus the radiographic image of the metal ball and of the carious lesion would exhibit the same magnification. The diameter of the metal balls (B) had been assessed by a micrometer screw-gauge (Digamatic, Mitutoyo, Tokyo, Japan). Mean diameter was calculated as B = 2.30 ± 0.07 mm. In addition, two orthodontic wires (0.016", round and square) each of approximately 1 mm in length were embedded coaxially and vertically into the walls of the hollow cylinder, 20 mm apart from each other (Lenhard & others, 1996). The distance was measured using callipers (Aesculap, Tuttlingen, Germany). This distance (20 mm) had already been used in filmholders for periodontal trials (Duckworth & others, 1983; Eickholz, Dörfer & Staehle, 1994; Eickholz, Benn & Staehle, 1996). At this stage, the specimens were stored in an acidified gel (methylcellulose, acetate-buffer, pH = 4.8) for a total of 42 days (minus 60 minutes) at 37 °C. In order to take radiographs, each specimen was removed from the gel for approximately 15 minutes at a time on days 14, 21, 28, and 35.

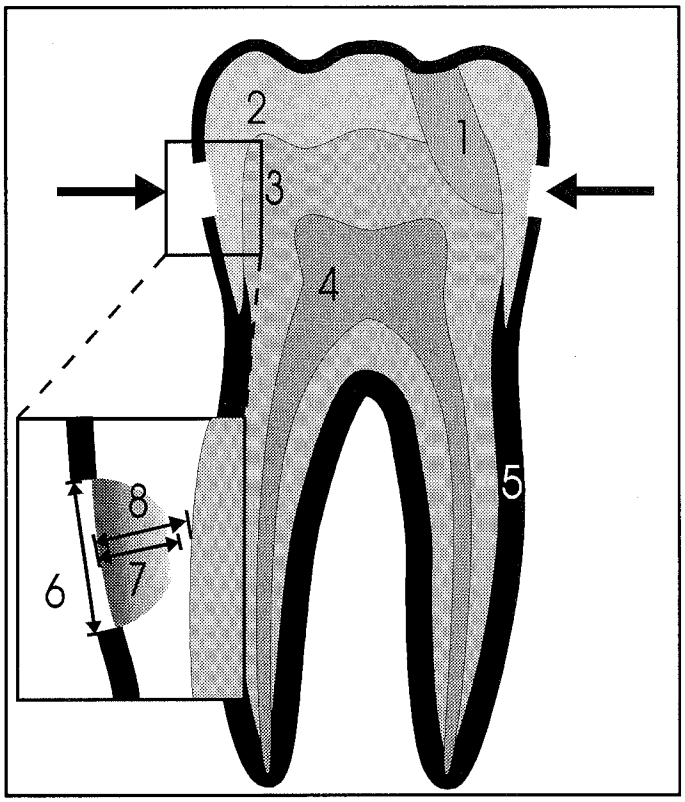

Figure 1. *Tooth prepared for immersion in acidified gel. 1 = glass-ionomer tunnel restoration; 2 = enamel; 3 = dentin; 4 = pulp chamber; 5 = layer of nail varnish; arrows = windows in the layer of nail varnish. Enlarged square with radiographic measurements (approximal surface with demineralization after immersion in acidified gel): 6 = coronoapical extension of the demineralization; 7 = central depth of the demineralization; 8 = thickness of enamel layer at the central site of the demineralization.*

Radiographic Evaluation

Radiographic evaluation has been previously described in detail elsewhere (Lenhard & others, 1996). In short, the evaluation was performed as follows: Immediately before initiation of demineralization and 14, 21, 28, 35, and 42 days thereafter, standardized radiographs were taken of each specimen. The test samples were placed on radiographic film (Ultraspeed 31 x 41 mm, Kodak, Stuttgart, Germany) and positioned in a distance

holder. The X-ray tube was fixed to the distance holder. The films were irradiated (exposure time 0.32 seconds; Heliodent 70, 70 kV, 7 mA, Siemens, Bensheim, Germany) and developed immediately following exposure under standardized conditions (Periomat, Dürr-Dental, Bietigheim-Bissingen, Germany). The radiographs were examined on a radiograph viewing box with a blackout screen apertured to the size of the radiographs. The horizontal (d_h) and vertical (d_V) distance between the radiographic images of the wires, as measured from the left rim of the shadows cast for horizontal, and from the coronal rim of the shadows cast for vertical distances, was assessed on each radiograph (as a reference the radiographs were oriented with the shadow of the metal ball at the upper right hand corner; Figure 2). In addition, the diameter of shadows cast by the metal ball (B_r) was measured. Finally the extent of demineralization was measured as (i) coronoapical extension on the enamel surface [CA], (ii) central depth of the demineralization [CD], and (iii) thickness of the enamel layer at the central site of the demineralization [TE] respectively (Figure 1). The TE value of the baseline measurement was used to relocate the central site of the demineralization for the consecutive assessments. All metric measurements were performed by one examiner (ML) using a X10 magnification loupe and a 0.1 mm grid (Scale loupe X10, Peak, Tohkai Sangyo, Tokyo, Japan). The assessments of CA, CD, and TE were repeated after 7 days by the same examiner.

Assuming a parallel central beam, the angulation (α) of the central beam as related to the orthoradial projection was calculated by the following formula (d = distance between the shadows cast by the wires): α = arc tan d/20 mm.

Using the angulation to the orthoradial projection of a single radiograph, vertical and horizontal angulation differences between consecutive radiographs could be calculated. The magnification factor (M) for each radiograph was calculated by: $M = B_r/B$.

After statistical analysis, the distance between the glass-ionomer restoration and the central extension of the demineralization was to be measured on the radiographs taken at the time that the first statistically significant difference between test and control could be identified, if any difference could be revealed at all.

Histologic Evaluation

After 42 days, the teeth were removed from the Trim material and embedded in methacrylate. Each artificial lesion was cut vertically in a mesiodistal direction into serial sections, using a microtome saw (Leica 1600, Bensheim, Germany). The vertical cuts completely spanned the buccolingual width of the white spot lesions. The sections were about 150 µm thick with a 200 µm tissue loss between slices due to the width of the cutting blade. From each lesion of the test side (glass-ionomer restoration), the section showing the greatest degree of demineralization in the central direction was chosen for the evaluation, whether the body of the lesion had reached the tunnel restoration or not. The evaluation of the sections was undertaken using polarized, transmitted, light microscopy at X100 magnification (Aristoplan, Leica, Bensheim, Germany) and was performed by one examiner (TP).

