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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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E D I T O R I A L

One-Year Postgraduate Education: A Requirement for Licensure?

There is no denying that the practice of dentistry has changed significantly over the past 20 to 30 years. Rapidly changing technology and changing demographics of dental disease have affected the profession in many ways. Patients are living longer, keeping their teeth, and are intensely interested in maintaining their dentition for the duration of their expanding lifetime. Care provided today is by far more complicated and demanding than ever before and requires increased clinical skills to deliver. The esthetic appearance of their teeth is of utmost importance to the yuppie generation and those following them. Since the 1950s the following have changed the character of dental practice:

(1) The advent of the high-speed handpiece, which has allowed for the preparation of many more teeth with greater ease.

(2) Significant improvements in the ability to make accurate impressions, going from the use of impression compound, plaster, and waxes for all impression to the new vinylpolysiloxanes which afford excellent, detailed reproduction of tooth structure.

(3) Composite resins and the acid-etch techniques which have supplanted the silicate cements as esthetic materials.

(4) Hollow ground porcelain facings and porcelain jackets, which have almost been replaced since the introduction of the porcelain-fused-to-metal crowns. For the first time, dentists could make fixed partial dentures which were both esthetic and accurately fitting.

(5) More recently, the introduction of esthetic castable ceramics.

(6) The use of castable ceramics and porcelain for laminate veneers and inlays/onlays.

The above are but a few of the changes which have occurred in the field of dental materials. The basic sciences have all acquired new knowledge which needs to be taught. Think back! It was not many years ago that few dental schools taught clinical endodontics or periodontics, and preventive dentistry was only a gleam in a few minds. Today we recognize the importance of those subjects in the dental curriculum and all schools are now required to teach them. As has been the case in restorative dentistry, changes have occurred in all of the other disciplines, making them more complex and requiring more time for the student to gain the basics.

We have tried to fit all of the new techniques and subject matter into the standard four-year undergraduate dental curriculum. Sure, we have increased content hours and many schools have expanded into the summer in order to include the ever-increasing mass of information the student must digest. But is it enough? Before the explosion of technology and other compounding factors, we had a required four-year curriculum, and we still have it. Can or should we hold onto this old and perhaps antiquated standard?

We must do something to enhance the ability of our graduates to treat the changing needs of patients in today's world and to provide the high level of quality care expected. Some have proposed adding a fifth year to the undergraduate dental education. While I agree that our graduates need more experience, I do not agree with the premise of adding a fifth year to the undergraduate curriculum. What is being suggested is that we follow the model of the medical community and require a minimum of postgraduate education for all graduates with a DDS or DMD before licensure be permitted.

Adding a fifth year to dental school would be just more of the same. Students would not acquire a great deal more knowledge or experience beyond what they acquire now. By participating in a postgraduate residency in General Dentistry, the new graduate would be exposed to more techniques, and could benefit by the added experience in increased levels of care. Past experiences with the General Dentistry Residencies and the General Practice Residencies (those which are hospital based) have shown that they produce clinicians well above the level of those graduates who go directly into practice.

The only way to make General Dentistry Residencies a reality for all graduates is to require the minimum of one year in a postgraduate education program or the completion of specialty training in one of the recognized specialty areas to be eligible for licensure. To do so, state dental associations, the American Dental Association, state legislatures, and state licensing boards must work together to secure the necessary legislation. The requiring of a minimal one year of postgraduate education would generate sufficient programs to fulfill the needs of the new graduates. The time for action is now and such action will enhance the quality of care being delivered to tomorrow's patients.

Rather than viewing this proposal as a wild wind from the west, perhaps someone out there will listen to what I feel is a realistic approach to a serious and complex problem with undergraduate dental education. Let us act together for the common good!

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ORIGINAL ARTICLES

Dentin Bonding: The Effect of Surface Roughness on Shear Bond Strength

A S MOWERY, JR • M PARKER
E L DAVIS

Summary

One aspect in the development of a system that can provide and maintain a strong bond between composite resin and dentin is the mechanical treatment of the dentin surfaces prior to bonding. In this study, 30 extracted human molars were serially ground to 60, 260, 600, and 1200 grits before bonding, then tested for shear bond strength. The 60-grit surface clearly yielded a significant increase in fracture resistance at the bond site.

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Introduction

A significant effort has been and continues to be directed toward research and development of a system capable of providing and sustaining a bond between resin and dentin (Gwinnett, 1985). Much of this research has focused on establishing an adhesive bond through a chemical bridge or coupling agent between the dentin and resin (Gwinnett, 1985). Numerous articles have been published on the effects of chemical alteration of the dentin surface prior to resin bonding (Brännström & Nordenvall, 1977; Bowen, Cobb & Rapson, 1982; Bowen & Cobb, 1983). The presence of a smear layer on the surface of dentin following mechanical preparation has been well established (Eick & others, 1970), but considerable controversy still exists over its significance and whether it should be removed or retained (Pashley, 1984; Bowen & others, 1984).

