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EDITORIAL

The Three Kinds of Dental Schools

Over the past 15 years I have visited a number of dental schools. I have observed the different management philosophies in these schools and, based on these philosophies, I have come to believe that there are three basic types of dental schools. Each type has its own attributes, assets, and liabilities. These three types exist because they evolved as the schools have evolved. There are consequences for all stakeholders in the educational process for each philosophical focus. The three primary focuses of schools are "faculty-centered," "student-centered" or "patient-centered." While all schools are some mix of these three, one of these focuses usually dominates.

I can list a number of faculty-centered dental schools. These are often, but not always, our major dental research institutions. The school is faculty-centered because the faculty is hired, almost exclusively, for their research potential: "How many research grants can the faculty members bring with them, and what is their research track record?" The key here is that the faculty is viewed as a revenue-generating resource for the school. If they can bring in or bring with them large amounts of money, they are desirable faculty members. Little or no attention is paid to their teaching skills or to their interest in students or patients. This model is proliferating in the ranks of dental schools because of the financial constraints that schools are experiencing. Exogenous money that is not tied to the normal appropriation sources is highly desirable. This "soft money" is usually dispensed through granting agencies to researchers with known skills, and hence these individuals are highly desirable income sources for beleaguered dental school budgets.

Student-centered schools are available in diminishing numbers. Perhaps that is as it should be. These schools are focused heavily on the students themselves and their educational process. They employ a number of educational consultants and have research interests in the areas of cognitive and psychomotor training in dental education. While being a student at these institutions can be highly desirable, there are deficits within this kind of program as well. The weakness of the student-centered program is seen when you examine a program of the third type of focus, the patient-centered institution.

Patient-centered schools focus on the delivery of excellent care to the patients enrolled in their programs. Patients are treated as if they were the most precious elements in the school. They are greeted as they enter the school. They are asked if they need assistance in finding the clinic to which they are assigned. They are met at their destination clinic by personnel assigned to assist patients and act as hosts. In some locations these greeters and hosts are from the retired community and serve either in a volunteer status or for nominal remuneration. Once in the clinic, the patients are treated with excellence, as they are in any well-run practice. They are seen in a timely manner and are treated with respect and dignity. They are not viewed as two amalgams and a crown requirement. Their business matters are handled in a private and professional manner, and both the student and the faculty work hard at presenting a highly professional image that fosters a desire to return to these schools for further treatment.

If I had the opportunity to attend a dental school as an entering student again and my primary interest was in becoming a superb practitioner, I would begin my search for a suitable school by asking the students already enrolled what type of school they have: "Is your school faculty-centered, student-centered, or patient-centered?" Most students have a pretty clear view of the focus of their school.

For those of us who want to practice dentistry, a patient-centered school teaches a number of life's lessons that the other two types of schools almost uniformly miss. Most dental schools are chartered to teach the art and science of dentistry. Part of that art and science of dentistry is in the thoughtful caring and treatment of our patients. Patient-centered institutions instill an attitude of what dentistry is really about--patient care!

This is my last editorial for *Operative Dentistry*, and I want to thank the academies for entrusting me and my superb Editorial Board with our journal. I leave you with my favorite quote from Norman MacEwan. "We make a living by what we get, but we make a life by what we give."

M H ANDERSON
Editor

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CLINICAL ARTICLE

A Modified Matrix Technique for the Application of Restorative Materials on the Facial Surfaces of Teeth

S DOUKOUDAKIS • A DOUKOUDAKIS

SUMMARY

A Tofflemire matrix is modified and is secured in place with the help of Super Floss and unfilled light-activated resin or light-activated impression material. The matrix prevents excess cementing medium escaping in the gingival area, providing excellent isolation. The technique is simple and provides good esthetics while minimizing lengthy and traumatic finishing procedures.

The increasing demand by patients for better esthetics has created the need for improvement of materials and clinical procedures. Direct application of composite resins and porcelain laminates on the facial surfaces of anterior teeth has proved to be very successful in modifying the form, shape, and shade of anterior teeth.

Careful case selection combined with preservation of tooth structure and maintenance of a healthy periodontium are important contributing factors leading to successful and predictable results. To provide the desired form and shape, the application of some form of matrix is essential in helping the operator maintain the appropriate approximal surfaces and contact areas. The matrix also helps to direct the flow of excess composite resin when used as a restorative material or cementing medium. Generally the matrices that we now use prevent the composite resin from escaping towards the adjacent teeth, but they do little to prevent the escape of cement toward the gingival tissue. This problem is ignored during cementation, resulting in traumatic and lengthy finishing procedures associated with excess bleeding and reduction of visibility.

The various types of existing matrices are designed to comply with the self-activated composite resins. The two most commonly used are celluloid strips and tooth forms. Celluloid strips are extremely helpful in the formation of the approximal surfaces; however, they direct excess composite toward the gingival and incisal areas. When celluloid strips are used, the resulting restoration usually is left with bulky incisal and gingival segments. The celluloid tooth form, on the other hand, provides an adequate incisal area, since the cementing medium has only one direction to escape. The gingival tissues, however, are commonly loaded with an increased amount of polymerized resin, which is extremely irritating to the tissues.

To solve these problems a matrix band was introduced by Vivadent (Vivadent USA Inc, Amherst, NY 14228). The contact molar band is adapted around the

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tooth, separating the adjacent teeth and can be secured in place with wedges. Instead of the wedges, small wetted sponges with unfilled resin can be lightly polymerized and placed. This type of matrix also presents some problems. Mainly it is too flexible and can be easily displaced when the materials are manipulated. It is also very difficult to place subgingivally when the margins are extended in the sulcus to cover extensive stains.

The alternate technique that is described in this article incorporates a Tofflemire matrix (Miltex Instrument Co, Inc, Lake Success, NY 11042), which is secured in place using Super Floss (Oral B Laboratories, Redwood City, CA 94065) or light-activated impression material (Genesis, L D Caulk, Milford, DE 19963). The matrix is made using a Tofflemire metal band. The band is shaped like the contact molar band by removing a v-shaped portion of the band with the help of curved scissors (Figure 1). The modified band is placed on the tooth,and the fit and configuration are examined. Super Floss is placed through the approximal sections of the tooth using the ends of the floss and not the thicker, saturated filament, which can displace the metal band (Figure 2). The filament section should stay on the labial side of the tooth and is wetted until fully saturated with light-activated unfilled resin. The ends of the wetted floss are pulled palatally, pressing the matrix band into position (Figure 3). In this way the filament section can only move towards the gingival margin of the band. During all this time the metal band is held in place with finger pressure until the unfilled resin is fully polymerized with a light-polymerization unit. The complete seal and accurate adaptation of the metal band is examined, and if it is unacceptable, the whole procedure must be repeated. Using a metal burnisher, the matrix is pressed to achieve the desired form and contact points. At this point the labial surface of the tooth is isolated and ready to receive the restorative material. Figure 4 shows the completed restoration of this lateral incisor. Instead of using Super Floss and unfilled resin, light-activated impression material can be used to secure the modified matrix in place (Figures 5-6). Following the conventional techniques, the tooth surface is etched and the unfilled resin, with or without tints or colorants, is applied. The application of composite starts from the gingival portion to ensure the absence of voids around the margin. The

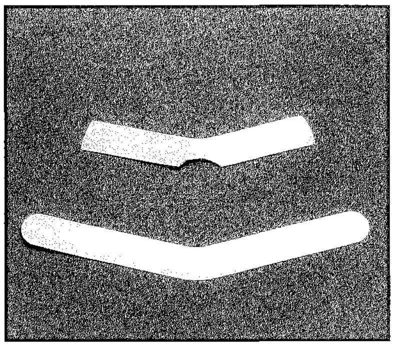

Figure 1. *Modification of the Tofflemire matrix band*

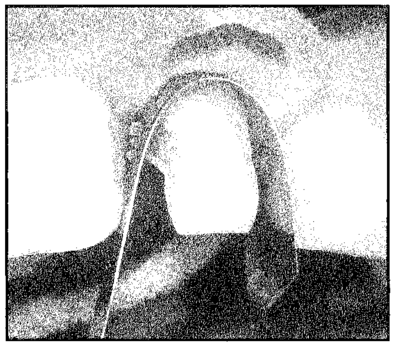

Figure 2. *Modified matrix band positioned in place. Super Floss has also been positioned mesially and distally and will be pulled palatally.*

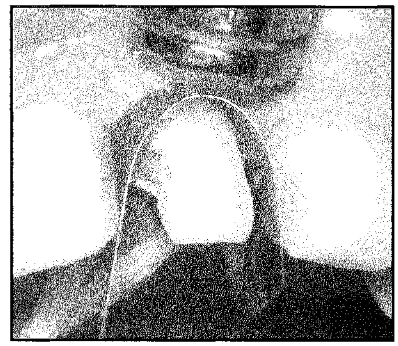

Figure 3. *The unfilled resin that has saturated the Super Floss is polymerized.*

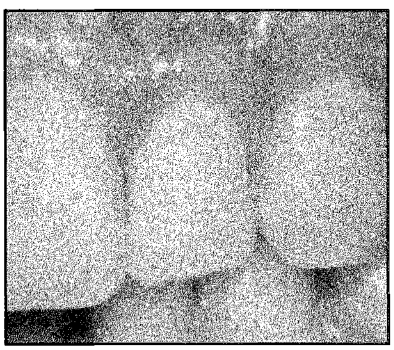

Figure 4. *Completed restoration on the lateral incisor*

Figure 5. *Occlusal view of metal bands secured in place with light-activated impression material. Note that margins of these laminate veneer preparations have been separated from the gingival tissue and can be easily viewed and detected.*

Figure 6. *Lateral view of the metal bands and the isolated teeth ready for the cementation procedures*

build-up proceeds in a labial-incisal direction. Although the metal band is very secure and strong resisting forces may be generated during the manipulation procedures, the band can be very easily removed if pulled in an opposite-to-seating direction.

For the cementation of porcelain laminates the same techniques are used as described for the composite build-up. Examination of fit and margin adaptability of the laminates should also take place prior to and after the matrix placement.

Upon completion of the cementation procedures and polymerization of the cementing medium, the matrix is then removed. Examination of the restoration should reveal no composite excess on the margins or the approximal areas. Conventional techniques are used for finishing the polishing procedures.

This technique is simple and provides the clinician with excellent isolation of the area while minimizing traumatic and lengthy finishing procedures. It is exceptionally helpful when the shape and form of teeth must be changed, as in cases of peg laterals and diastema closures, where it is impossible to apply the conventional procedures.

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ORIGINAL ARTICLES

Saliva Contamination of Dentin Bonding Agents

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Clinical Relevance
Some dentin bonding agents may provide a degree of bonding in the presence of saliva.

SUMMARY

This study examined the shear bond strength to dentin of two dentin bonding agents when contaminated with a measured amount of saliva at various stages in their application procedure. Eighty extracted human third molar teeth were randomly separated into four groups of 10 for each of the dentin bonding systems tested (All-Bond 2, Scotchbond Multi-Purpose). Group A specimens were not contaminated; primer/adhesive/resin were applied according to manufacturers' instructions. In Group B, samples were contaminated for 15 seconds with fresh whole human saliva, and then forcibly dried with a blast of oil-free air; this occurred after application of the primer but prior to application of adhesive. In Group C, contamination occurred after application of adhesive, prior to application of resin. In Group D, saliva was allowed to contaminate the surface as the primer was being applied, without forcible removal. Specimens were then thermocycled, mounted, and tested in shear on an Instron at 7 days. Bond strengths in MPa were obtained, and data were analyzed using a one-way ANOVA, at the $P = 0.05$ level of significance. Although shear bond strengths were lowered in saliva-contaminated samples, there was no statistically significant difference between group means.

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INTRODUCTION

Since its introduction over 35 years ago, the acid-etch technique has become a universally accepted method to bond composite resin restorative materials to enamel (Buonocore, 1955; 1981). The search for an equally effective agent to bond resin to dentin has proven to be more elusive. Dentin is a more heterogenous substrate, with a much higher organic and water content than enamel. After tooth preparation, ground dentin is covered by a smear layer, which further complicates the bonding effort. Many systems have arisen, using a variety of etchants, conditioners, primers, and adhesive resins, that either alter or remove the smear layer and create mechanical bonds to dentin (Bowen, 1985; Asmussen, 1985; Johnson, Powell & Gordon, 1991).

Shear bond strength has become a popular in vitro measure of the effectiveness of dentin bonding agents under different conditions. Many variables have been studied but controversies still exist on how the dentin is best prepared, whether in vitro testing accurately reflects in vivo conditions, and how to characterize the nature of the bond to dentin (Mowery, Parker & Davis, 1987; McInnes & others, 1990; Mitchem & Gronas, 1986; Suzuki & Finger, 1988; Beech, Tyas & Solomon, 1991; Aquilino, Williams & Svare, 1987; O'Brien & others, 1988; Tao & Pashley, 1989).

Several studies have suggested that the clinical success of resin bonding systems to enamel could be jeopardized by contamination with oral fluids. A 50% reduction in mean shear strength was demonstrated when composite resin was bonded directly to a saliva-contaminated etched enamel surface (Hormati, Fuller & Denehy, 1980). Significantly reduced fissure sealant/enamel bond strength has been demonstrated when bonding to saliva-contaminated, unwashed specimens (Thompson & others, 1981). Investigators have compared the effects of various surface treatments of etched enamel on SEM surface topography and reported that etched surfaces contaminated with oral fluids, regardless of the length of exposure, produced a dramatic alteration of surface topography. They speculated that this alteration represented the formation of an organic pellicle presumed to compromise the bond between enamel and resin (Silverstone, Hicks & Featherstone, 1985). An in vivo study demonstrated the effect of saliva contamination on etched enamel (Barghi, Knight & Berry, 1991). Cylinders of composite resin were applied to etched, flattened enamel surfaces of human posterior teeth. Half the restorations were placed isolating the teeth with a rubber dam; the remainder were placed using cotton roll/saliva ejector isolation. Two weeks later, the bonded teeth were extracted, and the restorations were tested in shear. Statistically significant reduction in bond strength occurred when the teeth were isolated with cotton rolls. Additionally, cohesive fracture occurred in only 25% of this group, whereas 45% of the composite resins placed under rubber dam isolation demonstrated cohesive fracture (the majority of fractures in both groups were mixed).