Statistical Analysis

The tooth was defined as a statistical unit and CD was looked upon as the main outcome variable, whereas CA served as a control variable. In order to reduce measurement error for statistical analysis means of the radiographically assessed CD and CA, replicate measurements were calculated. CD and CA of the lesions of control and test sites were then tested for statistically significant differences by

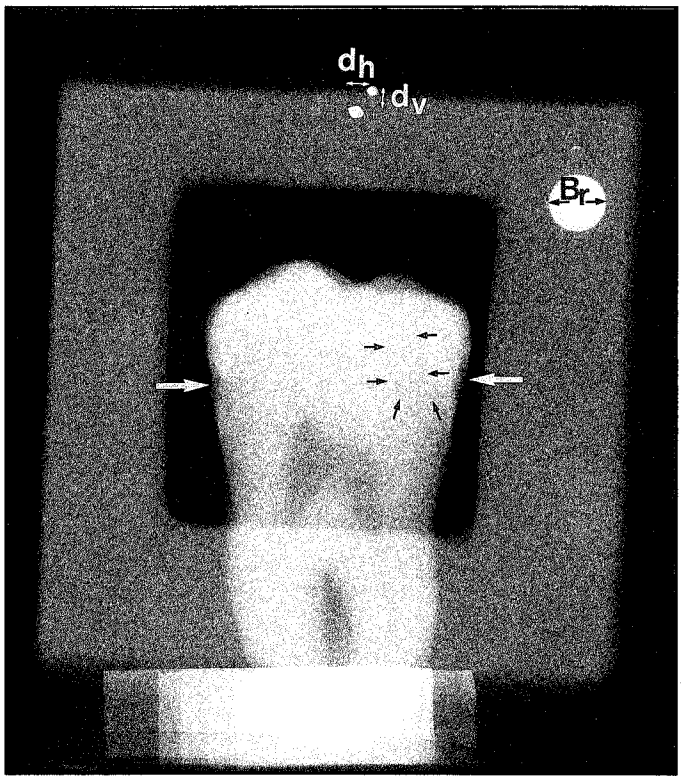

Figure 2. *Radiograph of a specimen after 42 days of immersion in acidified gel. Black arrows = glass-ionomer tunnel restoration; B_r = diameter of the image of the metallic ball; d_h = horizontal; d_v = vertical distance between the radiographic images of the wires; white arrows = demineralization. On the control side the demineralization has progressed into dentin; on the test side the lesion remains in enamel.*

means of the paired t-test ($P < 0.1$). Factors modulating the central depth were evaluated by stepwise linear multiple regression analysis (coronoapical extension, time, glass-ionomer cement restoration, vertical and horizontal angulation difference). A probability of $P < 0.05$ was defined to allow incorporation of a factor into the model.

RESULTS

Mean magnification of radiographs was calculated to be 1.086 ± 0.003. The mean angulation differences between consecutive radiographs ranged from $2.25 \pm 0.94°$ to $3.26 \pm 1.62°$ vertically and from $0.42 \pm 0.40°$ to $0.69 \pm 0.55°$ horizontally for examination days 14, 28, 35, and 42 respectively. Between baseline and day 21 radiographs, mean angulations of $4.55 \pm 2.68°$ vertically and $2.08 \pm 0.80°$ horizontally could be observed.

Central depth [CD] and coronoapical extension on the enamel surface [CA] of the artificial lesions in test and control sites at various time intervals are given in Figures 3 and 4. After 28, 35, and 42 days, the demineralizing lesions at the control sites as measured by CD had become statistically significantly deeper in comparison to the test side lesions ($P < 0.1$). With respect to CA, on none of the examination days could a statistically significant difference between test and control be revealed. The mean ± standard deviation of the distance between glass-ionomer restoration and the deepest extension of the demineralization, as assessed on radiographs from day 28, was 0.99 ± 0.47 mm. The demineralization did not reach the glass-ionomer restoration in any of the test samples.

Multiple linear regression analysis revealed that the central depth of the artificial lesions was modulated by the presence of a glass-ionomer cement restoration, demineralization time, and coronoapical extension of the lesion but not by vertical or horizontal angulation differences (table). The model explained 84% of the variation of the dependent variable [CD] ($P < 0.001$).

Histologic evaluation revealed that the body of the lesion on the test side had failed to progress into dentin in all but one of the samples. Furthermore, in all cases a layer of sound hard tissue, enamel or dentin, could be observed between the lesion and the glass-ionomer restoration.

DISCUSSION

New methods for the clinical, quantitative assessment of caries, for example, laser-induced fluorescence (Hafstrom-Bjorkman & others, 1992) or light scattering (Ogaard & ten Bosch, 1994), are currently being evaluated. However, further development and testing is required before these techniques can be adopted for routine clinical use (Angmar-Mansson & ten Bosch, 1993). At the present time, intraoral radiographs (e g, bitewing radiographs) are the only feasible method for confirming approximal caries progression in vivo (Shwartz & others, 1984). A radiographic method was chosen for this study to evaluate progression of demineralization in vitro. The advantage of this method is that the demineralization of each particular specimen could be assessed at several time points. The destruction of the specimens for examination, as is necessary for microradiographic or histological analysis, was avoided. Furthermore, results of this in vitro analysis may be transferred, to some extent, to in vivo studies using bitewing radiographs to assess approximal caries.

No threshold of angulation difference, to exclude pairs of radiographs from evaluation, was defined in this study because no statistically significant

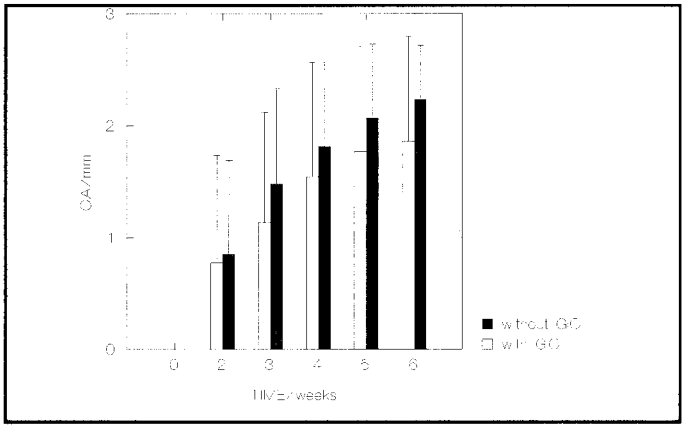

Figure 3. *Means and standard deviations of coronoapical extension (CA) of the demineralization in mm after 2, 3, 4, 5, and 6 weeks of immersion in acidified gel*