Very little, however, has been reported on the effect of mechanical alteration of the surface topography of dentin. Eick and others (1972) have addressed the issue of surface topography and its influence on wetting and adhesion in a dental adhesive system. They state that of the three major factors that affect wetting (surface free energy, surface topography of the adherend, and viscosity of the liquid) the influence of surface topography was the least understood. Eick and his coworkers suggest that there is an "ideal roughness" that produces optimum wetting because of capillary pressure, and that this ideal surface would have to be smooth enough to prevent air from becoming trapped at the interface of the dentin and composite restoration. It has been theorized that an increase in surface roughness would result in a decrease in adhesion (Buonocore, 1963; Hollinger & Moore, 1979). However, it has been demonstrated that an increased surface roughness decreased tensile bond strength but increased shear bond strength (Negm, Combe & Grant, 1981). The purpose of this study in vitro is to quantitatively investigate the effect of surface roughness on shear bond strength of a composite resin to human dentin.

Materials and Methods

Thirty extracted human molars which had been cleaned, disinfected, and stored in distilled water were selected for this study. Each tooth was attached to a faceting dop with the long axes parallel (Fig 1) by means of jeweler's dopping wax (Rio Grande Albuquerque, Albuquerque, NM 87109) on the occlusal surface. The dopped tooth was positioned in the arm of a

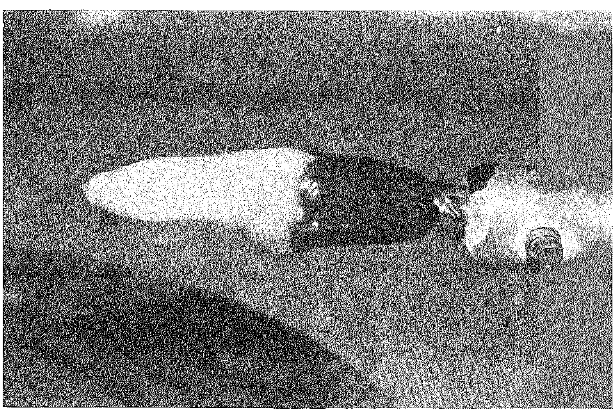

FIG 1. *An extracted molar attached to a dop and inserted into the arm of the faceting machine*

B & I Facetor (B & I Manufacturing Company, Fresno, CA 93728) and placed in a horizontal position. Four sides of the tooth were serially ground to 60, 260, 600, and 1200 grits, utilizing water-cooled diamond laps (Crystalite Corp, Marina del Rey, CA 90292) revolving at 600 to 800 rpm. The roots were then notched and the prepared tooth was mounted vertically in a Velmix base (Kerr Manufacturing, Romulus, MI 48174) (Fig 2). The tooth was returned to distilled water for storage until needed for specimen preparation.

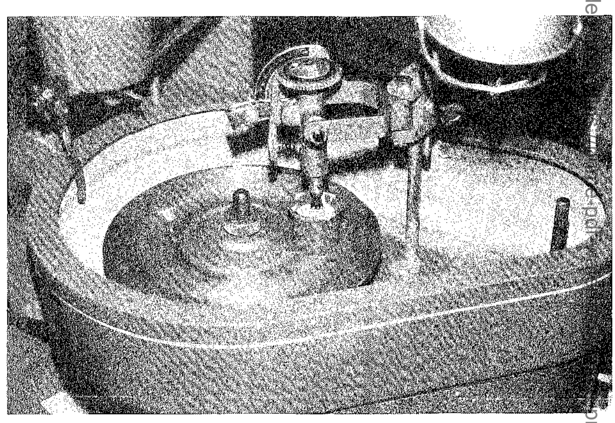

FIG 2. *The faceting arm positioned vertically with a base former partially filled with improved stone in place*

For specimen preparation, each mounted tooth was dried with an air syringe, evenly coated with light-cured Scotchbond (3M Dental Products, St Paul, MN 55144) and bonded by curing with a light for 10 seconds. Next, a No 4 pharmaceutical gelatin capsule, slightly overfilled with Prisma-Fil (L) (L D Caulk Company, Milford, DE 19963), was placed on one of the sites. The excess composite was carefully removed and the specimen was cured for 60 seconds. This process was repeated for each site, and the tooth was placed in distilled water at 37 °C for 24 hours prior to testing.

The apparatus selected for testing was the Instron Testing Machine (Instron Engineering Co, Canton, MA 02021). Each tooth was removed from water storage, the softened gelatin capsules were carefully removed, and the tooth approximately centered on a 500 kg load cell. A specially designed loading bar was positioned against one of the facets and carefully lowered to just lightly contact one of the specimens (Fig 3). Using a crosshead speed of 0.5 cm/min, each specimen was loaded until failure occurred. The resultant shear bond strength was reported in kilograms of force required to cause failure per square centimeter of interface area (kg cm^{-2}).