Results from other studies have less clearly defined the detrimental role of saliva contamination on enamel bond strength. There was no significant difference in the tensile bond strength of posterior composite resin to etched enamel contaminated with saliva, whether the surface was first re-etched or simply washed before bonding. This suggested that the need to re-etch contaminated enamel, rather than just thoroughly wash the surface, should be reconsidered (O'Brien & others, 1987).

Saliva contamination of two dentin bonding agents has been examined as related to shear strength and gap-reducing efficacy in a butt-joint cavity preparation (Hansen & Munksgaard, 1989). With these third-generation agents, gap-reducing efficacy was markedly reduced if the dentin was contaminated with saliva prior to application of the adhesive. When the adhesive itself was contaminated, the effectiveness of one agent was further reduced; with the other, the gap decreased if the contaminated resin surface was copiously rinsed, and a second layer of adhesive was applied. When shear bond strengths were measured, the values were lowered in saliva-contaminated samples, but were not significantly different from uncontaminated samples.

The use of dentin bonding agents as an intermediary under sealants to reduce sensitivity to saliva contamination has been studied both in vitro (Hitt & Feigal, 1992; Borem & Feigal, 1992) and in vivo (Feigal, 1992). In vitro results suggested that use of a dentin bonding agent could overcome saliva contamination and provide shear bond strengths equivalent to sealant bonded to uncontaminated enamel, as well as reducing microleakage to clinically insignificant levels. Two-year clinical trials in a half-mouth comparison study indicated that use of a dentin bonding agent prior to sealant application allowed successful sealant placement on enamel wet with saliva, with long-term retention equivalent to sealant alone placed on dry enamel.

While some evidence has suggested that saliva contamination can reduce the effectiveness of adhesive resin systems to enamel, the effect of saliva contamination on dentin bonding agents is less clear. While many newer dentin bonding agents purport to be more hydrophilic, their application involves several steps that are highly technique sensitive. Also, many carious lesions requiring use of dentin bonding agents for optimum restoration (i e, class 5 lesions) are in difficult-to-isolate areas, where saliva contamination might be more likely.

The purpose of this study was to measure the effect of saliva contamination of two dentin bonding systems at various stages of their application on shear bond strength to human dentin.

METHODS AND MATERIALS

Eighty previously unerupted extracted human third molar teeth were stored in 0.5% aqueous chloramine T solution, under refrigeration, until use. The facial surface of each tooth was flattened on abrasive carborundum disks of 400 grit, followed by 600 grit, on a Buehler polisher grinder (Buehler Ltd, Lake Bluff, IL 60044) under a water stream until dentin was exposed. A new section of disk was used for each tooth, such that each disk surfaced approximately eight to 10 teeth. After exposing the dentin, all teeth were stored at room temperature in deionized water. They were separated randomly into four groups of 10 teeth for each of two dentin bonding systems being studied: All-Bond 2/all-etch technique used with Bis-Fil posterior composite (Bisco Inc, Itasca, IL 60143); and Scotchbond Multi-Purpose used with Z-100 posterior composite (3M Dental Products, St Paul, MN 55144).

Teeth were air dried and examined under a light microscope at X10 power (American Optical Corp, model 384, Greenwich, CT 06830) to ensure that no enamel remained, or pulpal space was encroached upon, on the flattened dentinal surface. Teeth were randomly separated, and an indelible marker was used to inscribe a number on a noninvolved root surface to identify the sample group. Standardized holes were placed in Teflon-coated paper with adhesive backing. Microcalipers with an electronic digital readout ("Max-Cal," Fowler & NSK, Japan) measured the diameters of these holes at 2.96 ± 0.03 mm. The Teflon tape with the standardized hole was placed on the air-dried, flattened dentinal surface of each tooth and burnished into place to establish a standardized dentin bonding area. Teeth were returned to the deionized water at room temperature until further sample preparation.

Half the samples from each group were prepared 24 hours after surfacing, with the remaining 40 teeth prepared at 48 hours. A stopwatch with digital readout was used to ensure accuracy of timed intervals used for the dentin bonding steps. Sample groups were divided and specific preparations were as follows:

All-Bond 2, Group A: Each tooth was lightly dried with a quick blast of oil-free air from an electric hair dryer. Ten percent phosphoric acid semi-gel supplied with the kit (Lot #129191) was applied to the dentin surface for 15 seconds. The surface was then washed under a running stream of tap water for 15 seconds and lightly dried with the hair dryer (2 seconds) to provide a dentin surface that was somewhat moist and not desiccated. Equal amounts of Primer A (Lot #129181) and Primer B (Lot #129171) were mixed, and five coats were applied with a new brush. After a final dry for 5 seconds, the surface was inspected for a shiny appearance. The Dentin/Enamel Bonding Resin (Lot #129091) was applied and thinned with a separate brush and light cured for 20 seconds using an Optilux 400 visible-light-curing unit (Demetron Research Corporation, Danbury, CT 06810) with the 5 mm diameter wand. (Two units were used throughout the 2 days of sample preparation; adequate light-curing intensity was verified at the beginning and end of each day with a Demetron Curing Radiometer). A small cone (less than 2 mm in height) of Bis-Fil posterior composite (shade U, Lot #129201) was placed and cured for 20 seconds to ensure coverage, adaptation, and total cure of the resin to the bonding area. Teflon tubes (Berghof/America, Concord, CA 94524) with a standardized internal diameter slightly larger than the bonding area (3.04 - 3.07 mm) were selected, and an additional small increment of composite was placed within the tubes. The composite-filled tube was placed with finger pressure over the previously polymerized cone of composite (Figure 1). The new increment was further cured for 2 minutes, and the sample was returned to room-temperature deionized water. The Teflon tubes were gently removed from the cured specimens at the end of the bonding procedure.

Scotchbond Group A: Each tooth was lightly dried with a blast of oil-free air from the hair dryer. The 10% maleic acid multipurpose etchant (Lot #2AC) was applied for 15 seconds, and the surface was washed under running tap water for 15 seconds, then dried for 10 seconds, according to the manufacturer's directions. Four to five coats of multipurpose primer (Lot #2AC) were applied to the dentin surface with a new brush; the tooth was dried for 5 seconds, and the surface inspected for a shiny appearance. Multipurpose adhesive (Lot #2AB) was applied and thinned with a separate brush and cured for 20 seconds. A small cone of Z-100 (Shade B2, Lot #5904B2) was placed on the prepared dentin as previously described and light cured for 20 seconds. An additional small increment of Z-100, contained within a standardized-diameter Teflon tube, was applied over the cured composite resin cone and cured for an additional 2 minutes. Samples were returned to room-temperature deionized water; the Teflon tubes were gently removed from the cured specimens at the end of the bonding procedure.

Scotchbond Group B & All-Bond Group B: Specimens were prepared as in Group A, but after primer placement and drying, the dentin bonding surface was covered with 0.06 ml of fresh whole unstimulated saliva (a clinically feasible amount, which pooled over the bonding area), placed using a dialable micropipette (Nicriryo #130245, Oxford Bench-Mate; Figure 2). The saliva remained undisturbed for 15 seconds, the excess was gently shaken off, and the tooth was dried with the hair dryer for 20 seconds. Adhesive was applied and procedures continued as in Group A.

All-Bond Group C & Scotchbond Group C: Specimens were prepared as in Group A, but after adhesive application and cure, 0.06 ml of saliva was applied for 15 seconds to the prepared dentin surface. The excess was gently shaken off, and the surface was blow-dried for 20 seconds; resin was applied and cured as above.

Scotchbond Group D & All-Bond Group D: Specimens were prepared as in Group A, but after etch/wash/dry, 0.06 ml saliva was placed over the bonding area (Figure 3). After 15 seconds, the excess was gently shaken off, leaving the surface still moist with saliva; no blow drying was accomplished. Primer was directly applied and procedures continued as described in Group A above.

Specimens were fabricated as described above in the following order on each of the preparation days: All-Bond 2 uncontaminated samples, followed by Scotchbond Multi-Purpose uncontaminated samples; then Scotchbond Multi-Purpose Group B samples, followed by All-Bond 2 Group B samples; then All-Bond 2 Group C samples, followed by Scotchbond Multi-Purpose Group C samples; then Scotchbond Multi-Purpose Group D samples, followed by All-Bond 2 Group D samples.

All samples were thermocycled 2556 cycles, between 0 - 60 °C, with a 30-second dwell time. After water storage for 1 week, the specimens were placed in an Instron (Model 1125, Instron Corporation, Canton, MA 02021), to which a custom-built positioning/shearing device was attached. The teeth were mounted with their surfaced-dentin area parallel and flush with the flat plane of the shearing blade (Figure 4). The top edge of the resin cylinder was aligned with and protruding from a horseshoe-shaped cutout in the shearing blade template that provided a guillotine effect to shear the resin at a precise right angle at the resin-tooth interface (Figure 5). The device was sprayed with silicone spray (Ellman International Mfg Co, Hewlett, NY 11557) to minimize friction. Loading was at a crosshead speed of 5 mm/min until fracture.

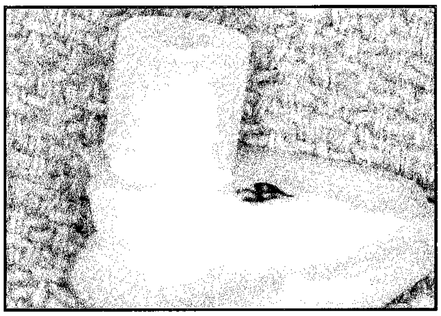

Figure 1. *Human molar specimen with a standardized bonding area (as defined by Teflon tape with a uniform opening, burnished into place on the prepared dentin surface)*

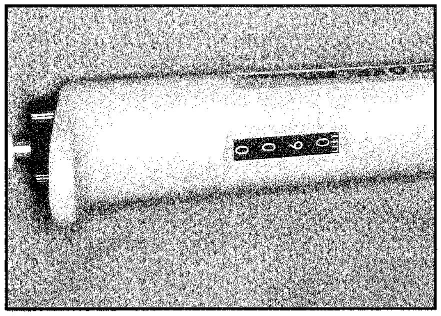

Figure 2. *Dialable micropipette used to deliver a standardized amount of saliva to contaminate the bonding surface*

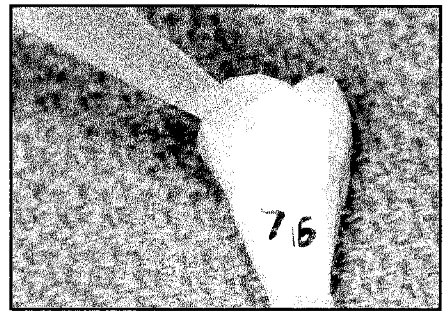

Figure 3. *Saliva contamination of the bonding surface. In Group D, the surface remained moistened with saliva as the dentin bonding agents were being applied.*

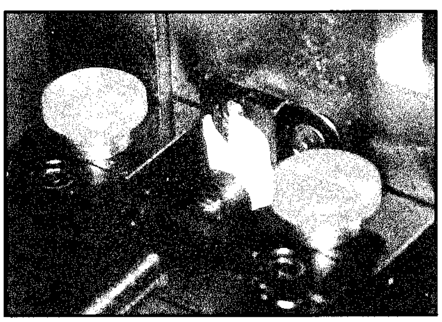

Figure 4. *Custom-built positioning/shearing device was attached to the Instron Model 1125. Teeth were mounted with their surfaced dentin area parallel to and flush with the flat plane of the shearing blade.*

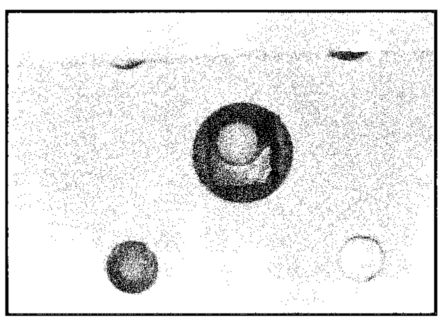

Figure 5. *The top edge of the resin cylinder was aligned with and protruding from a horseshoe-shaped cutout in the shearing blade template that provided a guillotine effect to shear the resin at a precise angle at the resin-tooth interface.*

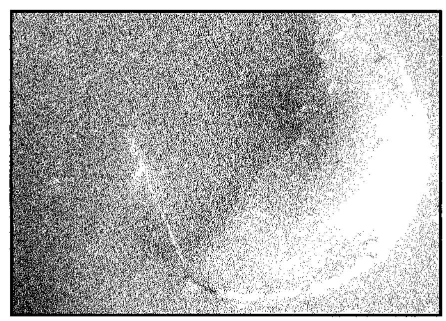

Figure 8. *A sample at X80 power, demonstrating cohesive failure through the resin*

Data were analyzed by a one-way analysis of variance at the 0.05 level of significance.

RESULTS

The mean shear bond strengths for the eight groups are shown in Figure 6. Although mean shear bond strengths were lower in saliva-contaminated samples, a one-factor ANOVA revealed no significant difference between any of the groups.

Fracture patterns were also examined under light microscope at X80 power (Nikon Corp SMZ10, Melville, NY 11747). In the All-Bond control group, 20% of the fractures were adhesive and 80% were cohesive within the resin. In the Scotchbond uncontaminated group, there were 10% adhesive failures, 20% mixed, and 70% cohesive (two of these showed some fracture within dentin). Overall, the All-Bond samples provided 60% adhesive failures, 15% mixed, and 25% cohesive within resin; in the Scotchbond samples 15% of the fractures were adhesive, 17.5% were mixed, and 67.5% were cohesive (Figures 7 and 8).