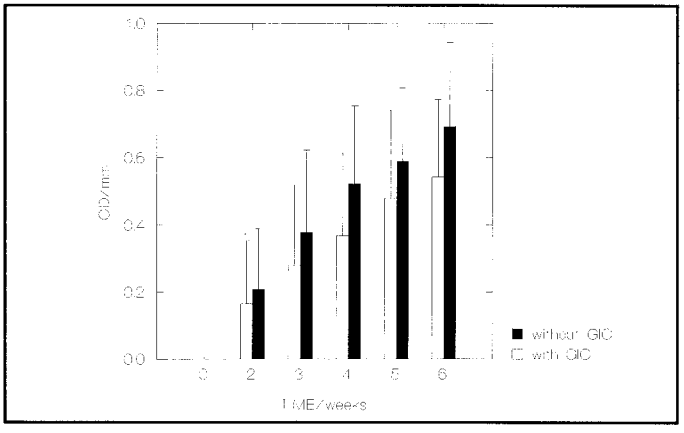

Figure 4. *Means and standard deviations of central depth (CD) of the demineralization in mm after 2, 3, 4, 5, and 6 weeks of immersion in acidified gel. Statistically significant differences between test and control after 4, 5, and 6 weeks (P < 0.1)*

Multiple Regression Analysis

	b	s e (*b*)	*β*	*P*
coronoapical extension	0.219	0.012	0.564	0.000
glass-ionomer cement	-0.043	0.018	0.979	0.021
time	0.034	0.007	0.571	0.000
constant	-0.030	0.023		0.182

Analysis of Variance

Source	SSQ	DF	MSQ	*F*-ratio	*P*
regression	12.545	3	4.182	300.844	0.000
residual	2.280	164	0.014		

Dependent variable: CD; n = 168; $R^2 = 0.846$; $R^2_{adjusted} = 0.843$; s e (estimate) = 0.118

influence, neither of horizontal nor of vertical angulation, on the main outcome variable CD could be revealed by multiple linear regression analysis. This may partially be due to the fact that effects caused by angulation differences in vivo, such as approximal overlapping, did not occur in this in vitro study. The specimens used in this study were designed to yield the same information about radiation geometry in vitro as work using modified filmholders by Duckworth and others (1983) yielded in vivo. Thus, the results of the present study may, to some extent, be applied to a clinical trial using these modified filmholders to monitor approximal carious lesions radiographically. However, for clinical studies, angulation differences between consecutive radiographs are expected to influence radiographic measurements.

A radiographic image of a demineralized area corresponding to a carious lesion is not a well-defined radiolucency as the degree of calcification increases towards the periphery of the lesion; therefore, detecting the true extent of the caries is difficult (Pitts, 1983, 1984; Pitts & Renson, 1986). For this reason, measurements of the extent of a carious lesion are difficult to perform accurately. The inter- and intraexaminer reproducibility of the radiographic measurements of the method used in this study had been calculated as standard deviation of single measurements (s) and ranged between 0.21 mm for CA and 0.07 mm for CD (Lenhard & others, 1996).

A favorable property of glass-ionomer cement is the release of fluoride when exposed to the oral environment (Tveit & Gjerdet, 1981; van de Voorde & others, 1988; Swift, 1988, 1989; Mount, 1991). Fluoride from glass-ionomer restorations can be incorporated into the surrounding dental hard tissues (Wesenberg & Hals, 1980; Retief & others, 1984). It has been demonstrated that the solubility of enamel is reduced by the intake of fluoride (ten Cate & Duijsters, 1983; Arends & Christofferson, 1986). Serra and Cury (1992) reported less demineralization adjacent to glass-ionomer restorations when compared to a composite filling material in an in vitro demineralization and remineralization model (Serra & Cury, 1992). Ten Cate and van Duinen (1995) could demonstrate hypermineralization of dentinal lesions adjacent to glass-ionomer fillings in an in situ study (ten Cate & van Duinen, 1995). Thus, it may be concluded that glass-ionomer restorations have caries-protective effects and may inhibit recurrent caries (Swift, 1988). Mjör evaluated the replacement of amalgam, composite resin, and glass-ionomer restorations in a study performed in four dental practices (Mjör, 1996). He reported recurrent caries as the reason for the replacement of almost half of the glass-ionomer restorations (Mjör, 1996). But this study was not well standardized and controlled with respect to validity of clinical caries diagnosis, patient characteristics in the different groups, caries activity, and different degrees of fluoride release for different glass-ionomer cement products (Mjör, 1996). In a better-controlled longitudinal clinical study, Powell, Johnson, and Gordon (1995) reported that 3 years after placement, just 3% recurrent caries occurred in the glass-ionomer group. This did not differ significantly from the 10% recurrent caries reported for the composite group (Powell, Johnson & Gordon, 1995). The overall low prevalence of recurrent caries in that study and the relatively short period of observation may explain the similar outcome for both materials (Powell, Johnson & Gordon, 1995). Whereas Wood, Maxymiw, and McComb (1993) found in a group of xerostomic patients who had been treated with radiation therapy, less recurrent caries adjacent to glass ionomer than to amalgam restorations (Wood, Maxymiw & McComb, 1993). It seems that the clinical relevance of the caries-inhibitory effect of fluoride-releasing glass-ionomer restorations depends on several factors (e g, caries activity, rate of fluoride release) that have to be well controlled in a clinical study, if this relevance has to be evaluated (Mjör, 1996).

A modification of the tunnel restoration has been used in this study as a model to study the influence of glass-ionomer cement on the demineralization of enamel. The tooth surface was insulated by nail varnish, so the only way fluoride released from the glass-ionomer cement could reach the demineralization area was through sound dentin and enamel. Fluoride could not be released into the acidified gel and thereby influence the lesions on either side, test or control.

For the first and second radiographic examination of the specimens, 14 and 21 days after initiation of demineralization, no statistically significant difference between test and control could be revealed for