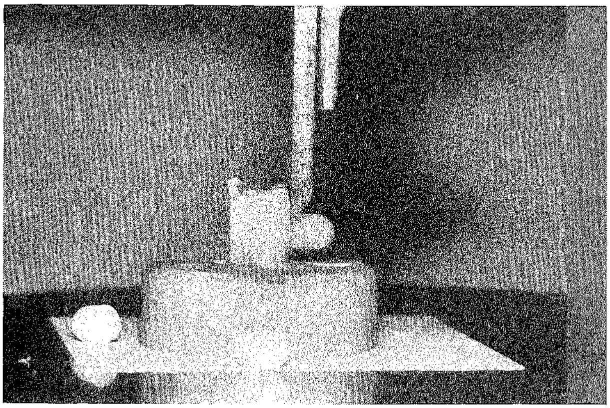

FIG 3. *A prepared dentin surface, with an attached composite specimen, positioned on load cell for testing*

Results

The data reported in the table were analyzed for differences among the four groups, using Duncan's multiple range test. The results indicated significant differences in fracture resistance between the 60-grit surface and all other sites, and between 260- and 600-grit surfaces at $P < 0.05$. Shear strength of the 60-grit surface was significantly greater than all other groups, and shear strength of the 260-grit surface was significantly greater than that of the 600-grit surface.

Data Obtained for Specimens Stored in 37 °C Distilled Water for 24 Hours

Dentin Surface	Mean Force in Kilograms	Mean Diameter of Specimen	Shear Bond Strength	Shear Bond Strength
	kg	mm	kg cm^{-2}	MPa
60 grit	9.71 ± 3.17	5.07 ± 0.04	47.57 ± 15.54	4.66 ± 1.52
260 grit	7.79 ± 3.06	5.07 ± 0.04	38.20 ± 15.02	3.75 ± 1.47
*600 grit	5.55 ± 2.31	5.07 ± 0.04	27.64 ± 11.04	2.71 ± 1.08
1200 grit	6.47 ± 2.06	5.07 ± 0.04	31.69 ± 10.09	3.11 ± 0.99

* The 600 grit is most frequently reported in bonding studies.

Discussion

The results of this study indicate that, of the four different surface topographies observed in dentin preparation, the 60-grit surface yields the greatest shear bond strength. Furthermore, under the same testing conditions, the 600-grit surface, which for years has been the standard for bond testing, yielded the lowest shear bond strength. The increase in fracture resistance noted with the rougher 60-grit surface might best be explained by the increase in total surface area available for adhesion at the bond site. The increase in bonding surface combined with the mechanical locking into the irregularities serves to increase the overall shear bond strength for a given cross-sectional area.

Although further testing in vitro is deemed necessary, the results of this study stimulate speculation on the possible clinical significance of producing a roughened surface to enhance dentin bonding (retention) of composite resin. Upon initial examination with an SEM, the 60-grit surface utilized for this study is very similar to that which is obtainable with a medium grit diamond bur.

(Received 12 August 1986)

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Preparation and Restoration of Anterior Teeth with Composite Resin: A Survey of Dental Schools

J DAVID HARDISON

Summary

Among the results of a questionnaire devised to determine the materials and techniques taught in dental schools in the United States and Canada in preparing, placing, and finishing class 3 and 4 anterior composite resin restorations were the following:

All schools teach the use of the rubber dam in preparing and placement of composite restorations; most place some sort of bevel; several list the use of shoulders and chamfers. No school teaches reliance on pins as the primary retentive feature; the majority rely upon a combination of features to retain the restoration. All schools use more than one type of composite; most use more than one curing system. Visible-light-cured composites are the materials of choice, especially for class 4 cavities. A variety of methods are taught for contouring and finishing.

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INTRODUCTION

As in so many areas of dental education, there is a diversity of approaches to the anterior composite restoration. The objective of this study was to identify the materials and techniques taught in dental schools in the United States and Canada for the preparation, placement, and finishing of anterior composite resin restorations.

METHODS

A questionnaire on class 3 and 4 composite resins was designed and evaluated by the members of the restorative faculty at this institution, then sent to the director of operative dentistry at the 67 dental schools accredited by the Commission on Accreditation of the American Dental Association. The areas of interest were defined as follows:

Class 3: A moderately large restoration that often replaces an existing smaller class 3 restoration of an incisor. The completed preparation extends from the contact area no further than the superior border of the gingival third of the interproximal area. The enamel of the incisal angle is assumed to be adequately supported. The preparation can be seen from the facial aspect, but does not reach the line angle. On the lingual aspect, the preparation does not extend beyond the crest of the marginal ridge. The preparation extends axially into dentin approximately 1 mm. For the purposes of this survey, we assume there are no occlusal, endodontic, or other considerations that would adversely affect treatment.

Class 4: The above parameters apply except that one-third of the incisal edge is now involved. The preparation may now also extend over the crest of the lingual marginal ridge.

The questionnaire contained 10 questions: one about rubber dam placement; two about the preparation; two about material selection for the restoration; one regarding the bonding system utilized; and four concerning contouring and finishing the restoration.

RESULTS

Fifty-six of the 67 (83.6%) returned the questionnaire. The results were analyzed for the group as a whole and by the regions established by the Conference of Operative Dentistry Educators. Each region was well represented with at least two-thirds of each region responding.

Questions and responses are listed below. Frequently more than one answer was circled for a question.

1. When preparing and placing composite resins do you teach the use of rubber dams as being:
   - necessary - 55
   - optional - 0
   - unnecessary - 0
   - no response - 1

2. What types of composite resins are being used by your students for:

   class 3 - macrofilled - 11
   microfilled - 42
   hybrid - 41
   no response - 1

   class 4 - macrofilled - 17
   microfilled - 32
   hybrid - 40
   no response - 3

   Six added that they use a "layering" or "sandwich" technique for the class 4 restoration.