DISCUSSION

The hydrophilic nature of the newer dentin bonding agents may allow them to function to some degree in the presence of saliva contamination, perhaps displacing, or diffusing through it, to infiltrate and polymerize within the exposed collagen bundles of demineralized superficial dentin. This creates the transitional resin-reinforced "hybrid zone" (Nakabayashi, Ashizawa, & Nakamura,1992) through micromechanical retention. It has been shown that wet (although not saliva-contaminated) dentinal surfaces exhibited significantly higher bond strengths than dry surfaces (Kanca, 1992; Gwinnett, 1992). The fact that there were no significant differences in shear bond strengths in Group D would tend to support the idea that newer dentin bonding agents may be able to function in a wet environment. Also, the fact that many failures were mixed or cohesive in nature (especially with the Scotchbond Multi-Purpose samples) would indicate that effective bonds were achieved.

The bond strength values obtained demonstrated fairly large standard deviations, as has been typical of dentin shear bond studies. An attempt was made to minimize variability in the present study by using previously unerupted molar teeth, which presumably had no reparative dentin, and by using standardized storage and surface preparation techniques. Uncontrolled variables were depth of dentin preparation, moisture content, and storage time from extraction to dentin preparation. No attempt was made to simulate positive intrapulpal pressure.

Although no significant difference in mean shear bond strength was discovered between groups, it may be noted that standard deviations for all experimental groups were higher than those of respective uncontaminated samples. This perhaps indicates a less predictable bond to dentin in the presence of saliva contamination.

Fresh whole saliva has been an accepted medium for contamination in research (Hormati & others, 1980; Thompson & others, 1981; Silverstone & others, 1985; O'Brien & others, 1987; Hansen & Munksgaard, 1989; Barghi & others, 1991; Hitt & Feigal, 1992; Borem & Feigal, 1992; Feigal, 1992); however, there may be differences in the chemical composition and effectiveness of saliva samples. Additionally, no blood proteins or products were applied as an experimental factor, as is often found in a contaminated field in vivo.

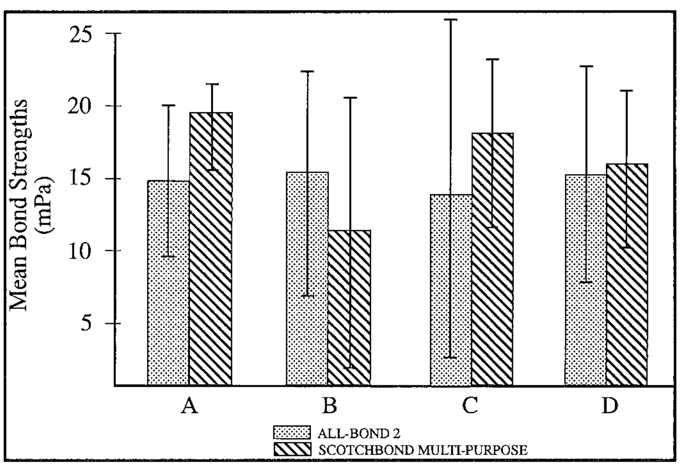

Figure 6. *Shear bond strengths of two dentin bonding agents under the following conditions: Group A—(uncontaminated) primer/adhesive/resin/ applied according to manufacturer's instructions; Group B—saliva contamination after primer application but prior to adhesive/resin; Group C—saliva contamination after adhesive application but prior to resin; Group D—surface left moistened with saliva contamination as primer was being applied. In all groups, n = 10 for each dentin bonding agent (except in All-Bond/Group A, where one value was discarded as a significant outlier, being 10 standard deviations from the mean. Discarding this value did not change the results of the ANOVA; with or without this value, there was still no significant difference in shear bond strengths between groups.)*

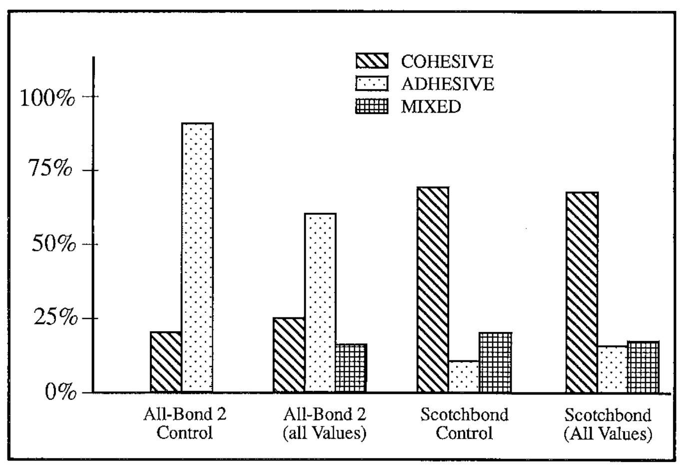

Figure 7. *Qualitative evaluation of fracture pattern under light microscope, X80 power*

Finally, in vivo clinical behavior cannot be totally based on in vitro results; this study in no way implies that improper technique should be followed when applying dentin bonding agents. However, these results do suggest that newer dentin bonding agents may provide some degree of bonding in the presence of saliva. Further corroborative research, and research in vivo, must be accomplished.

CONCLUSIONS

1. Saliva contamination at varying stages of application of All-Bond 2/all-etch technique and Scotchbond Multi-Purpose dentin bonding systems resulted in shear bond strength values that were not significantly different from uncontaminated specimens.
2. Forty-five percent of All-Bond 2/all-etch samples and 85% of Scotchbond Multi-Purpose samples demonstrated failures that were mixed or cohesive in nature, indicating that these systems were providing some degree of bonding, even in a saliva-contaminated environment.

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The Effect of Various Bases on the Fracture Resistance of Amalgam

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Clinical Relevance
Visible-light-curing bases may be too weak to support amalgam restorations.

SUMMARY

This study compared the compressive force required to fracture amalgam over nine base materials: a calcium hydroxide product (Dycal); two autocured glass ionomers (GlasIonomer Base Cement and Ketac-Bond); three light-cured glass ionomers (Photac-Bond, Variglass VLC, and Vitrebond); two light-cured resins (Timeline and VLC Dycal); and a zinc phosphate cement (Fleck's Zinc Cement). For the control group, 10 aluminum dies (25 mm x 12 mm x 10 mm) were milled with 3.0 mm x 3.0 mm slots, which were filled with hand-condensed Tytin amalgam with no underlying base. For experimental groups, 10 aluminum dies of equal dimension were milled with 3.5 mm x 3.0 mm slots. Following manufacturer's instructions, the nine base materials were successively placed in these 10 dies using a depth-limiting device made of light-transmitting clear acrylic to ensure a 0.5 mm thickness, and Tytin amalgam was again condensed over each base such that the depth of the amalgam equalled that in the control. All test specimens were stored in 100% humidity for 48 hours then fractured in compression on an Instron machine. Mean force, in Newtons (S D in parentheses), required to fracture the specimens was: Control: 1934(210), Zinc Cement: 1874(147), GlasIonomer Base Cement: 1839(174), Ketac-Bond: 1723(225), Vitrebond: 1485(155), Photac-Bond: 1422(294), Advanced Formula II Dycal: 1296(237), VLC Dycal: 1035(116), Variglass: 909(294) and Timeline: 906(275). ANOVA and Student-Newman-Keuls statistical analysis (alpha = 0.05) indicated that the autocuring glass ionomers, GlasIonomer Base Cement and Ketac-Bond, and a zinc phosphate cement, Zinc Cement, provided significantly more fracture resistance for amalgam than the other bases tested and were not statistically different from a no-base control.

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INTRODUCTION

Amalgam has been the primary posterior restorative material for many years. Failure of amalgam restorations continues to be a dilemma in restorative dentistry, and reasons for amalgam failure have been identified. Mjör (1981, 1985) and Klausner, Green, and Charbeneau (1987) have shown that secondary caries was the most common reason for replacement of amalgam restorations. Other investigations have shown that dissolution of cavity bases occurs and could contribute to development of secondary caries (Novickas, Fiocca, & Grajower, 1989; Pereira & others, 1990). New materials or methods are needed to increase the longevity of amalgam restorations by reducing the susceptibility of teeth restored with amalgam to secondary caries.

Bases are placed under amalgam restorations primarily to provide pulpal protection against thermal shock; however, large bases add little benefit to an amalgam restoration and reduce its fracture resistance (Eames & Scrabeck, 1985). Bases are prone to dissolution, are often overdimensioned within a cavity preparation, and weaken the overlying restoration (Robbins, 1986). The minimum basing concept, a technique of covering as little dentin as possible, was recommended, because the best foundation for amalgam is sound dentin, not base material (Eames & Scrabeck, 1985; Robbins, 1986). If pulpal protection is deemed necessary, a base thickness of 0.5 mm has been proposed as the minimum depth that provides adequate thermal protection (Peters & Augsburger, 1981).

Several in vitro investigations have shown that bases adversely affect fracture resistance of overlying amalgam. Rowe (1964) stated that compressive strength of a base was an indicator of its ability to support amalgam. Later, studies showed that modulus of elasticity, a property describing the rigidity of a material, better predicted the capacity of a base to support amalgam (Farah, Hood & Craig, 1975; Powers, Farah & Craig, 1976; Hormati & Fuller, 1980; Farah & others, 1981, 1983). It was also found that base thickness affected restoration strength with thinner bases, providing better fracture resistance (Farah & others, 1975; Hormati & Fuller, 1980; Farah & others, 1983; Reel, Lyon & Mitchell, 1987). Originally, zinc phosphate cement, possessing high strength and elastic modulus and good insulating properties, was used as a base under amalgam. Later, cements containing zinc oxide eugenol or calcium hydroxide replaced zinc phosphate as the preferred base material, as they were considered less irritating to the pulp (Council on Dental Materials and Devices, Council on Dental Therapeutics, 1972). The elastic moduli of both zinc oxide eugenol and calcium hydroxide cements is significantly less than that of zinc phosphate (Farah & others, 1983).

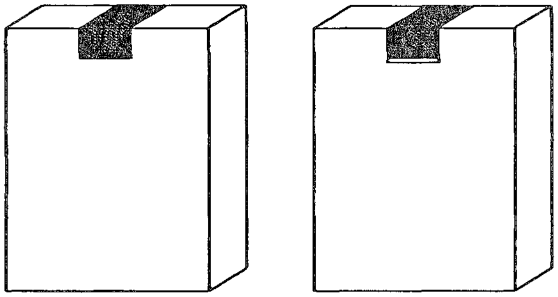

Figure 1. *Left: Control die with amalgam depth = 3.0 mm. Right: Test die with amalgam depth = 3.0 mm and base depth = 0.5 mm.*

New materials have been introduced that are recommended for use as bases under amalgam restorations. The compositions and setting reactions of these newer basing materials vary considerably. Some are self-curing glass-ionomer cements, others are light-cured resins, and a third class, the light-cured glass ionomers, reportedly combine the traditional acid-base glass-ionomer reaction with resin photosensitivity. Warren (1986) and Phillips (1991) respectively proposed that chemically cured and photosensitive glass-ionomer cements possess several desirable qualities that make them quite acceptable for use as bases under amalgam. These include low thermal diffusivity (Warren, 1986), sustained fluoride release (Olsen & others, 1989; Mitra, 1991b; DeSchepper & others, 1991), cariostasis (Hicks, 1986), antimicrobial activity (Scherer, Lippman & Kaim, 1989; DeShepper, Thrasher & Thurmond, 1989), adhesion to tooth structure (Mitra, 1991a), and low microleakage (Mitra, 1991a; Manders, García-Godoy & Barnwell, 1990). Phillips (1991) stated that light-curing glass-ionomer bases possess acceptable physical properties, low solubility, biocompatibility, and cariostatic activity, and should be placed to cover all exposed dentin in a prepared tooth. These materials may reduce the incidence of secondary caries and resulting amalgam restoration failure; however, no previous studies have shown that new light-cured glass-ionomer cement materials, when broadly extended over dentin, provide better fracture resistance for amalgam than other commonly used bases. The purpose of this in vitro study was to investigate the effect of several base materials of uniform depth, including new light-cured glass-ionomer bases, on the fracture resistance of a simulated amalgam restoration.

METHODS AND MATERIALS

Testing of amalgam fracture resistance was accomplished using metal dies (Figure 1). Metal dies have been used to model clinical cavity preparations and isolate the effects of underlying bases (Rowe, 1964; Vieira & Mondelli, 1973; Hormati & Fuller, 1980; Reel & others, 1987). Twenty anodized aluminum dies with dimensions of 25 mm x 12 mm x

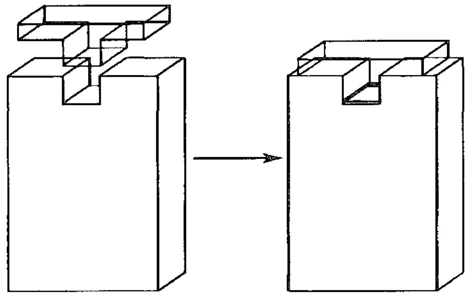

Figure 2. *The translucent acrylic matrix fabricated on a control die was used to standardize depth thickness when placed on test dies.*

10 mm were machined. For the control group, a centered 3.0 mm deep x 3.0 mm wide slot was milled across the 10 mm width of one end of 10 dies. The slot simulated a deep MOD cavity preparation with a flat pulpal floor. For the experimental groups, a similar slot was milled in the remaining 10 dies; however, the depth of the slot was increased to 3.5 mm. A translucent acrylic (Orthodontic Resin, LD Caulk, Milford, DE 19963) matrix was fabricated to completely fill the slot in the control dies. When placed with slight manual pressure into the slots of the experimental dies, a gap of 0.5 mm was present between this matrix and the floor of the slot (Figure 2). In the experimental dies, the matrix was used to standardize depth of bases under simulated amalgam restorations. Use of a translucent acrylic resin permitted testing of photosensitive materials. Figure 2 demonstrates that the base material was exposed on the approximal external surface in the simulated gingival margin area. Although extending base materials to the cavosurface is not seen clinically, this model approximates the clinical technique of basing all of the dentin as has been recommended (Phillips, 1991). Since in a deep MOD cavity preparation there is little or no enamel remaining at the gingival margin, a basing technique covering all the dentin would result in the base being placed very near or at the approximal gingival cavosurface. This configuration of the metal die cavity preparation isolated the effect of the base material itself and did not simulate the confounding effects of cavity preparation retention and resistance factors.