CD. For all further radiographic examinations (days 28, 35, 42), statistically shallower lesions (CD) were observed for the test (glass-ionomer cement tunnel restorations) compared to the control. The glass-ionomer restorations were located at the dentino-enamel junction, leaving a layer of dentin between the restoration and the enamel in a few cases. Presumably, the concentration of fluoride around the restoration decreases as the distance to the filling increases. Hence, the inhibitory effect of fluorides released from the glass-ionomer restorations should be amplified with decreasing distance between the demineralization front and the filling. This may explain the fact that the demineralization had to progress for 28 days before a statistically significant difference between test and control could be observed. This theory is supported by the observation that, for CA, there was no statistically significant difference revealed between test and control. If the demineralizing process has reached enamel that contains higher amounts of fluoride released from the glass-ionomer filling, outward diffusion may take place. This diffusion occurs predominantly along the interprismatic and intercrystalline spaces filled with water and proteins and is maintained by the concentration gradient of fluoride (Featherstone, Duncan & Cutress, 1979). By this mechanism not only demineralization in the body of the lesion may be inhibited, but also hypermineralization in the surface layer may take place due to outward fluoride diffusion. Hypermineralization of the surface layer, on the other hand, may lead to blocking of surface pores, and thus reduction of inward diffusion of acidic molecules, further reducing the rate of demineralization (Silverstone, 1983). The blocking of the surface pores cannot reduce the degree of remineralization as it does in case of external fluoride application (Silverstone, 1983; White, Chen & Nancollas, 1988), because the fluoride source is located beneath the demineralizing lesion. The demineralized body of the lesion acts like a sponge and takes up more fluoride than adjacent sound enamel (Silverstone, 1983). The presence of such a high concentration of fluoride within the lesion favors remineralization of dissolved calcium and phosphate ions (Silverstone, 1983). This explanation is based upon the model of enamel as a semipermeable membrane. But ten Cate and van Duinen (1995) have already shown that inhibition of demineralization and hypermineralization is not only possible in enamel but also in dentin adjacent to glass-ionomer restorations (ten Cate & van Duinen, 1995).

Multiple regression analysis revealed that CD was modulated by CA, time and test (glass-ionomer restoration) or control (no glass-ionomer restoration) (table). Presence of a glass-ionomer restoration influenced CD negatively, i e, glass-ionomer cement did inhibit progression of CD, while CA and time influenced CD positively, ie, CD and CA progressed simultaneously and CD progressed with time. This confirmed the results of the unifactorial comparison of test and control. Further, multiple linear regression revealed that angulation differences did not influence the assessment of CD progression in this in vitro study.

CONCLUSIONS

The design of this study is not meant to support the use of tunnel restorations for caries prevention. The tunnel restoration was chosen in this study as a model for a glass-ionomer cement depot within the tooth. Statistically significant reduced progression of the demineralization on the test side compared to the control could be observed at a mean distance of 0.99 mm between lesion and tunnel restoration. The clinical application of this observation may be the placement of glass-ionomer cement beneath occlusal restorations to reduce the individual risk for approximal caries in that particular tooth.

Further efforts should be directed toward incorporating the above findings and assumptions into clinical investigations about factors influencing the extent and change of caries progression.

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DEPARTMENTS

ABSTRACTS

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 these abstracts.

Margin design for porcelain fused to metal restorations which extend onto the root. *Bishop K, Briggs P & Kelleher M (1996) *British Dental Journal* 180 177-184.

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The authors present a varied approach to the restoration of teeth with root-surface exposure. Crown margins involving root surfaces may be necessary to improve anterior esthetics, to optimize available crown height, or to avoid termination of finish lines on existing restorations. The problems of preparing margins on exposed roots include: excessive tooth preparation due to tooth taper at the gingival area, crown-root angulation, potential pulpal damage, tissue thickness and response to subgingival margins, esthetics of the "smile line," and patient expectations. The 90° shoulder is the most commonly used margin design for porcelain fused to metal (PFM) restorations due to esthetics, yet requires removal of a significant amount of tooth structure. More conservative designs, such as the 135° shoulder or deep chamfer may be utilized for supragingival margins when esthetics is not a concern. Ideally, these designs should be used with all-metal margins, as this provides the most predictable marginal seal. Where an all-metal margin is esthetically unacceptable, porcelain butt or subgingival margins (deep chamfer or 135° shoulder) are proposed. Marginal design should be based on the individual clinical situation rather than applying a single margin for all preparations. It is important to balance the esthetic concern of the patient with the biologic effects of extensive tooth preparation and the location of the finish line. The authors advise that preparations be delayed at least 5-6 months if a thin gingival biotype is diagnosed and is inflamed or will be treated surgically. Newer techniques such as resin-bonded crowns or predictable soft tissue regeneration could potentially provide viable alternatives to traditional PFM restorations in the future.

Reducing the risk of sensitivity and pulpal complications after the placement of crowns and fixed partial dentures. *Brännström M (1996) *Quintessence International* 27 673-678.

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The purpose of this discussion was to explain the causes of prosthetic postoperative sensitivity and give recommendations on techniques to prevent it. Patient discomfort follows pulpal damage due to bacterial infection. A constant outward fluid flow through dentinal tubules increases with pulpal inflammation. Fluid shifts associated with thermal changes, masticatory forces, or proliferating microbes stimulate C-fibers, causing discomfort. Mechanical trauma and frictional heat during tooth preparation or maloccusion may cause pulpal inflammation. Provisional restorations allow escape of dentinal fluid due to porous luting agents and ill-fitting margins. However, the permanently cemented crown seals the tubules and pulpal pressure increases, accumulating prostaglandins, bradykinins, serotonin, and noxious substances. The author's treatment recommendations include: (1) replacing old restorations, cleaning and lining the cavity, as well as checking dentinal sensitivity before preparation; (2) using local anesthetic that does not compromise blood flow to the pulp, such as Citanest/Octapressin (Astra); (3) ensuring that provisional crowns fit well and cover all exposed dentin without encroaching on periodontal tissues. Bacteria trapped in the smear layer may reach the pulp in 3 weeks. Optimally, laboratory fabrication of the permanent prosthesis should take a matter of days to prevent bacterial migration into the pulp. If the provisional is in place a longer period of time, it must be rigid. The author advocates an etch for the preparation and sealing dentin with a bonding resin to occlude the tubules. The author states the smear layer should be removed with a dentin cleansing agent to accomplish cleansing, disinfection, and occlude tubules. Occlusion must not be high or pulpal inflammation may result; and (4) Prior to final cementation, the resin liner is removed to allow good micromechanical bonding. Next, the dentin is polished with pumice and detergent. Dentin should remain moist at all times until cementation. Normal evaporation may result in dehydration, causing pulpal inflammation. The author feels that by assuring proper treatment of the tooth during preparation, provisionalization, and cementation, patient discomfort related to pulpal inflammation or infection from bacterial invasion will be minimized.

Microleakage of four Class II resin composite insertion techniques at intraoral temperature. *Hilton TJ, Schwartz RS & Ferracane JL (1997) *Quintessence International* 28 135-144.