3. What do you teach as being the main retentive feature of the following preparations:

   class 3 - gross mechanical (grooves or other retentive areas) - 10
   micromechanical (etching) - 9
   combination - 39

   class 4 - gross mechanical - 4
   micromechanical - 21
   pins - 0
   combination - 34

   Ten schools specified that they never recommend pins for class 4 restorations or that they avoid them if at all possible.

4. Which composite resin polymerization system is used most often by your students?

   class 3 - autocure - 4
   visible light - 49
   equal usage - 7

   class 4 - autocure - 0
   visible light - 54
   equal usage - 1
   no response - 1

5. Which bonding system do your students use?
   - enamel - 23
   - dentin - 22
   - universal - 27
   - none - 0

6. For the following preps which do you teach as being the margin "of choice"?

   class 3 - shoulder - 6
   long bevel (>1 mm) - 2
   short bevel (≤1 mm) - 44
   other - 9
   no response - 1

   Four specified a chamfer as being their choice; the rest all listed some modifications or combination of shoulder and bevel.

   class 4 - shoulder - 7
   long bevel (>1 mm) - 27
   short bevel (≤1 mm) - 19
   other - 14

   Eleven listed a chamfer as their choice; one listed an "overfill seal"; the other two gave a combination bevel and shoulder as their first choice.

7. Do you have your students finish their composite resin restorations:

 a. same appointment - 54
 later appointment - 1
 no response - 1

 b. in a dry field - 32
 in a wet field - 7
 dry then wet - 13
 other - 3 (All three gave wet then dry as their selection.)
 no response - 2

8. Which of these instruments and materials are used routinely by your students to contour and finish their composite? (number = number of schools)

hand instrument	contour - 31	finish - 4
carbide finishing burs	contour - 46	finish - 8
diamond finishing burs	contour - 268	finish - 8
abrasive discs	contour - 40	finish - 54
abrasive strips	contour - 26	finish - 51
polishing paste	contour - 4	finish - 18

other - 4 (Three indicated the use of white stones, and one specified scalpels.)

9. Once the restoration has been finished do you routinely glaze the restoration?

 class 3 - always - 6
 sometimes - 2
 seldom - 16
 never - 32

 class 4 - always - 6
 sometimes - 3
 seldom - 17
 never - 28
 no response - 2

10. If you do glaze, do you re-etch the margins prior to placement of the glaze?

 always - 6
 sometimes - 9
 seldom - 8
 never - 4
 no response - 29 (This large number of nonresponses was directly related to "never-never" responses for number 9.)

DISCUSSION

Rubber Dam

All 56 respondents were unanimous concerning the necessity of the rubber dam for anterior composite resin restorations which is not surprising in view of supporting research (Ireland, 1962; Cochran, 1975).

Cavity Preparation

Most schools do not rely solely on enamel etching for retention; however, more schools acid etch for class 4 than class 3 restorations. Most schools rely on a combination of acid etching and gross mechanical undercuts to provide retention. No school teaches pin placement as the main retentive feature of class 4 anterior composite resin restorations.

A beveled margin is favored. The short bevel ($\leq$1 mm) is the overwhelming choice for class 3 cavities, and the long bevel ($>$1 mm) is favored for class 4 preparations. The chamfer and a shoulder with a bevel are the primary selections of several schools, especially in the South-Midwest region. This diversity reflects the lack of consensus on margin design found in recent studies (Qvist, Ström & Thylstrup, 1985; Hembree, 1980; Eriksen & Buonocore, 1976).

Material Selection

Preference is shown for the newer microfilled and hybrid composite resins over the conventional macrofilled resins. Some of those surveyed prefer to layer different types of composite resins in certain clinical situations, especially the class 4.

Both autocuring and visible-light-curing systems are still being taught by most dental schools, but the visible-light-cured composite resins clearly are the material of choice. Only one school preferred autocured resins over visible-light-cured resins when restoring a class 4 preparation.

Enamel etching to increase adhesion has been a significant part of restorative dentistry for many years (Buonocore, 1955). During the last five years, products which promise at least some bonding to dentin have generated a great deal of interest and research (Bowen & Cobb, 1983; Barkmeier, 1985). Assuming all respondents who circled "universal" meant an agent capable of bonding to both dentin and enamel, 80% of the schools teach dentin bonding. All schools teach enamel bonding.

Contour and Finish

Although recent authors disagree about the effect of immediate finishing upon the final finish of the restoration (Harris & others, 1983; deWet & Hardwick, 1984; Hassan, 1980), there is little disagreement among the dental schools. All but one school require that students finish composites on the same day they are placed.

A majority of schools responded that they ask their students finish the composite restorations in a dry field. A significant number prefers a wet field; others choose a combination; once again, the literature has not been unanimous in its conclusions (Staley & Kopel, 1979; Davidson & others, 1981).