A second matrix of the same acrylic resin was fabricated for use during amalgam condensation procedures. When dies were placed in this matrix, it extended 1 mm above the slotted end of each die. Hence, condensed amalgam had a 4 mm depth that was reduced to 3 mm when carved flush with the die surface. Specimens were then prepared for testing. In the control group, amalgam (Tytin Spherical Amalgam, Kerr Mfg Co, Romulus, MI 48174) was triturated (Varimix II Amalgamator, L D Caulk) according to manufacturer's instructions and hand condensed into all 10 dies using the condensation matrix. The condensation matrix was removed and the amalgam carved flat and flush with the end of the die to yield a uniform amalgam depth of 3.0 mm. Specimens were stored for 48 hours at room temperature in 100% humidity and then tested on an Instron Universal Testing Machine (Model 1125, Instron Corp, Canton, MA 02021). A die stabilizing device was used to hold dies while compressive force was applied to the center of the amalgam in each specimen using a 3 mm-in-diameter round-end probe and a crosshead speed of 0.5 mm/minute. The initial deflection of the stress-strain line on the Instron's strip recorder device was defined as amalgam fracture. For all specimens, amalgam fracture was confirmed visually by gross inspection or microscopic examination at X30 magnification with a Unitron microscope (Model 11377,

Table 1. Manufacturer and Description of Basing Materials Tested

Product	Manufacturer	Description
Fleck's Zinc Cement	Mizzy Inc Cherry Hill, NJ 08002	Zinc phosphate
GlasIonomer Base Cement	Shofu Inc Kyoto, Japan	Autocured glass ionomer
Ketac-Bond	ESPE-Premiere Norristown, PA 19404	Autocured glass ionomer
Vitrebond	3M Dental Products St Paul, MN 55144	Light-cured glass ionomer
Photac-Bond	ESPE-Premiere	Precapsulated light-cured glass ionomer
Advanced Formula II Dycal	L D Caulk Milford, DE 19963	Calcium hydroxide
VLC Dycal	L D Caulk	VLC resin with calcium hydroxide
VariGlass VLC	L D Caulk	Light-cured glass ionomer
Timeline	L D Caulk	VLC resin with fluoride additive

Unitron Instruments, Plainview, NY 11803) if fracture was not apparent visually. Load applied at amalgam fracture was recorded.

Table 2. Mean Fracture Load of Control and Nine Base Groups

Test Group	Fracture Load in Newtons (± 1 S D)	Subsets
Control (no base)	1934 (210)	*
Fleck's Zinc Cement	1874 (147)	*
GlasIonomer Base Cement	1839 (174)	*
Ketac-Bond	1723 (225)	*
Vitrebond	1485 (155)	#
Photac-Bond	1422 (294)	#
Advanced Formula II Dycal	1296 (237)	#
Prisma VLC Dycal	1035 (116)	+
VariGlass VLC	909 (294)	+
Timeline	906 (275)	+

Groups with different subset symbols are statistically different from each other ($P \leq 0.05$). Depth of base = 0.5 mm. Depth of amalgam = 3.0 mm.

In the experimental groups, nine basing materials (Table 1) were tested in succession in the experimental dies. All base materials were mixed and handled according to manufacturer's recommendations. Autocuring materials were placed into the die slots and the depth-standardizing acrylic matrix was fully seated and held in accordance with the manufacturers' recommended setting times. The matrix was lightly lubricated with a silicone spray (Radiator Specialty Co, Charlotte, NC 28208) prior to its use. Light-cured materials were placed, the matrix was positioned, and initial curing (Optilux, Demetron Research Corp, Danbury, CT 06810) was accomplished through the matrix for the time recommended by the material's manufacturer. The matrix was then removed and the material was again cured for the same recommended time. Adequate light intensity output was confirmed for the curing unit with a Curing Radiometer (Demetron Research Corp). Excess base material was removed at each end and from the vertical internal walls of the slot. All bases were inspected and if defects such as cracks, voids, and porosities were found, those specimens were discarded. Amalgam placement commenced after base setting was achieved. Techniques for amalgam condensation, storage, and fracture testing of experimental specimens were accomplished using methods described for control specimens. Following testing of each group, the fractured amalgam and underlying base were removed and the die cleaned in preparation for testing of subsequent groups. Mean compressive loads causing amalgam fracture were then evaluated using analysis of variance. Specific comparison between groups was made by applying the Student-Neuman-Keuls test at the 0.05 level of significance.

RESULTS

Mean loads, including standard deviations, applied at fracture for the control and experimental groups are reported in Table 2. While the load required to fracture amalgam with an underlying base was less in all test groups compared to the no-base control, this difference was not always statistically significant. The Fleck's Zinc Cement, GlasIonomer Base Cement, and Ketac-Bond groups did not differ significantly from the unbased control group. Conversely, the mean fracture loads of these three test groups were significantly higher than the means demonstrated by the Vitrebond, Photac-Bond, and Dycal groups. Mean loads at fracture for amalgam overlying VLC Dycal, Variglass, and Timeline were significantly less than all other groups tested.

DISCUSSION

The results of this study indicate that chemically cured glass-ionomer cement bases provide fracture resistance for amalgam restorations comparable to amalgam supported by zinc phosphate cement and a no-base control. These results conflict with those in a recent study by Reel and others (1987), who concluded that glass-ionomer cements provided low amalgam fracture resistance. More recently, Tam and others (1989) measured elastic moduli of several base materials including GlasIonomer Base Cement (5.7 GPa), KetacBond (4.7 GPa), Dycal (2.2 GPa), and VLC Dycal (0.6 GPa). Their results for these four bases were exactly predictive of the ranking of the same materials in the present study, giving more evidence to the position that elastic modulus best predicts the fracture resistance a base imparts to an overlying amalgam restoration.

Results of this study indicate that addition of light-curing capability to glass-ionomer bases adversely affects their ability to support amalgam. Light-cured bases have recently been introduced by manufacturers to give these products a faster set, improving their convenience. Unlike autocuring glass-ionomer bases such as GlasIonomer Base Cement and Ketac-Bond, the light-cured glass-ionomer bases, including Vitrebond, Photac-Bond, and Variglass, have a photosensitive component. In this study, the fracture resistance provided by the three light-cured glass-ionomer materials was no better than the calcium hydroxide base, Advanced Formula II Dycal, and lower than that provided by the self-cured glass-ionomer bases, Ketac-Bond and GlasIonomer Base Cement. In this investigation, Variglass was statistically equivalent to two resin materials without glass-ionomer cement, Timeline and VLC Dycal, and did not support amalgam as well as the other light-cured glass-ionomer products or Advanced Formula II Dycal.

An important characteristic of dental basing materials is their ability to adequately resist compressive forces during restoration placement and, later, during mastication. Chong, Swartz, and Phillips (1967) determined that a compressive strength in the range of 100-170 psi is needed for a base to resist the forces generated during amalgam condensation. The repeated use of the same metal dies for each experimental group in this study required that the fractured amalgam be removed between testing of different materials. This provided an opportunity to inspect the underlying bases in each specimen prior to their removal. Gross visual inspection revealed no displacement or thinning of any base materials tested, indicating that all base materials successfully resisted forces of compression resulting from amalgam condensation.

In designing the present study to investigate the effect of different bases on amalgam fracture resistance, use of clinically relevant methodologies proved challenging. The authors recognize that differences exist between the aluminum dies used in this study and restored human teeth in their natural environment. The use of these dies allowed excellent standardization of such variables as amalgam and base thickness and point of load application. Previous studies using metal dies have provided useful information regarding the interaction between amalgam restorations and underlying bases (Rowe, 1964; Vieira & Mondelli, 1973; Hormati & Fuller, 1980; Reel & others, 1987).

Farah, Hood, and Craig (1975) stated that a new basing material with mechanical properties similar to zinc phosphate but without its deleterious biological properties was needed. In the present in vitro study, two self-cured glass-ionomer bases 0.5 mm thick were statistically equivalent to a zinc phosphate cement base of equal thickness in supporting amalgam placed in metal dies. Considering the resistance to caries these materials could provide via sustained fluoride release, their use with amalgam could increase restoration longevity. Light-cured bases containing glass ionomer provided significantly less support when placed in equal thickness. While it has been suggested that these materials be placed to cover all exposed dentin in a prepared tooth (Phillips, 1991), this study indicated that they may not support amalgam restorations as well as other glass-ionomer base materials.

CONCLUSIONS

1. The fracture resistance of simulated amalgam restorations overlying GlasIonomer Base Cement, Ketac-Bond, and Fleck's Zinc Cement were not statistically different than amalgam restorations of equal depth with no underlying base.
2. Vitrebond and Photac-Bond bases supported simulated amalgam restorations as well as Advanced Formula II Dycal, but not as well as GlasIonomer Base Cement or Ketac-Bond.
3. Variglass, Timeline, and VLC Dycal were not statistically different from each other and did not support simulated amalgam restorations as well as the other materials tested, including Advanced Formula II Dycal.
4. Under the conditions of this study, conventional chemically cured glass-ionomer bases of 0.5 mm thickness provide maximum fracture resistance to amalgam restorations.

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Effects of Secondary Curing on Indirect Posterior Composite Resins

J W REINHARDT • D B BOYER • N H STEPHENS

Clinical Relevance
Although individual composite resin inlay materials vary in mechanical properties, the primary benefit of laboratory curing is improved flexural strength.

SUMMARY

This study was designed to compare strength, elastic modulus (stiffness), and hardness for five composite resin materials that are used for laboratory-fabricated posterior composite restorations. Ten specimens of each material were processed according to the manufacturer's instructions. Statistical analysis indicated that there were significant differences in mechanical properties among the materials tested. In addition, materials that are incrementally light cured prior to secondary processing were tested for changes in mechanical properties following secondary processing. It was determined that secondary processing provided improvement in flexural strength (11%) when compared to samples that were only light cured.

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INTRODUCTION

The use of composite resin materials to restore class 1 and 2 cavity preparations has increased significantly since the initial reports of poor clinical performance of posterior composite restorations in the early 1970s (Phillips & others, 1973). Much of the increasing use of posterior composites is due to improvements in the mechanical properties of the composites, advances in dentin/enamel bonding systems, and better knowledge of the techniques for cavity preparation and placement (Christensen, 1992). Another factor causing increased use of posterior composite restorations is patient interest in esthetic (tooth-colored) nonmetallic restorations (Stoffels, 1991; Bryant, 1992).

Mechanical properties of composite resins are quite different than those of cast metals or dental amalgams. Composite resins are generally softer and more flexible than restorative metals. Because of the differences between metals and composite resins, metallic restorations are preferred in areas of high occlusal stress. Recent improvements in composite resin technology have led to lower rates of occlusal wear (Dickinson & others, 1990) in selected posterior situations. However, case selection is important and factors such as isthmus width, occlusal wear pattern, and location (premolars vs molars) are important considerations when planning posterior composite restorations (Johnson & others, 1992; Jordan & Suzuki, 1991). The most ideal conditions for posterior composites are small carious lesions in premolars where there is no evidence of excessive occlusal wear.

Using composite resins that have greater strength and hardness is believed to improve clinical longevity of posterior composite resins. One method for improving strength and hardness is the application of heat following initial polymerization to increase the degree of conversion of carbon double bonds in the resin matrix (Ferracane, 1985; Wendt, 1987; Covey, Tahaney & Davenport, 1992).

Table 1. Mean Mechanical Values (with Standard Deviations) and Duncan Groupings for Each Secondarily Cured Product Tested

Material	Flexural Strength (GPa)	Elastic Modulus (GPa)	Knoop Hardness
CR-Inlay	119.6 (11.0) A	10.8 (1.5) A	73.5 (12.0) A
Brilliant	98.1 (32.8) B	7.3 (2.2) B	52.8 (7.1) B
Herculite Lab	70.8 (26.3) C	6.5 (0.9) B	52.5 (5.2) B
Visio-Gem	61.4 (8.1) CD	0.9 (0.3) C	15.6 (1.7) C
Concept	46.7 (7.9) D	2.1 (1.9) C	49.5 (10.3) B

Numerous systems for fabricating indirect (laboratory-processed) composite resin inlays and onlays have been developed. Those systems allow secondary curing of composites using various combinations of heat, intense light, pressure, or vacuum processing. The purpose of this study was to compare specific mechanical properties of five laboratory-processed composite resin materials that are promoted for use as indirect posterior restorations. The first phase of the study compared the mechanical properties of those materials to each other, and the second phase determined the degree of change in mechanical properties following secondary curing.

METHODS AND MATERIALS

For the first phase of this study, five commercial composite resin products were chosen for testing. Those products were: Brilliant (Coltene/Whaledent Inc, New York, NY 10001), Concept (Ivoclar Vivadent, Ivoclar North America, Amherst, NY 14228), CR-Inlay (J Morita USA Inc, Tustin, CA 92680), Herculite XRV Lab (Kerr Manufacturing Co, Romulus, MI 48174), and Visio-Gem (ESPE-Premier Sales Co, Drive, Norristown, PA 19404).