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Volumetric contractions of composite resin during polymerization is a well-documented problem. Gap formation at the gingival margin coupled with the high coefficient of thermal expansion promotes microleakage: the passage of bacteria, fluids, and ions between the cavity wall and the resin during thermocycling. Various placement techniques, alternative matrixing and wedging, as well as combining autocured and visible-light-cured (VLC) resins and dentin bonding agents (DBA) in a "directed shrinkage technique" have been recommended to reduce the marginal gap and resultant microleakage. This study evaluated microleakage of class 2 resin restorations placed at intraoral temperatures using these varied placement techniques. A second goal of the study was to compare the microleakage in a longitudinal section to a three-dimensional view after restoration removal. Caries-free third molars were extracted, cleaned, stored at 37 °C in 0.525% NaOCl, then prepared with two slot preparations (both ending on dentin). The prepared teeth were embedded in poly(vinyl siloxane) impression material and stone to simulate a tooth held in an alveolus. Restorations were all placed at simulated mouth temperature (30-37 °C) using one of four techniques. Technique A: VLC DBA (All-Bond 2), VLC composite (Bis-Fil P), a clear matrix, and cure-through wedges were used. Incremental placement started with shade L placed horizontally at the gingival box floor, cured through the wedge (40 seconds), then from the occlusal (40 seconds). The second increment was shade U placed vertically along the lingual wall and cured from the lingual (40 seconds), and from the occlusal (40 seconds). The last increment was cured from the facial, then from the occlusal (40 seconds each). Technique B: VLC DBA, VLC composite, metal matrix and wooden wedges; incremental placement in three horizontal increments and cured from the occlusal for 40 seconds each. Technique C: Dual-cure DBA (All-Bond 2), autocure (Bis-Fil IIB) and VLC composite, metal matrix, with the autocured resin placed to the CEJ then VLC resin placed and cured from the occlusal. Technique D: VLC DBA, autocure and VLC composite, metal matrix, placement was similar to group C. All restorations were finished wet immediately with disks and abrasive points, thermocycled, sealed, and stained with silver nitrate. After photographic development, the teeth were sectioned longitudinally through the middle of both restorations. Microleakage evaluation of the four techniques showed extensive leakage involving the axial wall (grade 4/4) of all gingival margins in both two- and three-dimensional studies. The enamel margins leaked significantly less and no significant difference was found among any of the groups. Comparing two- and three-dimensional studies, the two-dimensional evaluation underestimated the extent of microleakage in both enamel and dentin margins, though it was not clinically significant. One limitation of the three-dimensional view was that leakage down the dentinal tubules was not evident, since the tooth was not serially sectioned. An interesting finding was the large amount of leakage at the lingual and facial walls, which the authors attribute to the enamel rod orientation. This study suggests that with thermocycling, the use of autocured resin and directed shrinkage techniques do not significantly improve microleakage.

Microleakage of multi-step and simplified-step bonding systems. *Castelnuovo J, Tjan A & Liu P (1996) *American Journal of Dentistry* 9 245-248.

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Theoretically dentin bonding systems (DBSs) with dentin bond strength greater than 20 MPa should be capable of minimizing microleakage. Fourth-generation dentin bonding agents achieve this strength, yet the complexity of these multi-step systems complicate clinical use. Simplified-step DBSs have been developed to reduce the time and complexity for clinical application. The aim of this study was to compare pairs of multi- and simplified-step DBSs for their efficacy in reducing marginal microleakage. The DBSs evaluated were OptiBond and OptiBond FL, All-Bond 2 and One-Step, and Tenure and Tenure Quik. Thirty freshly extracted mandibular human molars were cleansed, received standardized class 5 preparations on mesial and distal surfaces, and were randomly assigned into three groups of 10 teeth. These V-shaped cavities had occlusal margins in enamel and cervical margins in cementum. Materials were placed as per the manufacturers' instructions. Each tooth was treated on one side with a multi-step DBS and the other with the simplified-step version DBS from the same manufacturer. Pertac Hybrid composite was placed into all preparations and the restorations polished. Specimens were stored for 7 days in 37 °C water and then thermocycled for 300 cycles between 5 and 55 °C. Except for the test site, the specimens were sealed with a lacquer varnish and immersed for 24 hours in 0.5% basic fuchsin dye. Specimens were

then placed in acrylic, dried, sectioned, and evaluated using dye penetration. All DBSs with the exception of Tenure exhibited minimal or no microleakage at the enamel margins. The authors observed that the simplified-step DBSs OptiBond FL and One-Step showed no significant difference in microleakage at both enamel and cervical margins and exhibited less microleakage than their multistep counterparts at the cervical margins. Tenure and Tenure Quik were equivalent in microleakage scores at the cervical margin and consistently displayed greater microleakage than the other DBSs tested.

Secondary caries formation in vitro around glass ionomer-lined amalgam and composite restorations. *Dionysopoulos P, Kotsanos N & Papadogiannis Y (1996) ***Journal of Oral Rehabilitation*** **23 511-519.**

(*Aristotle University of Thessaloniki Dental School, Department of Operative Dentistry, 54006 Thessaloniki, Greece)

The purpose of this in vitro caries study was to examine the effect of a conventional and light-cured glass-ionomer liner on wall lesion inhibition under amalgam and composite resin restorations. Class 5 preparations on 21 extracted premolars were prepared with 10 restorations in each of seven groups. The amalgam (Dispersalloy) groups included restorations with no glass-ionomer liner, conventional glass-ionomer cement (GIC) liner 1.0 mm short of the margins, and visible-light-cured (VLC) GIC liner 1.0 mm short of the margins. The composite groups included restorations with no GIC liner, conventional GIC liner 1.0 mm short of the margins, VLC GIC liner 0.3 mm short of the margins, and VLC GIC liner 1.0 mm short of the margins. Groups with liners 1.0 mm from the margins represented closed sandwich restorations, while the group 0.3 mm from the margin was an open sandwich. The teeth were immersed in an acid gel for caries-like formation. After 15 weeks, the teeth were sectioned longitudinally through the restoration and measurements were taken of the outer surface lesion and the cavity wall lesion using a calibrated eyepiece reticule. Results showed that artificial recurrent caries were significantly reduced in wall lesion length and depth in teeth lined with glass-ionomer liner under amalgam. However, no significant difference was found for recurrent caries inhibition in the outer lesion for teeth lined with glass-ionomer liners under amalgam restorations. Results also demonstrated that placing a VLC glass-ionomer liner 0.3 mm short of the cavosurface margins under composite resin restorations resulted in a reduction of artificial recurrent caries, but no effect on wall lesions was noted when the liner was placed 1.0 mm short of the cavosurface margins.