There has always been a plethora of instruments and techniques for finishing composite restorations. No strong preference emerged for any one of the listed materials for contouring and finishing composite restorations. The following regional differences were noted: the Pacific Region uses fewer hand instruments; the South and South-Midwest use fewer diamonds; the South-Midwest and the Northeast use fewer abrasive discs and strips; and the South-Midwest uses polishing paste much more frequently than any other region.

Glaze

Schools in the South-Midwest region glaze their restorations more frequently than any other region. Schools that did glaze reported they "always" re-etch the restoration prior to placement of the glaze. It is not difficult to find articles supporting or contesting glazing. Garman and others (1977) and Williams and others (1978), for example, point out the initial superior smoothness of glazed restorations may be lost due to the more rapid wear of unfilled resin.

To dental education's credit, when there is consensus in the research data there is agreement on materials and techniques for anterior composite resin restorations. When such consensus is lacking, a diversity of materials and techniques are taught. This study points to areas where further research is needed to better identify the materials and techniques that should be taught.

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Effect of Bonding Agents on Gap Formation in Dentin Cavities

W J FINGER • M OHSAWA

Summary

The efficacy of three combinations of dentin bonding agents and composite resins was studied in vitro by testing the shear bond strength and by microscopic evaluation of the adaptation in cylindrical butt-joint dentin cavities. None of the three systems tested achieved an initial perfect seal of the cavities.

INTRODUCTION

The purpose of this study in vitro was to investigate the adaptation of three light-cured hybrid composite resins to tooth structure, together with the modern dentin adhesives marketed by the manufacturers of the respective resins. The two tests employed were: (1) measurement of the bond strength to dentin, considered a screening test only; and (2) evaluation of the adaptation of the resin to dentin in the cavities.

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MATERIALS AND METHODS

The three light-activated restorative resins together with the accompanying dentin bonding agents investigated are listed in Table 1. All materials were used in accordance with the manufacturers' instructions.

Bond Strength Test

Five specimens were prepared for each test. Extracted human teeth which had been stored in a 1% aqueous chloramine solution (Jörgensen & others, 1985) for a maximum of four weeks were embedded in slowly setting epoxy resin in cylindrical rubber molds (diameter = 25 mm, height = 10 mm). A flat dentin surface was prepared by wet grinding on carborundum paper (No 220 and No 1000).

For Gluma Dentin Bond with Bayer Resin L/Lumifor (Bayer Dental, 5090 Leverkusen, West Germany), the dentin was treated with

Table 1. Materials Investigated

Product	Batch Number	Manufacturer
Clearfil New Bond	NC 326/426	Kuraray, Japan
Clearfil-Ray	HAS 1004	
Gluma Dentin Bond	9116 A/9102 A	Bayer, West Germany
Bayer Resin L	9136 A	
Lumifor	65216 A	
Scotchbond, light-cured P-30	5 N 1/5 1 1 4 L 1 P	3M, USA

Gluma Cleanser for 60 seconds followed by water spraying and drying with compressed air prior to a 30-second Gluma Bond application and gentle drying by an air blast. A cylindrical Teflon splitmold (diameter = 5 mm; height = 3.5 mm) was placed on the pretreated dentin and a thin layer of Resin L was applied by a small brush. The restorative resin Lumifor was inserted by a HAWE C-R Mark III syringe (Hawe-Neos Dental, 6925 Gentilino, Switzerland), covered by a Mylar strip and activated by a Translux light-curing unit (Kulzer u Co GmbH, Bereich Dental, 6393 Wehrheim/T, West Germany) for 80 seconds.

For Scotchbond, light-cured, with P-30 (3M System; 3M Co, St Paul, MN 55144), the dentin was treated with a 3% aqueous solution of H_2O_2 for 10 seconds, then water sprayed and dried prior to application of the dentin adhesive, the solvent of which was evaporated by a gentle blast of air. The adhesive was light-activated for 10 seconds, the restorative inserted by a syringe, and finally light-activated for 80 seconds.

For Clearfil New Bond with Clearfil-Ray (Kuraray Co Ltd, Osaka 530, Japan), the dentin was etched for 40 seconds by the proprietary etching solution, rinsed, and dried prior to application of a single layer of bonding agent. Following a 10-second time for evaporation of the solvent, the restorative was injected in the mold and light-activated for 80 seconds. Immediately after light-curing, the specimens were stored in a physiologic NaCl solution until the shear test was performed in a universal testing machine at a loading rate of 1 mm/min. Bond strengths were determined after two to three minutes, 24 hours, one week, and four weeks.

Marginal and Cavity Wall Adaptation

The method used for the preparation of the test cavity has been fully described in a previous paper (Komatsu & Finger, 1986). Briefly, cylindrical butt-joint cavities (diameter = 2.9 - 3.3 mm, height = 1.5 mm) were prepared in a flat, ground dentin surface of extracted teeth. The cavities were treated and filled as described for the bond strength specimens. The slightly overfilled cavities were covered by a Mylar strip and light-activated for 60 seconds by the Translux (Kulzer, West Germany) unit. Immediately after light-activation the teeth were placed into a physiologic saline solution until investigation of the marginal adaptation, or until the adaptation along the lateral cavity walls and the cavity floor was carried out. Five specimens were prepared for each test.