Each product was processed according to the manufacturer's instructions. Ten specimens (1 x 4 x 12 mm) of each product were fabricated in dental stone dies. For all products except Concept, a visible-light-curing unit (Coltolux II, Coltene) was used to cure each specimen for a total of 120 seconds. Following that treatment, specimens were taken immediately to the secondary processing unit. Concept was not light treated, since that product is designed to be laboratory cured with heat and pressure only. The other four composite resins were secondarily processed by 1) heat and light (Brilliant); 2) heat alone (CR-Inlay, Herculite); or 3) light and vacuum (Visio-Gem), using the laboratory equipment and method recommended by each manufacturer. Instructions for Herculite indicate that the heat may be applied either in a dry oven or boiling water. We chose boiling water as the secondary curing method for this study.

Following secondary processing, specimens were stored in distilled water at 37 °C for 24 hours and then tested for transverse flexural strength using a Zwick Universal Testing Machine (Model 1445, Zwick GmbH & Co, Ulm, Germany). A three-point test was used, with the edges of the triangular supports separated 10 mm. The crosshead speed was 1 mm per minute.

Modulus of elasticity was also calculated with the following formula: $E = Pl^3/4dbt^3$, where P = applied load, l = length of specimen, d = deformation, b = width, and t = thickness, using measured values of force and corresponding deformation of the beam. Finally, one-half of the specimens were tested for Knoop hardness ("top" surface: that which was closest to the curing light) using a Micromet II Micro Hardness Tester (Buehler Ltd, Lake Bluff, IL 60044). One-way analysis of variance ($P < 0.05$) was used to determine whether there were significant differences between products. When significant differences were determined, a post hoc Duncan's test was used to determine specifically which groups differed from the others.

Table 2. Summary of ANOVA Calculations for Flexural Strength, Comparing Materials with and without Secondary Curing

Source	DF	Sum of Squares	Mean Square	F-Test	*P* Value
Between groups	7	39128.79	5589.83	15.66	0.0001*
Within groups	71	25536.57	356.85		
Total	78	64465.36			
Material	3	36966.47	12322.16	34.53	0.0001*
Cure	1	1493.01	1493.01	4.18	0.0445*
Material *Cure	3	669.31	223.10	0.63	0.6011

*Statistically significant at $\alpha = 0.05$.

For the second phase of the study, identical specimens were fabricated but subjected to light curing only (without secondary processing). Only four materials were included in this part of the study, since Concept is not light-curable. Following storage for 24 hours in distilled water at 37 °C, those samples were also tested for flexural strength and hardness. Two-factor ANOVA was used to determine whether significant differences existed between specimens which were and were not secondarily processed. Again Duncan's test was used if significant differences occurred.

Table 3. Summary of ANOVA Calculations for Knoop Hardness (Top), Comparing Materials with and without Secondary Curing

Source	DF	Sum of Squares	Mean Square	F-Test	*P* Value
Between groups	6	15199.94	2171.42	37.32	0.0001*
Within groups	28	1861.79	58.18		
Total	34	17061.73			
Material	3	14578.54	4859.51	83.52	0.0001*
Cure	1	90.30	90.30	1.55	0.2219
Material *Cure	2	531.09	177.03	3.04	0.0430*

*Statistically significant at $\alpha = 0.05$.

RESULTS

For phase one of the study, analysis of variance determined significant differences in flexural strength ($P < 0.0001$), elastic modulus ($P < 0.0001$), and hardness ($P < 0.0024$) among the products. Those mean values and Duncan groupings are shown in Table 1. CR-Inlay specimens were significantly higher in all three mechanical categories than the other products. Brilliant specimens ranked second in flexural strength and were not significantly different than Herculite Lab specimens in elastic modulus and hardness. Visio-Gem and Concept specimens demonstrated the lowest elastic modulus and were not significantly different in flexural strength. The product that resulted in the lowest hardness values was Visio-Gem.

In the second phase of this study, two-factor ANOVA detected significant differences ($P < 0.05$) between curing methods for flexural strength (Table 2) but not for hardness (Table 3) or elastic modulus (Table 4) when the four materials were grouped. Secondary processing produced, on average, an 11% increase in flexural strength (Table 5). The differences between materials for all three mechanical properties tested remained statistically significant ($P < 0.0001$) when the primarily and secondarily processed results were combined. Table 6 shows the mean mechanical values and Duncan groups combining those data. The Duncan groups remained the same as those for the specimens that were only secondarily processed (Table 1).

Table 4. Summary of ANOVA Calculations for Elastic Modulus, Comparing Materials with and without Secondary Curing

Source	DF	Sum of Squares	Mean Square	F-Test	*P* Value
Between groups	7	1064.22	152.03	90.31	0.0001*
Within groups	71	119.53	1.68		
Total	78	1183.75			
Material	3	1054.20	351.40	208.73	0.0001*
Cure	1	1.89	1.89	1.12	0.2932
Material *Cure	3	8.14	2.71	1.61	0.1944

*Statistically significant at $\alpha = 0.05$.

DISCUSSION

The first part of this study indicated that certain composite resin materials marketed for laboratory processing have mechanical properties (flexural strength, elastic modulus, and hardness) that exceed those properties of other similar products. In general, the trend was for the most highly filled product (CR-Inlay, approximately 86% by weight) to exceed the next most highly filled (Brilliant and Herculite XRV Lab, approximately 78%), and all of those products exceeding the microfilled products (Concept and Visio-Gem). The relative strengths of all these materials are likely to be affected (improved) in clinical use by the bonding process, since they are mechanically attached to tooth structure.

Flexural strength is an important property of dental restorative materials in which the biting stress may be severe (Craig, 1989). Likewise, elastic modulus is an important property. It is a measure of the stiffness of a material (higher elastic modulus = higher stiffness). In general, stiffness is beneficial for composite resin inlays and onlays, because excessive flexibility might stress the restoration-to-cement bond over time and lead to failure of the bond with subsequent recurrent caries.

The second part of the study examined the mechanical improvements provided by secondary processing for each of the four products that are incrementally light cured before secondary processing. The increase in flexural strength (11%) may be of some clinical benefit, since a recent study found an inverse linear relationship between flexural strength and clinical wear for posterior composites (Peutzfeldt & Asmussen, 1992). That finding indicates that flexural strength may be useful as a predictor of clinical wear.

Table 5. Mean Flexural Strength with Statistical (Duncan's Test) Groupings of Light-cured Composites with and without Secondary Processing

Processing	Flexural Strength (MPa)
Secondary cure	88.1 (31.2) A
Light only	79.4 (25.0) B

These findings indicate that flexural strength of composite resins can be improved by secondary processing, although the improvement is relatively small. This study did not address wear resistance, an aspect of consideration for which the microfilled products may excel. The most distinct advantage of indirectly processed composite resins may be the control of polymerization shrinkage, rather than improvement in strength and hardness. Controlling polymerization shrinkage in the laboratory, rather than allowing it to occur on the tooth, should help overcome cuspal tension problems. Additionally, the problem of polymerization shrinkage and marginal leakage (especially at cervical margins) should be minimized, since only a thin layer of cement is polymerizing in the mouth, instead of a substantial volume of composite resin (Robinson, Moore & Swartz, 1987; Hasegawa, Boyer & Chan 1989).

Table 6. Mean Mechanical Values and Duncan Groupings for Combined Primarily and Secondarily Cured Materials

Material	Flexural Strength (GPa)	Elastic Modulus (GPa)	Knoop Hardness
CR-Inlay	116.4 A	11.2 A	66.4 A
Brilliant	88.5 B	6.7 B	55.7 B
Herculite Lab	68.4 C	6.4 B	50.8 B
Visio-Gem	60.3 C	0.8 C	17.4 C

CONCLUSIONS

This study determined that numerous composite resin products developed and marketed for indirect processing possess varying degrees of strength, stiffness, and hardness. Overall, secondary processing improved flexural strength by an average of 11% among those products tested.

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Verification and Maintenance of Dental Explorer Sharpness

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Clinical Relevance
Examination variability can be minimized by standardizing explorer sharpness.

SUMMARY

An ongoing study of the relationship between different chewing gums, remineralization, and caries rates was started in 1989 in Belize, Central America. Initially 1277 children, age 10 years, were assigned in equal randomized groups to four dentists who had been trained to identify a standard of caries diagnosis. The same children were examined according to a modified WHO caries code by the same dentist in each of the three subsequent years. To eliminate one possible variable, all 200 dental explorers used were examined under a X20 binocular Bausch and Lomb dissecting microscope initially and at each exam period. Any explorer not comparable to an explorer that was originally marked and kept unused as a standard was sharpened by hand on an Arkansas oilstone wetted with engine oil for lubrication. Explorers that could not be restored to a condition comparable at X20 to the standard were discarded. Approximately 10% of the explorers needed correction at each exam period and about 1% were discarded. In any study related to dental caries evaluation with dental explorers or comparison of explorer use versus nonuse, verification and maintenance of sharpness of used and even new dental explorers should be addressed to remove that factor as a possible variable.

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INTRODUCTION

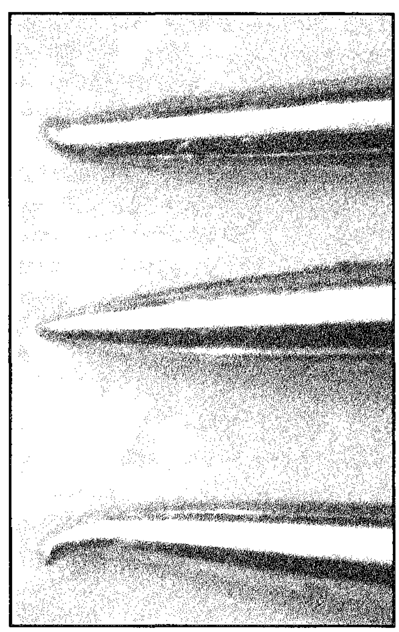
The variety of dental explorers available for dental caries examination and the possible variation between tips of even new identical explorers was shown by Charbeneau and others (1988), and the importance and methods of sharpening dental hand instruments also has been published (Gilmore & others, 1982). The necessity of standardization of recording dental conditions has been covered by Marthaler (1966). The present codes and criteria of the World Health Organization (1987) standards and the "Criteria for Caries Diagnosis" from the Conference of the Clinical Testing of Cariostatic Agents (Council on Dental Therapeutics, 1968) presume the use of an explorer. These criteria are also presented in the text published by Charbeneau and others (1988). A study of the use of an explorer for only eight examinations before discarding was done by Koch (1967). His discussion of the need of a stick with little pressure and for a definite pull for removal from pits and fissures relates to the procedure followed in this study. If a dental explorer becomes dulled during use or slightly bent during use or cleaning and sterilization, the modification of the tip could cause a variable in an examiner's diagnosis and in ultimate consistency of caries documentation. Variations in the sharpness of explorers will significantly handicap the evaluators of visually inaccessible margins, as described by Rappold, Ripps, and Ireland (1992). Variability in the tip diameter or taper could also affect the consistent duplication of caries diagnosis not only for the same examiner but also for multiple examiners. The use of dental explorers for general dental caries examination has come under review for the possibility of the transmission of bacteria from one site to another in the oral cavity (Loesche, Svanberg & Pape, 1979), and the need for reduction of the explorer's possible contamination has been addressed by D'Hondt, Pape, and Loesche (1982). There has also been a presentation by Pitts (1993) at an International Association of Dental Research Symposium of the trend by authorities toward the nonuse of the explorer and preferable use of visually based criteria.

METHODS AND MATERIALS

An ongoing study of the relationship between different chewing gums and caries rates was started in 1989 in Belize, Central America, in conjunction with the Belizean Ministry of Health (Mäkinen & others, 1993). Initially 1277 children, average age 10 years, were assigned in equal randomized groups to four dentists who had been trained to identify a standard of caries diagnosis using DMFS (Decayed, Missing, Filled Surfaces) scoring of all permanent teeth, with determination of enamel, dental, and pulpal depth lesions, but not recording white-spot lesions without contour loss. This is according to the WHO codes (1987), except that WHO's caries code 1 (enamel caries without loss of substance) was equal to a sound surface in this study. The protocol of the clinical trial did not presume brushing of the teeth prior to clinical examination. The same children were examined by the same dentist in each of the three subsequent years. Due to individual preference two examiners utilized Hu-Friedy EXD#6 double-ended modified shepherd's hook/straight explorers (Hu-Friedy Mfg Co Inc, Chicago, IL 60618), while the other two examiners selected Hu-Friedy EXD#2 double-ended cowhorn (pigtail) explorers. Both designs have very sharp points, are used primarily for caries examination (Nield, 1990), and are similar in appearance under magnification. Since each examiner was assigned approximately 50 new explorers at the beginning of the study and did not cross over to the other design, subsequent examination results should not have varied. Also all examinations were performed by the same examiner on the same subjects for the entire study. In order to eliminate one possible variable, all dental explorers used were compared by the same examiner under a X20 binocular Bausch and Lomb dissecting microscope (Bausch & Lomb, Tucker, GA 30084) initially and at each exam period to an explorer of each type that was originally marked and kept unused as a standard (figure). Any explorer that did not appear similar was sharpened by hand on an Arkansas oilstone wetted with engine oil for lubrication until the tip was brought back to the shape of the unused standard explorer. Explorers that could not be restored to a condition comparable at X20 to the standard were discarded. Approximately 10% of the explorers needed correction after approximately eight examinations, and about 1% were discarded. The variation in the sharpness of the tips was not discernible clinically with the unaided eye and only the most damaged explorers with the tip bent to a miniature fishhook could sometimes be felt catching on a dry gauze or the damage seen by very careful visual inspection under a bright light.