2-year clinical evaluation of a gallium restorative alloy. *Osborne JW & Summitt JB (1996) ***American Journal of Dentistry*** **9 191-194.**

(*University of Colorado Health Sciences Center, School of Dentistry, Box C284, Department of Restorative Dentistry, Denver, CO 80262)

The purpose of this in vivo study was to assess the 2-year clinical performance of gallium alloy restorations. Parameters evaluated were: (1) marginal fracture, (2) tarnish, (3) surface roughness, (4) tooth fracture, (5) restoration fracture, and (6) any adverse medical and/or dental reactions occurring during the study. Initially, nine patients requiring 30 class 1 restorations were used. One patient was lost for follow-up, and 27 restorations were evaluated at 2 years. Fifteen of the restorations were lined with a BIS-GMA resin and the remainder sealed with Amalgambond. Strict attention was paid to moisture control, e g, rubber dam, sealing dentin, and sealing the occlusal surface of all restorations with a BIS-GMA resin. Restorations were evaluated at 2 weeks, then at 3, 6, 12, and 24 months. Almost one-half exhibited tarnish, and 60% showed surface roughness. There was one tooth fracture (not attributable to the material), and there were no fractures through the body of any restoration. Marginal fracture was rare, there were no medical problems reported, and postoperative sensitivity was minimal. There was no significant difference between which sealing material was used.

Clinical evaluation of gallium alloy as a posterior restorative material. *Navarro MFL, Franco EB, Bastos PAM, Teixeira LC & Carvalho RM (1996) ***Quintessence International*** **27 315-320.**

(*University of São Paulo, School of Dentistry, Department of Operative Dentistry, Bauru, São Paulo, Brazil)

This in vivo study compared 30 gallium alloy (Gallium alloy GF) and 31 amalgam (Dispersalloy) restorations in 28 human subjects over an 8-month period.

Each patient had at least one restoration of each material. All restorations were placed under rubber dam; however, no cavity varnish was used with the gallium restorations. The following parameters were evaluated: secondary caries, anatomic form, marginal adaptation, surface texture, postoperative sensitivity, and bulk fracture. At baseline, 67% of the gallium and 29% of the Dispersalloy restorations were sensitive. At 8 months, 35% of the gallium and 4% of the Dispersalloy restorations were sensitive. Other parameters were evaluated according to criteria described by Cvar and Ryge. For Dispersalloy restorations, 29 of 31 were rated as Alfa for all parameters evaluated. However, of the 26 gallium restorations evaluated at 8 months, there were three tooth fractures attributed to the material and therefore, they were not considered in the re-evaluation. There were also three other teeth that exhibited cracked enamel originating at the restoration margin that were not present at the baseline evaluation. Five of the 23 gallium restorations (28%) presented with bulk fracture. All 23 were rated Charlie for surface texture. Severe tarnish and corrosion were the most frequent observations. For marginal adaptation, 14 of the 23 Gallium alloy restorations were rated Beta. The authors state that Gallium alloy GF is unacceptable for clinical use. It has a high postsetting expansion (64.1 μm/cm according to Okabe and others), which exceeds the ADA standard.

A new design for all-ceramic resin-bonded fixed partial dentures. *Pospiech P, Rammelsberg P & Unsöld F (1996) *Quintessence International* 27 753-758.

(*Ludwig-Maximilians University of Munich, Department of Prosthodontics, D-80336 Munich, Germany)

The purpose of this study was to describe the clinical and laboratory techniques for fabricating an In-Ceram all-ceramic resin-bonded fixed partial denture replacing one anterior tooth. The listed advantages of this design are minimal tooth preparation, excellent esthetics, and good function. An intraoral parallelometer was used for preparing four parallel grooves in the abutment teeth. Minimal dimensions for the interproximal grooves were 2.0 mm in width, 4.0 mm in height, and 0.8 to 1.0 mm in depth with 1.0 mm of tooth left between adjacent grooves. Rounded interdental edges are recommended. A study cast was then poured and surveyed to ensure proper alignment prior to final finishing with fine-grit diamonds. Following this step, the definitive impression was made with polyether impression material, and the master cast was poured in Type IV stone. An alumina slip framework was made on a refractory cast, dried, sintered, and glass infiltrated. The ceramic framework was then fitted to the master cast and the prosthesis was finished to final form with Vitadur Alpha porcelain. The location of the cervical porcelain margin was not specified. The bonding areas of the fixed partial denture were air-abraded and silica-coated with the Rocatec system to prepare them prior to luting. The prosthesis was cemented with Variolinik Ultra, a dual-curing resin cement. Finally, the occlusion was marked and the restoration finished with Sof-Lex disks. At the time of publication, a high success rate was reported for an unspecified number of fixed partial dentures that had survived in vivo for 4 years. The authors felt this 4-year survival rate supported this technique for replacing a single anterior maxillary tooth. A general recommendation for the use of this technique could not be given at this time pending further long-term results.

The effect of fissure morphology and pretreatment of the enamel surface on penetration and adhesion of fissure sealants. *Symons AL, Chu CY & Meyers IA (1996) *Journal of Oral Rehabilitation* 23 791-798.

(*University of Queensland Dental School, Department of Dentistry, Brisbane, Queensland 4000, Australia)

The purpose of this in vitro study was to determine if resin fissure sealant adhesion and penetration were altered by varied fissure morphology or by variations in the preparation of the enamel surface or by pretreatment with dental adhesive systems. A total of 108 freshly extracted premolars and molars devoid of caries, defects, and previous sealants were grouped according to morphology (shallow, intermediate, or deep fissures). Six teeth from each group were treated according to the following method and sealed with chemically activated Delton pit and fissure sealant. Group 1 had a 60-second etch with 37% phosphoric acid, 30-second rinse, and 15-second air dry. Group 2 had a 15-second etch with 37% phosphoric acid, 30-second rinse, and 15-second air dry. Group 3 received a 15-second etch with 10% maleic acid, 30-second rinse, and a 15-second air dry. Group 4 had a 15-second etch with 10% maleic acid, 30-second rinse, 15-second air dry, followed by an application of Scotchbond Multi-Purpose primer and adhesive as per the manufacturer's instructions. Group 5 received

a 60-second etch with 10% phosphoric acid, 30-second rinse, 15-second air dry, followed by five coats of All-Bond 2 primer. Group 6 had a 15-second etch, 30-second rinse, 15-second air dry, and five coats of All-Bond 2 primer. Teeth were stored in buffered saline for 12 hours and thermocycled 200 times between 5 and 55 °C. The teeth were then placed in 1.5% Procion reactive orange dye for 3 minutes followed by 12 hours in buffered saline. The teeth were sectioned, examined at X50 light microscopy and divided into groups according to fissure depth. The sections were examined for: (1) adaptation of sealant to the enamel surface and dye penetration; (2) vertical and lateral penetration of sealant or primer into the fissures; (3) presence of associated defects in the sealant. Results showed that all sealants successfully adapted to the occlusal enamel margins as evidenced by the dye failing to penetrate any of the sealed tooth sections. There was a 58% agreement between the visual determination of fissure depth and the microscopic exam. The percentage of sealants penetrating to the base of the fissure decreased as the depth of the fissure increased. All groups using primers, as well as groups with 60-second etch times, exhibited a higher percentage of sealants penetrating to the base of the fissure. Sealant adaptation to lateral walls was similar in all groups. Porosity in the body of the sealant generally increased with fissure depth. The authors surmised that complete penetration of the fissure may not be of consequence if the sealant is retained.