Marginal adaptation was investigated after storage times of 10 minutes, 24 hours, and 28 days, as previously described (Komatsu & Finger, 1986). The excess of the composite restoration was removed by wet grinding on carborundum paper No 1000 followed by polishing on linen with an aqueous slurry of 0.3 μm aluminum oxide (Micropolish II, Buehler Ltd, 41 Waukegan Rd, Lake Bluff, IL 60044) and thorough rinsing with deionized water. Then the restoration margin was inspected in a light microscope (X1000, Orthoplan, Ernst Leitz GmbH, 6330 Wetzlar, West Germany). The maximum width of a possible gap was measured within a time interval of less than 10 minutes. The adaptation at the cavity walls was investigated by the same microscopic technique on sections parallel and close to the cylinder axes of the restorations after cutting with a diamond blade (Isomet, Low Speed Saw, Buehler Ltd). The sections were produced after storage times of 10 minutes, 24 hours, one week, two weeks, and four weeks in the saline solution. The excess of the filling materials was not removed to ensure that a possible displacement of the restorations could be detected during the microscopic inspection. The sections were polished, rinsed, and dried as described above. The maximum widths of gaps along the lateral walls and the cavity floor were registered.

All procedures of the investigation were carried out in a thermostatically controlled room at 23 ± 1 °C. The relative humidity was 50 ± 5%.

Results

The bar diagram (Fig 1) illustrates the shear bond strengths found as mean values of five specimens each. There is a slight increase of strength with prolonged storage time for the Gluma samples. The difference between the strength figures found after two minutes and four weeks are statistically highly significant (Student's t-test, $P < 0.01$). The Scotchbond figures are considerably smaller. Based on the comparison of the individual mean values by Student's t-test, there is no significant difference between the value found after two minutes and any other of three mean strength figures ($P > 0.05$). In contrast, Clearfil produced a high bond strength after two minutes. This initial strength is significantly larger ($P < 0.01$) than each of the mean strength figures found after 24 hours, one week, and four weeks, respectively.

The maximum marginal contraction gaps found after storage times of 10 minutes, 24 hours, and 28 days storage are shown in Table 2. The widths of the gaps found for the three material combinations after 10 minutes storage are significantly different from each other on the 5% level (Student's t-test). When the figures for the 10 minutes and the 28 days are compared by Student's t-test, the 28-day means are significantly smaller (Clearfil, $P < 0.01$; Gluma, $P < 0.05$; Scotchbond, $P < 0.01$).

Figure 2 (a,b,c) illustrates the maximum widths of gaps found on the sections. The paired bars show the mean for the gaps of 10 specimens, as found along the side walls and at the cavity floor. For each material system studied, the paired bars illustrate from left to right the storage periods of 10 minutes, 24 hours, one week, two weeks, and four weeks. In all cases the gaps were narrower at the side walls than at the floor. Gluma/Lumifor maintains a clear tendency toward improved adaptation with increasing storage time. The adaptation of Scotchbond/P-30 follows the same tendency; the gaps, however, are significantly wider.

Table 2. Maximum Widths of Marginal Contraction Gaps (x5 ± SD, μm)

Storage Time in 0.9% NaCl	Clearfil NB/ Clearfil-Ray	Gluma/ Lumifor	Scotchbond, Lightcured/ P-30
10 minutes	5.4±3.0 (1)	3.0±1.8 (1)	9.6±2.7 (0)
24 hours	6.3±3.9 (1)	3.3±3.4 (2)	8.3±0.9 (0)
28 days	0.5±0.7 (3)	0 (2)	2.8±1.4 (0)

The figures in parentheses list the number of gap-free specimens out of five in each group.

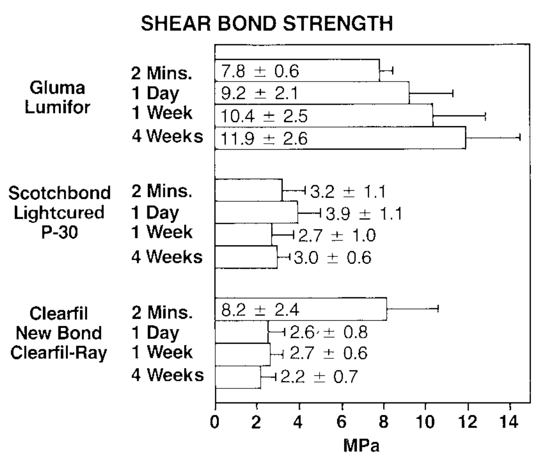

FIG 1. *Shear bond strengths to dentin of the three bonding agents/composite resin systems studied. The height of each bar gives the mean value of five measurements, the T-shaped signature the standard deviations. Storage times in a physiologic saline solution prior to testing are as indicated.*