DISCUSSION

To eliminate one possible variable in this study, every dental explorer was compared to a standard and then maintained at a level higher than was discernible by normal clinical means, in this case at



Examples of explorers used in Belize study: upper—correctable, center—standard, lower—discarded a magnification of X20. The need for resharpening of 10% of the explorers following considerable use shows that diameter and sharpness will change, and the need to discard 1% of the explorers due to major alteration of the tip underscores the fact that consistent examiner evaluation could be affected by these changes. Quite possibly the explorers that needed discarding were actually damaged during cleaning and sterilization, since their numbers were so small compared to the number of examinations performed. The discarding of explorers after a certain number of examinations would help eliminate deterioration during use, but not variation in original manufacture or possibility of damage during cleaning and sterilization. Also cost and needless environmental impact of use of natural resources in manufacture and disposal seem unnecessary when other methods can be used. In this study alone over 700 explorers would have been needed and discarded, rather than the 200 utilized and still clinically functional. In any study, verification and maintenance of sharpness of used and even new dental explorers should be addressed to remove that factor as a possible variable in dental caries evaluation. In the caries-prevention program referred to (Mäkinen & others, 1993), a large number of arrested enamel caries lesions were observed as a result of the program intervention and because of the operation of the natural repair mechanism of saliva. Since long-term consumption of polyol-containing chewing gums especially can be associated with the arrest of caries, it is crucial to carry out the blind clinical caries registrations in such studies by paying meticulous attention to explorer sharpness, since rehardening of caries lesions would be difficult to judge by visual means. Also since the protocol of this study did not presume brushing of the teeth prior to clinical examination, it would have been very difficult to reliably carry out the caries diagnoses without explorers because of the presence of abundant plaque and even calculus on tooth surfaces.

CONCLUSION

While it may be justified to advise against the general use of an explorer in clinical diagnosis to decrease the potential spread of odontopathic organisms and the capability of caving in remineralizable lesions, the purpose of the present report is to underline the importance of maintaining the shape and condition of explorers used in any long-term clinical study. There is a definite need for further study of the standardization of clinical caries detection and evaluation; however, there is also a need to specifically address the standardization and maintenance of the condition of the dental explorers used in those studies as outlined in this paper.

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Amalgam Shear Bond Strength to Dentin Using Different Bonding Agents

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Clinical Relevance
The bond strength of amalgam to dentin was significantly higher with Amalgambond Plus using the High-Performance Additive than with the other four bonding agents.

SUMMARY

This study evaluated the shear bond strength of amalgam to dentin using five different bonding agents: Amalgambond Plus, Optibond, Imperva Dual, All-Bond 2, and Clearfil Liner Bond. Flat dentin surfaces obtained by grinding the occlusal portion of 50 human third molars were used for this study. To contain the amalgam on the tooth surface, cylindrical plastic molds were placed on the dentin and secured with sticky wax. The bonding agents were then applied according to the manufacturers' instructions or light activated and Tytin amalgam was condensed into the plastic molds. The samples were thermocycled and shear bond strengths were determined using an Instron Universal Testing Machine. Analysis by one-way ANOVA indicated significant difference between the five groups ($P < 0.05$). The bond strength of amalgam to dentin was significantly higher with Amalgambond Plus using the High-Performance Additive than with the other four bonding agents.

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INTRODUCTION

Amalgam restorations have been used in dentistry for more than a century with clinically adequate results. Several advantages of amalgam include relatively low cost, ease of manipulation, good wear resistance, less technique sensitivity and self-sealing ability (Leinfelder, 1983; Jordan, Suzuki & Boksman, 1985). However, amalgam lacks the ability to bond to tooth structure, and therefore has traditionally been retained in cavity preparations by retentive features that often require the removal of sound tooth structure. In badly destroyed teeth, these modifications may weaken the remaining tooth structure and lead to fractures or endanger the pulp (Balanko, 1992; Harris, 1992).

The use of an amalgam bonding agent may help overcome the need for additional retentive features. It has been found that some of these bonding agents strengthen the restored tooth (Eakle, Staninec & Lacy, 1992; Ianzano, Mastrodomenico & Gwinnett, 1993). A reduction in microleakage has also been reported when bonding agents are used in conjunction with amalgam as the restorative material (Edgren & Denehy, 1992; Cooley, Tseng & Barkmeier, 1991; Charlton, Moore & Swartz, 1992; Shimizu, Ui & Kawakami, 1986).

It is believed that the bond formed between the resin and amalgam is a micromechanical bond. The alloy is condensed against the adhesive resin before polymerization, allowing the amalgam to surround the resin and lock into it as both the alloy and the resin set (Gendusa, 1992).

Studies have been conducted to evaluate the bond strength of amalgam to enamel and dentin with the use of different bonding agents. DeSchepper and others (1991) reported that the mean tensile bond strengths of amalgam to dentin using All-Bond ranged from 10 to 11 MPa. Roeder, DeSchepper, and Powers (1991) reported amalgam to amalgam bond strengths of 3.4 to 8.8 MPa with All-Bond. Hasegawa and others (1992) studied the shear bond strength of freshly mixed amalgam to dentin using Amalgambond and found that it was 5.10 ± 1.73 MPa. Covey and Moon (1991) tested the shear bond strength of four dentin bonding agents. They found that the mean shear bond strengths for Amalgambond, Panavia, Ketac-Cem, and Scotchbond 2 were 3.56, 3.46, 3.26, and 4.87 MPa respectively.

Since the dentist is unable to light cure the adhesive layer through the amalgam, the use of a dual-cure or self-cure adhesive is recommended to achieve proper polymerization of the adhesive with the amalgam.

Two new hydrophilic bonding systems, Optibond and Clearfil Liner Bond, have recently been introduced into the dental market. Both of these systems are unique in that they contain a filled adhesive resin. Although the manufacturers do not specifically recommend these products for amalgam bonding, their filled adhesive resin may offer potential.

The purpose of this study was to evaluate the shear bond strength of amalgam to dentin using five different bonding agents, including the two systems with a filled adhesive resin along with three bonding systems specifically recommended for amalgam bonding.

Amalgam Shear Bond Strengths to Dentin (MPa)

Group	Mean	SD	Range
Amalgambond Plus	11.97	3.63	5.09-17.32
Optibond	8.24	2.07	5.30-11.20
Imperva Dual	7.23	3.35	4.04-13.79
Clearfil	6.82	3.01	3.06-11.82
All-Bond 2	6.23	1.63	4.02- 9.34

Values connected by the line are not significantly different (α = 0.05).

METHODS AND MATERIALS

Fifty extracted human noncarious third molars were used in this study. The teeth were mounted in phenolic rings with acrylic resin and the occlusal enamel was removed to produce a flat dentin surface perpendicular to the long axis of the tooth. The dentin surfaces were then ground wet with 240-, 400-, and 600-grit silicone carbide paper to obtain a uniform smear layer surface.

The teeth were randomly assigned to five test groups of 10 samples each. A cylindrical plastic mold 3 mm in diameter was secured to each dentin surface of the teeth using sticky wax.

The dentin bonding agents tested were: Amalgambond Plus (Parkell Products, Farmingdale, NY 11735), Imperva Dual (Shofu Inc, Kyoto, Japan), Optibond (Sybron/Kerr, Romulus, MI 48174), Clearfil Liner Bond (Kuraray Co, Osaka, Japan and J Morita USA Inc, Tustin, CA 92680) and All-Bond 2 (Bisco Inc, Itasca, IL 60143). Tytin (Sybron/Kerr), a predosed high-copper spherical alloy, was used for the test restorations.

The dentin was conditioned and bonding agents were applied. Manufacturer instructions for amalgam bonding were followed for Amalgambond Plus, Imperva Bond, and All-Bond 2. For Optibond and Clearfil Liner Bond the adhesive resin was light polymerized for 40 seconds with a Demetron 401 (Demetron Research Inc, Danbury, CT 06810) light curing unit, then the alloy was triturated and condensed into the plastic molds.

The plastic molds were split and removed 20 minutes after amalgam condensation. The samples were stored in distilled water for 24 hours and thermocycled 300 times between 5 and 55 °C. The dwell time in each bath was 33 seconds, with a transfer time of 13 seconds. At 48 hours, shear bond strengths were performed using an Instron Universal Testing Machine (Instron Corp, Canton, MA 02021) at a crosshead speed of 5 mm/min until fracture occurred.

RESULTS

The mean shear bond strength of the different bonding agents ranged from 6.23 to 11.97 (table). One-way analysis of variance revealed a significant difference in mean shear bond strength ($P < 0.05$). Duncan's multiple range test showed that the mean shear bond strength of Amalgambond Plus specimens was significantly higher than the other groups and that the other four groups were statistically similar.

DISCUSSION

Under the conditions of this study, all of the bonding agents tested were able to bond amalgam to dentin; however, these bond strengths were lower than those reported for composite to dentin (Kanca, 1992; Miller & others, 1992).

Amalgambond Plus demonstrated better shear bond strengths than the other four bonding agents. The higher bond strengths for Amalgambond Plus may have resulted from the use of what the manufacturer calls a "High-Performance Additive," which contains polymethylmethacrylate fibers. These fibers may cross the interface between the amalgam and the bonding agent, producing a reinforced connection between the two materials. It should be noted that the manufacturer recommends using these fibers only in cases that need additional adhesion, not in normal amalgam bonding.

Of the five bonding agents tested, one (Amalgambond Plus) was self-cured, one was a light-cured resin (Clearfil Liner Bond), and the other three were dual-cured systems. Manufacturers' instructions for amalgam bonding recommended the placement of the amalgam before the adhesive resin has had the chance to polymerize. In this way the amalgam and the adhesive mix together before both set. These recommendations were followed for three of the systems tested, Amalgambond Plus, All-Bond 2, and Imperva Dual.

The two new filled adhesive resins, Optibond and Clearfil Liner Bond, are not currently recommended by their manufacturers for amalgam bonding, and contain no amalgam bonding instructions. It was decided to light polymerize the adhesive of both systems before the amalgam addition.

Despite the fact that Optibond and Clearfil Liner Bond were light polymerized before amalgam placement, they produced similar bond strengths to the two dual-cure adhesive resins, Imperva Dual and All-Bond 2.

It is known that oxygen inhibits polymerization of the surface layer of composite resins (Ruyter, 1985). This unpolymerized surface layer is called the oxygen- or air-inhibited layer, and can range from 7 to 150 μm depending on the type of composite resin (Ruyter, 1981; Erickson, 1989; Peutzfeld & Asmussen, 1989). It would appear from the results of this study that the oxygen-inhibited layer may have played a role with the light polymerized adhesives in the formation of the micromechanical retention to amalgam. It is possible that when the amalgam is condensed against the air-inhibited layer both will mix. The amalgam eliminates the oxygen at the interface and free radicals consume the remaining oxygen. The adhesive then polymerizes by the free radicals produced by the chemical activator or by free radicals already present in the air-inhibited layer or in polymerized sub-layers that diffuse to this layer.

A future study will further investigate this hypothesis and compare different amalgam bond strengths with condensation of amalgam into prepolymerized and nonprepolymerized bonding agents.

CONCLUSIONS

In this study all the bonding agents tested demonstrated bonding of amalgam to dentin. Amalgambond Plus using the High Performance Additive demonstrated the highest shear bond strengths of all the groups. No significant difference was found between the bond strengths of the other bonding agents.

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Placement and Replacement of Amalgam Restorations in Germany

K-H FRIEDL • K-A HILLER • G SCHMALZ

Clinical Relevance
Secondary caries is the most common reason for replacement of amalgam in Germany.

SUMMARY

From 15 September to 15 October 1991, 102 dentists practicing in a rural area of Germany provided information on 5240 amalgam restorations. The aim of the present cross-sectional study was to investigate the reasons for placement and replacement of amalgam fillings and to register the age of the failed restorations. First placements because of primary caries were made in 47.1% of all cases; 52.9% were replacements of failed restorations. The most frequently recorded reason for replacement was secondary caries, irrespective of size of the filling, dentition, and age group. The second most frequently recorded reasons for replacement depended on the size of the filling, the age and the dentition of the patient: Bulk fractures were predominant in primary teeth and in fillings with three or four surfaces, primary caries in permanent teeth of patients 16 years old or younger and marginal gaps in adults and in fillings with one or two surfaces. The median age of replaced amalgam restorations in adults was 60 months.

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INTRODUCTION

Rapid advancements in the development of dental materials were made during the past decade, leading to new materials; e g, composite resins for stress-bearing restorations in posterior teeth and new restoration techniques (Dahl & Eriksen, 1978; Qvist, Qvist & Mjör, 1990). However, easy handling and superior material properties still make amalgams the most frequently used filling material for restorations in posterior teeth (Van Meerbeek & others, 1991; van Noort, 1991; Welbury & others, 1991).

In order to test the efficiency of restorative treatment, many studies on different dental materials were made worldwide during the last decades. They were dealing with the longevity of the restorations (Hendriks & Letzel, 1988; Mjör & Toffenetti, 1992; Qvist & others, 1986, 1990; Richardson & Boyd, 1973; Smales, Webster & Leppard, 1991) and the criteria for replacement (Akerboom, Advokaat & Borgmeijer, 1986; Allan, 1969; Allander, Birkhed & Bratthall, 1990; Elderton, 1976). The design of these surveys ranged from a longitudinal prospective study, lasting 20 years (Robinson, 1971), to cross-sectional retrospective studies on dental records (Allander & others, 1990; Mjör & Toffenetti, 1992; Qvist & others, 1986, 1990). In spite of the inherent disadvantages of cross-sectional studies, they provide valuable information on the restorative treatment in private or public practice (Mjör, Jokstad & Qvist, 1990; Qvist & others, 1990).

The aim of this study was (1) to record the reasons for placement or replacement of amalgam restorations and (2) to record the age of the replaced fillings in a rural area of southern Germany, in order to update our knowledge about restorative treatment patterns in private practice. A detailed analysis of the tooth-colored restorations will be reported on elsewhere.