Intrapulpal injection: Factors related to effectiveness. *Van Gheluwe J & Walton R (1997) ***Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*** **83 38-40.**

(*University of Colorado School of Dentistry, Department of Endodontics, Denver, CO 80262)

Prior research on pressures created during dental intrapulpal injections has caused speculation that local anesthesia is related to direct tissue injury or nerve compression. The purpose of this in vivo study was to determine whether the effectiveness of intrapulpal injection was dependent on a combination of back pressure and local anesthetic solution, or solely back pressure. In a prospective double-blind study, 35 adult patients presented for root canal treatment with vital pulp tissue. These patients could not be profoundly anesthetized with primary anesthesia techniques as evidenced by pain during access preparation or pulp extirpation. Patients were administered intrapulpal injection with either 2% lidocaine with 1:100,000 epinephrine or normal saline using a technique that the clinicians deemed appropriate to develop back pressure. Anesthesia was determined to be effective if the patient could tolerate treatment. A second intrapulpal injection was used if required, but if more anesthesia was needed, the technique was considered unsuccessful. The results show that intrapulpal injections are quite successful with no statistically significant difference between the two solutions. Lidocaine was successful in 19/19 and saline in 14/16 cases tested. As the effectiveness of the intrapulpal injections was independent of the solution used, the importance of achieving back pressure for clinical success is underscored. Back pressure may be achieved by the use of smaller gauge needles to wedge into the canal or by developing a seal using pellets around the needle.

Allergies to dental materials. *Wiltshire W, Ferreira M & Ligthelm J (1996) ***Quintessence International*** **27 513-520.**

(*University of Pretoria, Department of Orthodontics, Pretoria, South Africa)

The biocompatability of all dental materials should be a chief concern to the practicing dentist. Dermatitis at the site of contact or at a distant site may result from various dental products including acrylic resin, resin composite, impression materials, eugenol-containing products, amalgam, nickel, chromate, cobalt, gold, and platinum. Isolating an allergen involves using an epicutaneous patch test where readings of skin reactions are usually completed after 48, 72, or 96 hours. Examples of these patch tests include the Nordic Institute of Dental Materials, M-9 series, and the Fleigl patch tests. The article offers the following recommendations: (1) Though there are several materials in dentistry with an allergic potential, no material presents a historical basis for its discontinuance; (2) Medical/dental history taking is advisable concerning past hypersensitivity following dental procedures, or when associated with specific dental materials; (3) Epicutaneous testing should be used sparingly, but is indicated to confirm a contact dermatitis in close proximity to a dental restoration, prosthesis, or orthodontic appliance, and specifically when a concomitant skin rash develops. If a positive test confirms an allergy, the treatment involves discontinuance of all contact with the allergenic material, which usually results in prompt remission of all lesions.

BOOK REVIEWS

CONTEMPORARY ORAL AND MAXILLOFACIAL PATHOLOGY

J Philip Sapp, Lewis R Eversole & George P Wysocki

Published by Mosby-Year Book Inc, St Louis, 1997. 433 pages, 839 illustrations. $59.95.

For use as a chairside reference for the practicing dentist or as a student text, this color atlas of pathology is very effectively organized to give the reader information on a large variety of maxillofacial disorders. There are 12 chapters that present these disturbances in specific groups such as "Cysts," "Infections of Teeth and Bone," "Bone Lesions," "Odontogenic Tumors," "Immune-mediated Disorders," "Connective Tissue Lesions," and "Injuries," among others.

This text is graphically pleasing to the eye with colored headings that make finding individual chapters very fast and accurate. Title pages for each chapter provide outlines for the chapter's content. There is a concise introduction at the beginning of each chapter, and definitions are presented in screened text to make them easy to find. Colored headings and subheadings match the chapter pages so as to keep a consistent organization throughout the entire text. I found that looking into these sections of interest to me was very easy.

There are a large number of colored illustrations included throughout the atlas. Many of these are presented along with the appropriate text in the large side margins, and this unfortunately restricted their size to 2.25 inches long by 1.5 inches tall. This was fine for the the photographs of periapical radiographs, as I am quite used to seeing detail in them at that size. However, many of the clinical illustrations would have been better in a larger format within the text itself so as to show clearer details.

Histologic illustrations were of excellent quality, but the computer-generated illustrations need a lot of improvement. Many of these were overly simplistic and lacked the stylistic excellence of the overall presentation.

The text itself is very clearly written and organized. For many of the disorders the text is presented in sections that discuss clinical features, histopathology, diagnosis, and treatment. At the conclusion of each chapter there is a section that references additional reading. I found this section very easy to navigate through, as once again it is presented in the same groups as the rest of the chapter.

I would recommend this atlas as an excellent chairside reference tool for the general or specialty practice. Overall, I found it clear and concise as well as easy and fast to use.

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CHANGE YOUR SMILE
Third Edition

Ronald Goldstein

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 328 Pages, 575 color illustrations, $38.00.

This successful esthetic dentistry book is now in its third edition. Written for patients, its aim is to educate them about possible solutions for esthetic dental problems and to facilitate communication with the treating dentist. Using high-quality color photographs and clearly written explanations in an attractive format, this book covers a broad range of esthetic treatment options.

Chapters address treatment of stained, fractured, and crowded teeth, treatment with implants, othodontics, orthognathic and periodontal surgery, and even plastic surgery. This new edition also describes how computer imaging can assist in making treatment decisions and provides many examples of its use. Each color-coded chapter describes a related set of problems and possible solutions. Treatments are summarized with clear statements of expected treatment time, maintenance required of the patient, treatment life expectancy, cost, and advantages and disadvantages of treatment. The text is well written at a level appropriate for patients. Numerous before-and-after photographs illustrate cases. Drawings of crowns, bridges, implants, orthodontics, and other treatments are high quality and clearly explain treatment.

Several special features show that this book has been well thought out. Tips for patients who have composite resin bonding, including warnings not to chew ice, grind teeth, or bite fingernails, are thorough and practical. There is a table that states the advantages and disadvantages of various posterior restorative materials and a section that describes

what to do if a tooth is knocked out. A short quiz entitled "Does Your Habit Affect Your Smile?" introduces a section that describes common and not so common oral habits and their effect on teeth. Tips on preventing esthetic problems during childhood help parents by providing information on everything from antibiotic (tetracycline) and fluoride use to the need for good oral hygiene during orthodontic treatment.