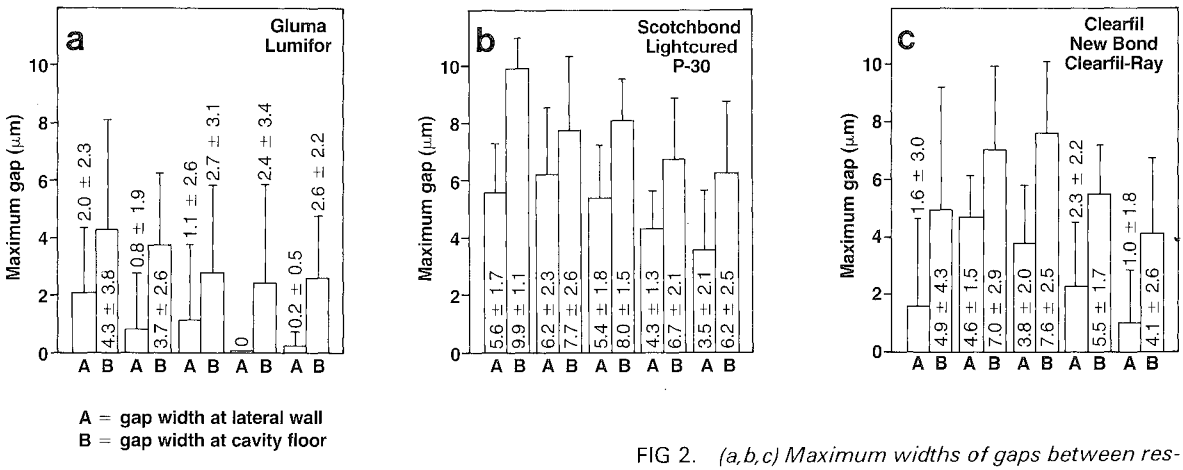

FIG 2. *(a,b,c) Maximum widths of gaps between restoration and lateral cavity walls (left of the paired bars) and cavity floor (right), respectively. The height of each bar and the T-shaped signature illustrate the mean value and standard deviation from 10 specimens each.*

Clearfil New Bond/Clearfil-Ray is characterized by good initial adaptation with seven out of 10 specimens exhibiting no gap formation along the side walls, but after 24 hours storage in the saline solution the gaps are clearly wider and none of the specimens were gap free. Following longer storage times the gap dimensions gradually decrease (Table 3).

Table 3. Number of Gap-free Specimens over Time (n = 10)

Time	Clearfil NB/ Clearfil-Ray		Gluma/ Lumifor		Scotchbond, Lightcured/ P-30	
	(A)	(B)	(A)	(B)	(A)	(B)
10 minutes	7	3	5	3	0	0
24 hours	0	0	8	2	0	0
1 week	1	0	8	4	0	0
2 weeks	4	0	10	6	0	0
4 weeks	7	2	9	3	1	0

(A) = gaps at lateral wall;
(B) = gaps at cavity floor

DISCUSSION

The present investigation has shown that the bond strength figures qualitatively reflect the degree of cavity adaptation of the three restorative systems studied. For obvious reasons an increase in bond strength with time will not be displayed by the gap widths registered, whereas a drop in bond strength, as seen in the Kuraray system, is reflected by the gap dimensions. Marginal contraction gaps were not found occlusally but along the cervical semicircle of the preparation. This is in good accordance with the observations of Hansen (1982a,b). As a rule, gaps at the cavity floor were wider than gaps along the lateral walls, which is in agreement with the findings of Bergvall and Brännström (1971).

The evaluation of adaptation from vertical cuts through restorations is seldom reported (Bergvall & Brännström, 1971; Brännström, Torstenson & Nordenvall, 1984; Staninec & others, 1986). It must be emphasized that measurements done on sections will not give true quantitative results, since the direction of the section arbitrarily can reveal either the maximum width of an interfacial gap or a perfect adaptation in spite of the fact that a gap may be present in another area, or any kind of adaptation imperfections may occur between these extremes. However, these are much the same imponderables as encountered in microleakage tests, where the interfacial space is indirectly evaluated by dye or isotope penetration. In contrast, the description of gap dimensions by figures indicates, at least when evaluated together with marginal contraction gaps, whether such interfacial failures have clinically relevant dimensions and whether they are likely to be closed with time by water absorption. As shown, perfect marginal adaptation of a restoration does not necessarily mean good overall sealing. Due to mechanical and/or thermal stresses the marginal integrity of a restoration can be compromised and a gateway opened toward deeper-lying spaces along the interface.

CONCLUSION

None of the three systems tested produced a perfect seal of the butt-joint dentin cavities initially. Scotchbond in combination with P-30 gave both a low bond strength to dentin and a poor cavity seal. Even after four weeks storage in saline solution the hygroscopic expansion of P-30 was too small to close the marginal gap. The bond obtained with the Clearfil system seems to suffer from early hydrolysis. Gluma Dentin Bond in combination with Lumifor showed the highest bond strengths and the narrowest gaps. After soaking in saline solution for one month, no restoration displayed a marginal gap, but gaps were still present, particularly along the cavity floor.

It is likely that the adaptation to the cavity can be improved when an incremental insertion and curing technique is used instead of the bulk filling technique used in the present study.

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Placement and Replacement of Amalgam Restorations: A Challenge for the Profession

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Summary

A national survey of the members of the Academy of Operative Dentistry was conducted to assess the factors underlying the placement and replacement of amalgam restorations. The following questions are addressed: 1) What is the expected length of service of amalgam restorations? 2) What are the most frequently cited reasons for failure? 3) What are the potential causes of failure?