METHODS AND MATERIALS

In August 1991 a questionnaire was sent to all 481 dentists practicing in a rural area of Germany (Oberpfalz). They were asked to record information from 15 September to 15 October 1991 on all fillings made because of primary caries, which will be referred to as "first placement," or made as a replacement of an old filling. The following reasons for replacement were provided on the questionnaire: primary caries, secondary caries, marginal gap without caries, fracture (tooth, isthmus, other), pain, discoloration, loss of contour, and lost filling. The clinicians were also asked to indicate size and material of the old and new filling and, if known, the age of the old filling.

The dentists were allowed to mark several reasons for replacement. In order to distinguish the reasons for placement and replacement in primary and permanent teeth among the young and adult patients, and to have the possibility of comparing the results with other studies, the patients were divided according to Qvist and others (1990) into three groups:

PRT Group: primary teeth and the patient is 16 years old or younger,

PET 1 Group: permanent teeth and the patient is 16 years old or younger, and

PET 2 Group: permanent teeth and the patient is older than 16 years.

RESULTS

The response rate to our questionnaire was 21.2%. The 102 participating dentists provided information on 8794 restorations: A total of 5240 (59.6%) amalgam restorations were placed during the given period; 3994 (76.2%) of them were placed in adults. Figure 1 shows the distribution of all amalgam fillings according to age, dentition, and size of the restorations.

Primary caries was the reason for filling 2472 teeth (47.1%) for the first time, 98.7% of them were posterior teeth. In premolars and molars the relation between amalgam and composite fillings made for the first time was 4.2:1.

Amalgam was used as the material for the first placement of a filling in primary teeth in 79.1%, in the PET 1 group in 75.8%, and in the PET 2 group in 51.4%.

Figure 2 shows the distribution of first placements according to age, dentition, and size of the restorations.

Altogether, 2961 amalgam restorations were replaced. In 86.2% of the 2961 replaced restorations, amalgams were replaced by amalgams, 10.9% were replaced by composites. The most frequently recorded reasons for replacement in the PRT group were secondary caries, fracture, and marginal gap

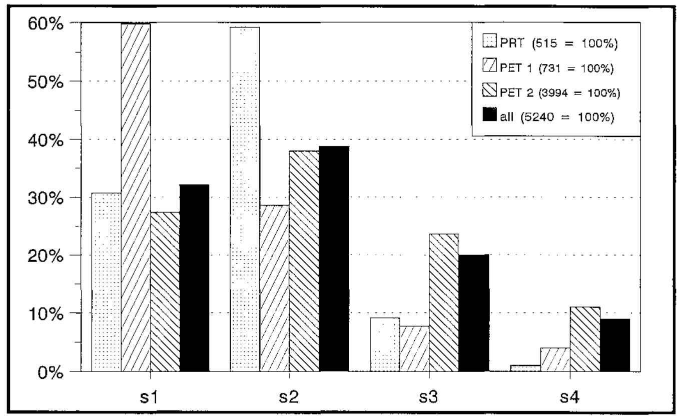

Figure 1. *Distribution of all amalgam restorations (%) according to age of the patient, dentition and size of the restoration (number of surfaces: s). PRT = primary teeth; PET 1 = permanent teeth and patient is 16 years old or younger; PET 2 = permanent teeth and patient is older than 16 years.*

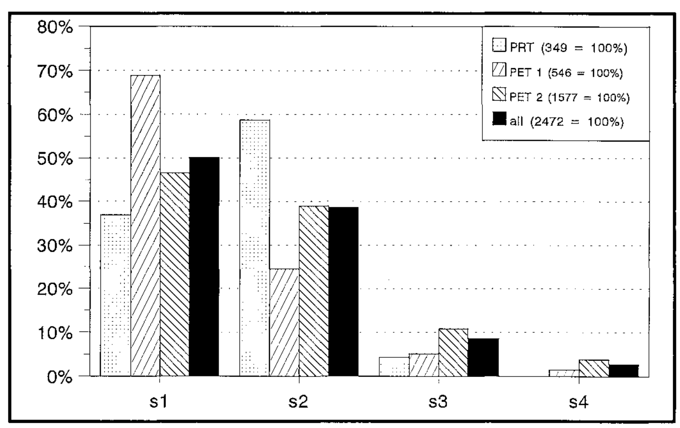

Figure 2. *First placement with amalgams (%) according to age of the patient, dentition and size of the restoration (number of surfaces: s). PRT = primary teeth; PET 1 = permanent teeth and patient is 16 years old or younger; PET 2 = permanent teeth and patient is older than 16 years.*

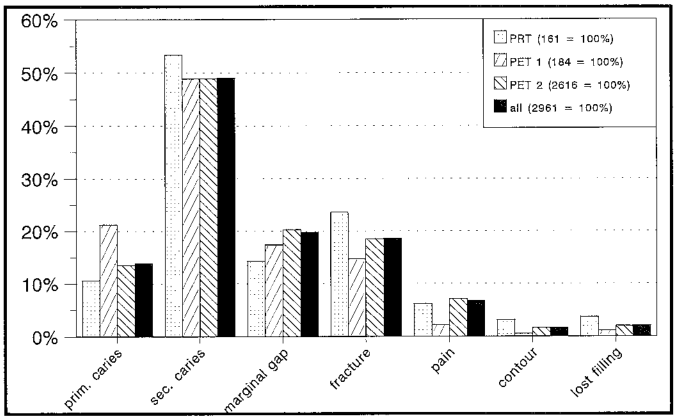

Figure 3. *Reasons for replacement (%) of failed amalgam restorations according to age of the patient and dentition. PRT = primary teeth; PET 1 = permanent teeth and patient is 16 years old or younger; PET 2 = permanent teeth and patient is older than 16 years.*

without caries; in the PET 1 group they were secondary caries, primary caries, and marginal gap without caries. The major reasons for replacement in the PET 2 group were secondary caries, marginal gap without caries, and fracture (Figure 3). When a filling was replaced because of fracture, 50% of the fractures were located at the isthmus of the filling and 30% in the tooth itself. Primary caries as the only reason caused the replacement of an intact filling in 10.5% of all cases.

Secondary caries was the main reason for replacement of all sizes of fillings. The second most frequent reason for the failure of a filling with three or four surfaces was the fracture of the restoration; for the failure of the fillings with one or two surfaces, it was marginal gap without caries (Figure 4).

The age of the restoration was recorded in 1790 (60.5%) of the 2961 replaced restorations. The oldest replaced filling was 40 years old. In the PET 2 group (n = 1535), 60% of the restorations were replaced within the first 60 months after placement; the median longevity of all replaced restorations was 53 months, in adults it was 60 months. Figure 5 shows the median longevity of the replaced fillings with respect to the size of the filling.

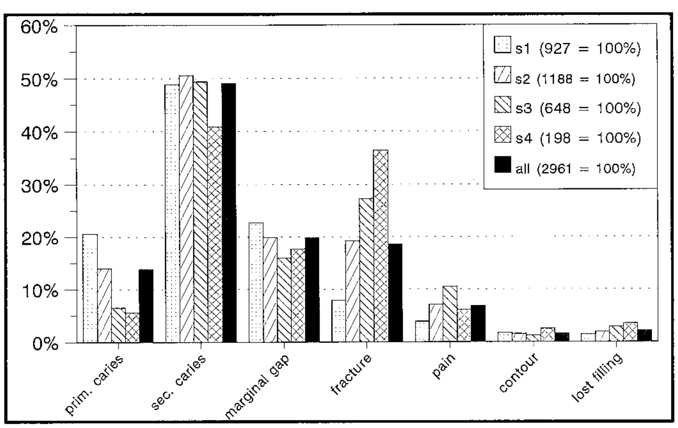

Figure 4. *Reasons for replacement (%) of failed amalgam restorations according to size of the restoration (number of surfaces: s)*

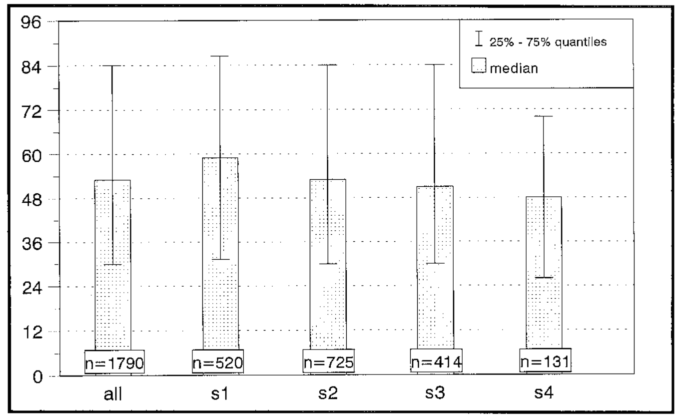

Figure 5. *Median recorded longevity (months) of the failed amalgam restorations according to size of the restoration (number of surfaces: s)*

DISCUSSION

The prospective longitudinal study provides the most exact data in registering the age of a filling (Mjör & others, 1990; Robinson, 1971). The disadvantages of such studies include the selection of patients and dentists, low numbers of patients, and examination periods longer than 10 years, which are difficult to perform mainly due to the patients dropping out (Mjör & others, 1990). Therefore, the cross-sectional approach, as used in the present survey, is the most feasible method to register the work of the dentists in daily practice (Mjör & others, 1990; Qvist & others, 1986, 1990). The results of the normal daily treatment are recorded rather than results attainable during optimal conditions. However, the disadvantages of the cross-sectional study are that the dentists are not exactly calibrated, i e, the decision whether a filling should be placed or replaced is based only on the dentists' personal judgment, and criteria leading to this decision cannot be as exactly defined as in prospective longitudinal studies (Allan, 1969; Mjör & others, 1990; Richardson & Boyd, 1973).

In our investigation, 47.1% of the fillings were first placements because of primary caries and 52.9% were replacements of old restorations. This supports findings of Allander and others (1990) and Mjör (1981) that the dentist spends more than half of his time replacing old fillings.

In the PET 1 and PET 2 groups, the number of "first placement with amalgams" decreases with the increasing size of the filling. However, in primary teeth the number of those that had to be filled on two surfaces the first time is more than 20% higher than those requiring only one surface. This may be an indication that: (1) parents neglect the importance of care and treatment of the primary teeth, and (2) that the progress of caries in a primary lesion and the right treatment are difficult to ascertain (Nuttall & Pitts, 1990).

Reports in the literature that the reasons for the replacement of a restoration vary with the age of the patient, the dentition, and the size of the fillings (Qvist & others, 1986) are confirmed by our results. Secondary caries has been shown to be the major reason for replacement of restorations in many studies (Allander & others, 1990; Dahl & Eriksen, 1978; Mjör, 1981; Qvist & others, 1986, 1990; Richardson & Boyd, 1973), which is also confirmed in the present study. In fillings with three or four surfaces the replacement caused by fracture plays an important role, which is also consistent with findings reported by Qvist and others (1990).

In the primary dentition the replacement caused by secondary caries was more frequent than replacement caused by fracture, which contradicts findings from Denmark (Qvist & others, 1986, 1990), where fracture was the major reason for replacement. The high rate of secondary caries in our investigation may be attributable to the possibility that the dentist could mark more than one reason in our questionnaire, which was not allowed in other studies (Qvist & others, 1986, 1990). So secondary caries may be the result of fracture and/or other reasons.

Carlos and Gittelsohn (1965) and Kotsanos and Darling (1991) point out that the caries risk may be higher in an early posteruptive state of the teeth. The observation in the present study is that primary caries on other surfaces causes replacement of 21.2% of intact fillings in the PET 1 group. Thus, the low median age of 30 months in failed amalgam fillings of the PET 1 group may be in part due to these types of replacements, and our results in this age group are lower than the 44 months reported by Qvist and others (1990).

It has to be considered that the PRT, PET 1, and PET 2 groups in our study are very different in number of fillings and age structure of the patients. Thus a direct comparison of the median longevities of failed amalgam restorations between the groups in our survey is not appropriate. Only the median longevities either of all fillings or of adequate groups in different surveys can be compared.

The median longevity of the replaced restorations of 53 months in the present study is lower than the findings of Qvist and others (1990) of about 8 years or the results of Mjör (1981), who found that 50% of all amalgam fillings are older than 8 - 10 years, but it is higher than that reported by Mjör and Toffenetti (1992).

The reasons for these differences in longevity of replaced fillings cannot be determined by cross-sectional studies. However, these differences may be attributable to the fact that longevity of a filling is not only dependent on material and restoration technique, but also on the skill and judgment of the dentist as well as on the oral hygiene of the patient (Allan, 1969; Allander & others, 1990; Dahl & Eriksen, 1978; Mjör & others, 1990; Qvist & others, 1986; and Smales & others, 1991).

CONCLUSIONS

Amalgam is still the most often used material for restorations in posterior teeth. The high percentage of amalgam fillings replaced because of secondary caries demands an improvement of the operative technique as well as effective prophylaxis programs and good oral hygiene.

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DEPARTMENTS

ABSTRACTS

The editor wishes to thank the second-year Advanced General Dentistry residents at US Army Dental Activity, Fort Knox, Kentucky, for their assistance in the preparation of these abstracts.

Comparison of shear strength, fracture patterns, and microleakage among unfilled, filled, and fluoride-releasing sealants. *Park K, Georgescu M, Sherer W & Schulman A (1993) *Pediatric Dentistry* 15(6) 418-421.

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This study compared unfilled, filled, and fluoride-releasing filled sealants to each other through shear bond, scanning electron microscope, and microleakage evaulations to determine if fluoride-releasing sealants exhibit similar bonding characteristics. The following materials were evaluated in each test: Delon Pit and Fissure Sealant, Prismashield, and Fluoroshield. The shear bond strength test utilized freshly extracted, noncarious human molar teeth. One enamel surface (facial, lingual, or approximal) was ground flat to 600-grit and etched with 50% phosphoric acid for 60 seconds. Clear plastic cylindrical tubes were placed in a vertical position on the flat ground enamel surface, filled incrementally with sealant, and cured for 60 seconds with visible light. The sealant posts were sheared using an Instron Universal Testing Machine. In the SEM analysis, enamel occlusal surfaces were treated in a similar fashion as the shear bond study: the teeth were dissolved in HCl and dessicated and coated with a 50 nm film of gold-palladium alloy. In the microleakage analysis, the teeth were prepared in the same manner as the SEM study: teeth were etched, sealants applied, 60-second visible-light cured, thermocycled, and the specimens were sectioned and scored for microleakage.