Placing a copy of this book in one's reception area is sure to generate some interest in esthetic dental treatment on the part of patients (as it is intended to do). Also having a copy available in one's operatory would serve as a valuable patient education tool when explaining treatment options. Because of its thorough and relatively balanced coverage of this topic, I would recommend this book to any dentist, whether or not she or he practices esthetic dentistry.

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FUNDAMENTALS OF PERIODONTICS

Thomas G Wilson & Kenneth S Korman, editors

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 576 pages, 620 illustrations. $74.00, softbound.

For student and practitioner Drs Wilson and Korman have compiled a well-organized resource text that clearly and succinctly lays out both the basic science and the clinical application for understanding periodontics.

This well-illustrated and organized text provides a user-friendly, durable softbound document that would serve as a useful reference for all members of the dental profession. Each chapter clearly outlines and highlights the essential contents. To the practicing dentist or hygienist, the text acts as a valuable ready resource of clinically applicable material for diagnosis and treatment of dental patients. The text has been designed with the student in mind as well. The format is both visually attractive for quick reference use and enticing to the student in search of knowledge.

Using a collection of 620 color and black-and-white plates the authors have compiled this 576-page volume in a very instructive manner. The text is divided into three sections: "Knowledge Required to Diagnose and Treat Periodontal Diseases," "Clinical Management of the Periodontium in Health and Disease," and "Adjunctive Therapies Relevant to the Maintenance of Periodontal Health." An appendix for Health History and one for Premedication are also included, making it a handy model for use by the dental office.

The authors have supplied through the contributors the basic knowledge needed in assessing health and disease of the periodontal structures. They have also given the reader the opportunity to critically assess research data and reference materials in a manner that supports critical thought. The nearly excessive number of references for each section of the book alone makes this book a who's who in periodontal research.

Contributors to this text are a broad cross section of national and international contributors to the current knowledge base in this subject. The authors have provided the dental profession with a valuable reference and teaching text well worth the $74.00 price tag.

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DENTIN/PULP COMPLEX

Masaki Shimono, editor

Published by Quintessence Publishing Co Inc, St, Louis, 1996. 377 pages, 337 illustrations. $90.00.

For those interested in the biology of and research about the dentin/pulp complex and who could not attend the international conference held in Tokyo in 1995, the proceedings have finally been published.

The manuscript is a compilation of the most recent and ongoing research about this most complicated and intriguing dental phenomenon. It is a very comprehensive collection of the papers presented. The manuscript is divided into three sections: "Clinical Topics," "Symposium," and the "Poster Session."

The "Clinical Topics" section is further divided into

three categories: adhesive resin bonding and its effect on the dentin/pulp complex, restorative procedures and materials and their effects, and pulpal and periapical inflammation and management of tooth pain. Each section was moderated (and perhaps edited) by respected authorities in the field. Each section contains results of up-to-date investigations by renowned investigators as well as those who are on the threshold of their careers. The topics include the effects of lasers, tissue regeneration, microcirculation, adhesive resins and their effect on dentin and pulp, orofacial pain, and management of hypersensitive teeth.

The "Symposium" section is presented in four categories: pulp regeneration and dentinogenesis, function of pulpal nerves, pathophysiology of pulp, and dentin/pulp complex and adhesive resin. The moderators for each category are very respected investigators and clinicians. The symposium included topics like gene regulation, odontoblast-related issues, osteogenic proteins and their role in reparative dentin formation, functional roperties of intradental nerves, etc. This section also presents topics related to the low compliance environment of pulp, pulpal blood flow outside the dental pulp, and neurogenic components of pulp inflammation.

The "Poster Session" section presents short papers based on 57 posters presented during the conference. The topics are varied and interesting and relate to almost every aspect of the dentin/pulp complex, many with significant relevance.

The papers presented, in general, are accompanied by excellent illustrations and micrographs that help in the understanding of the material being presented. The manuscript, overall, is edited by a group of editors who gave of themselves in a significant manner. Minor drawbacks are some typographical errors and some misspellings. Quintessence Publishing also made a great contribution to the profession and the science with this publication at a reasonable cost. It would have been nicer if the manuscript were hardcover.

This manuscript should be very useful as an excellent reference source for those who want to know what is going on in the area of the dentin/pulp complex in terms of research and clinical implications. Many graduate students, post doctorate fellows, faculty, and other investigators should find this manuscript very useful whether it is being used to further their own research or to update the teaching of the dentin/pulp complex.

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University of Nebraska Medical Center College of Dentistry, Department of Adult Restorative Dentistry is actively searching for applicants for faculty positions in the areas of Prosthodontics (two positions), Operative Dentistry, and General Practice. Positions include complete benefit package, intramural practice opportunity, and research opportunities in a clinical research addition to be completed in early 1998. Salary and academic rank are commensurate with qualifications and experience. Positions are open immediately and a review of applications will continue until the positions are filled. Send curriculum vitae, three letters of reference, and indicate position # to:

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PROSTHODONTIST (Positions #7-6139 and #7-6140). Responsibilities include teaching undergraduate preclinical restorative dentistry and conducting clinical and/or laboratory research. DDS/DMD from an ADA-accredited institution, MS in prosthodontics or graduate of a residency program is preferred; prior teaching and research experience is desirable.

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ANNOUNCEMENTS

27th ANNUAL MEETING of the
ACADEMY OF OPERATIVE DENTISTRY

18-20 February 1998
WESTIN HOTEL
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The 27th annual meeting of the Academy of Operative Dentistry will focus on the use of dental materials and clinical techniques by the general dentist. Thursday will feature Dr Max Anderson ("When to Place a Restoration"), Dr Ivar Mjör ("What Materials To Use To Replace a Restoration"), Dr Ken Anusavice (Buonocore Lecture), Dr John Osborne ("Dental Amalgam, Mercury, and Gallium Alloys"), Dr Jan Pameijer ("Restorative Treatment behind the Cuspids"), and Dr Terry Donovan ("Another Look at Cementation"). Friday's schedule includes Dr Mark Friedman ("Porcelain Veneers"), Dr Terry Tanaka ("TMJ and Restorations—the Relationship"), and Dr Karen Baker ("Medications—Actions and Reactions"). Friday afternoon will offer an outstanding array of Table Clinics. In addition, an excellent companion activities program will include a special program by Mark McCauley, senior interior designer for Marshall Field's, and a delightful "From Market to Menu" tour that includes the Chicago Board of Trade, Randolph Street and South Water Street Markets, and a visit to Treasure Island for a tour and cooking demonstration. Of course, the famous Gala Reception on Thursday evening is a must for everyone.

For meeting information please contact Dr Gregory Smith, P O Box 14996, Gainesville, FL 32604-2996; FAX (352) 371-4882.

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