Microleakage study results revealed that all three sealants bonded to etched enamel as noted by polymer tag formation. The tag formations promote micromechanical adhesion between sealant and enamel. Microleakage is thereby minimized. SEM revealed that Prismashield and Fluoroshield adapted to the etched enamel surface more completely than did Delton, producing more continuous and uniform sieve-like tag formations throughout their entire surfaces. Delton exhibited diffuse resin tags. No significant differences were noted in microleakage, but a signficant difference in shear bond strength was noted between Delton and the two filled sealants. Filled sealants had higher shear-bond values. Differences in bond strengths between unfilled and filled relate to the ability of the sealants to adapt or intimately contact the etched enamel surface. Prismashield and Fluoroshield (both containing urethane BIS-GMA, a monomeric matrix) may cause differences in flow properties. It may confer more elasticity and adhesiveness to the resin than BIS-GMA monomer, as contained in the Delton product. SEM micrographs revealed sealants to be in intimate contact with enamel rods. No enamel fractures were observed in Delton specimens. Enamel fractures were noted with Fluoroshield. Prismashield exhibited both enamel and adhesive fractures and combination adhesive and cohesive fractures. Insignificant differences in microleakage were noted among the three sealants. Prismashield and Fluoroshield exhibited significantly higher mean shear bond strength values than the Delton Pit and Fissure sealant.

A six-month clinical study of the effect of a prebrush rinse on plaque removal and gingivitis. *Worthington HV, Davies RM, Blinkhorn AS, Mankodi S, Petrone M, DeVizio W & Volpe AR (1993) *British Dental Journal* 175(9) 322-326.

(*University of Manchester, Dental Health Unit, Department of Oral Health and Development, Manchester Science Park, Lloyd Street North, Manchester UK M15 6SH)

The purpose of this study was to compare the effectiveness of a prebrush rinse containing 0.03% triclosan and 0.125% copolymer (Colgate Plax, Colgate, UK) and a matching placebo prebrushing rinse on existing plaque and gingivitis over a 6-month period. It was a double-blind, parallel study of 6 months' duration using 125 adult male and female subjects, of which 117 completed the study. One group used a prebrush rinse containing 0.03% triclosan and 0.125% of a copolymer of methoxyethylene and maleic acid. The other group used a matching placebo rinse. The subjects rinsed twice daily (morning and evening) for 60 seconds with 15 ml of their assigned rinse. Immediately after rinsing subjects brushed their teeth for 30 seconds with a fluoride dentrifice and a soft-bristled toothbrush.

After 3 and 6 months, the levels of plaque and gingivitis were significantly lower in the triclosan/copolymer rinse group when compared with the placebo rinse group. The most significant improvements in oral hygiene and gingival health were found on those surfaces that initially had the highest levels of plaque and gingivitis.

The results of this study demonstrate that a prebrush rinse containing triclosan and copolymer is an effective adjunct to mechanical cleaning.

Evaluation of ferric oxalate as an agent for use during surgery to prevent post-operative root sensitivity. ***Wang HL, Yeh C-T, Smith F, Burgett FG, Richards P, Shyr Y & O'Neal R (1993)** ***Journal of Periodontology*** **64 1040-1044.**

(*University of Michigan, School of Dentistry, Department of Periodontics/Prevention and Geriatrics, Ann Arbor, MI 48109)

To evaluate the effectiveness of a 6% ferric oxalate solution applied during periodontal surgery to prevent postoperative tooth hypersensitivity, 25 adults with bilateral periodontal defects had baseline data collected 1 week prior to surgery and at 1, 2, 4, and 6 weeks following the surgery. Sensitivity was determined by utilizing 1) mechanical stimulation with a dental explorer, 2) water at 50 °C, 3) ice, and 4) EPT. Teeth were randomly selected to either receive the 6% ferric oxalate in 0.9% saline (test group) or simply 0.9% saline (control group).

The results demonstrated a statistically significant reduction in the responses to cold stimuli for the test group (a 26% increase) versus the control group (a 91% increase). This increased with time from the baseline until 6 weeks. Statistically significant differences in heat stimuli (which were lower) were also observed but only at 2 and 4 weeks. There were no differences between tactile or EPT clinical parameters.

It was concluded from this study that 6% ferric oxalate was effective in reducing postsurgical cold sensitivity when applied during periodontal surgery. The authors did not study the effects of this procedure on cell attachment or wound healing.

This procedure could prove to be a nice adjunct for patient comfort when any surgery or operative procedure could cause postoperative root sensitivity. One might consider this procedure along with desensitization of the root surface when not attempting to gain reattachment.

Potential efficacy of chlorhexidine against mutans streptococci and human caries. *Emilson CG (1994) ***Journal of Dental Research*** **73 682-691.**

(*University of Göteborg, Göteborg, Sweden)

The purpose of this presentation is to discuss the use of chlorhexidine as a chemotherapeutic agent against mutans streptococci. Susceptibility to chlorhexidine varies with more potent effects on Gram-positive than on Gram-negative microorganisms. Treatment with chlorhexidine gel in humans has been found to decrease mutans streptococci to low levels in saliva and plaque, although after treatment they gradually increase to pretreatment levels. Clinical trials to study the caries-prevention effect of chlorhexidine were conducted in the 1980s. Participants were mainly schoolchildren with a high salivary number of mutans streptococci and high incidence of dental caries. They also demonstrated a higher colonization level of mutans streptococci and caries incidence on premolar and molar approximal tooth surfaces than on equivalent anterior surfaces. Zickert and others gave 1% chlorhexidine gel in vinyl applicators only to children with greater than 2.5×10^5 mutans streptococci per mL saliva. Salivary samples were collected every 4 months. On each occasion only schoolchildren with high numbers of salivary mutans streptococci were healed again. After 3 years, children in the control group had developed 9.6 new lesions and the healed group only 4.2, a difference of 56%. Several other studies using similar criteria of patient selection yielded similar percentage reductions in caries incidence. The main clinical problem with these studies was the difficulty of suppressing mutans streptococci for an extended period. Re-colonization times varies among subjects. In persons in whom cultivable mutans streptococci had been reduced by 99% after chlorhexidine gel treatment, the bacteria returned more slowly than in persons with a smaller reduction. Clinical trials have shown that the combination of chlorhexidine and fluoride has a synergistic effect. No antimicrobial except fluoride has been shown to be more effective in caries prevention than chlorhexidine. The most persistent reduction in mutans streptococci has been achieved by chlorhexidine varnishes, followed by gels and mouthwashes.

Effect of APF gel on light-cured glass ionomer cements: an SEM study. Triana RT, Millan CP, Barrio JG & *García-Godoy F (1994) *Journal of Clinical Pediatric Dentistry* 18 109-113.

(*University of Texas Health Science Center at San Antonio, 7703 Floyd Curl Drive, San Antonio, TX 78284-7888)

A scanning electron microscopic study was done on the surface morphological effect of a 1.23% acidulated phosphate fluoride (APF) gel (Oral-B Minute) on two glass-ionomer cements with and without an unfilled resin (Ketac-Glaze) protective layer. VariGlass and Vitrebond glass-ionomer cylinders were each divided into four test groups: 1) No treatment (control), 2) APF treatment for 4 minutes, 3) Resin application, and 4) Resin application plus APF treatment for 4 minutes. Glass-ionomer cement cylinders were fabricated by handling the materials according to manufacturers' instructions, with the exception of the resin application. The resin was brushed on and light-cured for 30 seconds. APF gel was applied with cotton applicator, rinsed with water for 20 seconds, and dried. APF gel on unprotected glass-ionomer samples resulted in the exposure of surface glass-ionomer particles characteristic of etching. The surface of the resin-protected glass-ionomer samples, both with and without the application of APF gel, remained smooth. Results demonstrated that an unfilled resin glaze on light-cured glass-ionomer cements protected the surface from the etching effects of an APF gel. This suggests the need for resin glazing prior to APF treatment or the use of a neutral fluoride treatment to protect glass-ionomer cements.

BOOK REVIEW

PORCELAIN & COMPOSITE INLAYS & ONLAYS: ESTHETIC POSTERIOR RESTORATIONS

David A Garber, Ronald E Goldstein

Published by Quintessence Publishing Co, Inc, Chicago, 1993. 158 pages, 284 illustrations. $68.00.

The purpose of *Porcelain & Composite Inlays & Onlays: Esthetic Posterior Restorations* is to present alternatives to conventional methods of restoring posterior teeth. Drs Garber and Goldstein have lectured and published extensively in the area of esthetic dentistry and are recognized authorities in this field. Although the use of porcelain as an intracoronal restoration has not been particularly successful in the past, the authors' optimism concerning the placement of ceramic as well as heat-cured composite resin inlays is based primarily on the improved bond to enamel and dentin by present-day resin cements.

Described by the authors as a "procedural atlas," *Porcelain & Composite Inlays & Onlays: Esthetic Posterior Restorations* outlines, in an easy-to-read format, the various aspects of esthetic posterior restorations. The text begins with a comparative review of conventional materials used to restore posterior teeth, i e, amalgam, gold alloys, and composite resins, and their respective advantages and disadvantages. Next is a discussion of the proposed etched porcelain inlays and onlays including advantages, disadvantages, indications, and contraindications. The physical properties of porcelain and principles of its use as a restorative material are discussed. The next four chapters detail step-by-step procedures for accomplishing etched porcelain inlays and onlays, and composite resin inlays including tooth preparation, provisionalization, laboratory procedures for restoration fabrication, and restoration delivery. The book concludes by suggesting other applications of etched porcelain, e g, resin-bonded fixed partial dentures and occlusal overlays. The new CAD/CAM ceramic systems are mentioned briefly. The clarity of the written text is greatly enhanced by outstanding illustrations. The number and quality of clinical photographs are truly impressive.

It is obvious that much time and effort has gone into the creating of this text. Certainly the goals of the authors were achieved. However, I have some difficulty in sharing their optimism when it comes to their recommendations for using the resin-bonded, etched porcelain inlays. The stated indications run the gamut from the most conservative occlusal lesion to the visibly fractured, endodontically treated molar. The inlays are encouraged because of the tooth-strengthening ability of the resin-bonded restoration. Until long-term data demonstrating longevity of the bond is available, I will not feel comfortable using this restoration in other than conservative cases.

I would recommend this book to the general practitioner interested in adding posterior esthetic restorations to his/her armamentarium.

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LETTER

A NEW APPROACH TO PAINLESS DENTISTRY: FACT OR FOLLY?

Forty years ago the S S White company produced an airbrasive unit called Airdent. Fine aluminum oxide was propelled at high speed from a hand instrument through a small tip made of tungsten carbide that resisted damage from the aluminum oxide powder. Indeed, the concept was effective in removal of hard tooth structure and enjoyed popularity for its uniqueness. For many who used the equipment, and those of us who taught its use, the curiosity wore thin. The quality of dental care dropped sharply, and after a few years the unit faced a much-deserved demise. Its attributes, however, included an ability to remove enamel, dentin, and some active caries with little or no pain. Endodontic openings could be accomplished with equal ease. Anesthesia was unnecessary. With considerable practice a cavity could be cut, but the product required much refinement before a proper restoration could be placed. Removal of amalgam or gold from a tooth could not be accomplished without reducing the surrounding tooth structure to loosen the filling from its mooring. Chronic caries, with its softened texture, could not be removed without incidental reduction of surrounding healthy enamel and dentin. Saliva, blood, or moisture virtually neutralized the effectiveness of the abrasive powder.

Recently, television news has glamorized a "new" method for painless dentistry. It has portrayed dentists as having the opportunity now to perform procedures completely without discomfort to the patient. While this may be factual in some respects, it is alarmingly short of accuracy in others. Aside from the equipment being very costly, it has limited use in the practice of general dentistry. Those who have trumpeted this "revolutionary" item, called KCP 2000 (American Dental Laser Co, 2600 W Big Beaver St, Troy, MI 48084), have been careful to state that it is to be used for composite restorative materials. The purpose here is to appraise the equipment and its usefulness in dentistry today.

Many questions surface:

Are there limitations to its use?

If KCP 2000 can be used successfully to painlessly prepare cavities for composite restorations and create access openings into the pulp through enamel and dentin, it has a useful place in the dental office, albeit a costly one. All other procedures require a more demanding, accurate method since cavity refinements are not possible with this instrument. When teeth are to be restored with metallic or ceramic materials, details can only be achieved with burs, stones, and hand instruments. Of course, when these instruments are used, anesthesia is desirable.

Can defective metallic, ceramic, or plastic restorations be removed with KCP 2000?

Generally speaking, the answer is "No." If the clinician circumscribes the restoration by removing sound structure, the filling can be loosened. The alumina will not cut through metal, ceramic, or composite.

Does the KCP 2000 create air contamination?

If a carefully used high-velocity vacuum system is used, this problem is minimal. If rubber dam is in place, the danger of pathogen distribution is equally minimal.

With its limited indications for use, is there justification for purchasing the KCP 2000?

It seems unlikely in light of its very high cost, but for those who perform composite and bonded restorative procedures extensively, this instrument may have appeal.

Conclusion

Television is hungry for news that is exciting, different, glamorous, or controversial. Often we find it to be only semi-factual. A modicum of investigation by the reporters would have given the viewing audience a more accurate appraisal of KCP 2000.

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OPERATIVE DENTISTRY

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

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