Of the 5511 restorations placed by 191 respondents, 46% were placed because of primary caries, while 54% were replacement restorations. Of the replacements, 53% were replaced because of secondary or recurrent caries, 17% for poor margins, 13% due to tooth fracture, 8% because of isthmus fracture, and 9% for other reasons. A review of the ages of replaced restorations showed that 19% were replaced within five years following placement, 29% between five and nine years, 25% between 10 and 14 years, 13% between 15 and 19 years, 9% between 20 and 24 years, and 5% were 25 years or older to a high of 50 years. Possible factors responsible for failure are discussed and a distinct challenge to the profession is identified.

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INTRODUCTION

Over the past 160 years, dental amalgam has become established as the restorative material most widely used. Acceptance and usage have been based on its biomechanical properties, clinical characteristics, versatility in application, and a long experience relating to the serviceability of amalgam in the oral environment. Through the years it has survived despite political dissension such as the "Amalgam War" (Miscellaneous notices, 1845; Baker, 1847), economic and availability crises, and challenges by comparable alternative restorative materials, and continues to remain the material of choice for most routine operative procedures in posterior teeth.

Concern for the serviceability and durability of dental amalgam has been the subject of a number of publications (Easton, 1941; Healey & Phillips, 1949; Elderton, 1976; Boyd & Richardson, 1985). Numerous studies have assessed the clinical integrity of amalgam restorations (Eames & MacNamara, 1976; Osborne & others 1978; Mahler & Nelson, 1984) and many investigators have reported the need for early replacement (Robinson, 1971; LaVelle, 1976; Allan, 1977; Mjör, 1985; Klausner & Charbeneau, 1985). Data from these studies indicate that approximately half of those amalgam restorations replaced lasted less than 10 years, with many lasting less than five years. There is a justifiable suspicion that the length of service of amalgam restorations may be less than the real potential of which they are capable, despite improvements in their physical and clinical properties over the last several decades.

To increase the longevity and serviceability of amalgam restorations, answers to the following questions are necessary:

1. What is the expected length of service of amalgam restorations?

2. What are the most frequently cited reasons for failure?

3. What are the potential causes for these failures?

These questions were addressed in a national survey, conducted to assess the factors underlying the placement and replacement of amalgam restorations.

SURVEY METHOD

Consent was obtained from the Executive Council of the Academy of Operative Dentistry to survey its membership regarding amalgam placement and replacement practices during a two-week period in their offices in late January and early February 1985. A survey questionnaire (Fig 1) was modified from one used previously by the authors (Klausner & Charbeneau, 1985) and originally adapted from Mjör (1981). Specific instructions, including a completed sample data collection form, were provided to each member together with two blank copies of the data collection form. The respondents were asked to record all amalgam restorations placed or replaced. For each amalgam restoration, practitioners were asked to provide the reason for placement or replacement, the classification of the restoration, the location of secondary caries if present, the age of the restoration replaced if known, and the age of the patient.

Amalgam Restoration Survey
The University of Michigan
under the auspices of the
Academy of Operative Dentistry

	Case Number	Reason for Placement or Replacement P - Primary caries S - Secondary caries M - Poor margins (but no caries) I - Isthmus fracture F - Fracture of tooth O - Other (explain)	Classification of the Restoration I MO or DO MOD 3 5 C - Complex	Location of Secondary Caries O - Occlusal P - Proximal C - Cervical PCA - Proximal-Cervical angle	Age of the Restoration (Years) U - Unknown	Age of the Patient (Years) U - Unknown
Examples	a	P	1	O	–	12
	b	S	MOD	PCA	9	37
	c	M	DO	–	U	28
	d	O (open prox. contact)	C	–	1	46
	1					
	2					
	3					
	4					
	5					

FIG 1. *Survey questionnaire*

RESULTS

One hundred and ninety-one usable surveys were returned, representing 21% of the 894 US and Canadian members surveyed. During the identified two-week period, a total of 5511 amalgam restorations were placed. Forty-six percent (2515) were placed because of primary caries, while 54% (2996) were replacement restorations (Table 1). Of the replacements, 53% (1582) were replaced because of secondary caries, 17% (506) for poor margins, 8% (244) because of isthmus fracture, 13% (383) due to tooth fracture, and 9% were attributed to other causes, such as "endodontics, open proximal contacts, and overhangs."

Table 1. Summary of Results of Amalgam Restoration Survey

			Number	%
Total number of restorations placed			5511	
Number of restorations placed due to primary caries			2515	46
Number of restorations replaced due to:		%		
Secondary caries	1582	(53)	2996	54
Poor margins	506	(17)		
Isthmus fracture	244	(8)		
Tooth fracture	383	(13)		
Other causes	256	(9)		
Unspecified reasons	25	—		

For those amalgam restorations replaced as a result of secondary or recurrent caries (Table 2), 15% (236) were class 1 restorations, 57% (898) were class 2, 4% (64) were class 3, 10% (162) were class 5, and 14% (216) were complex. For the 886 class 2 restorations replaced because of secondary caries and because the class of restoration was specified, 90% of the recurrent lesions occurred in the approximal portion of the restoration, while 10% were observed to have occlusal caries only (Table 2A). For complex restoration replacement because of secondary caries, 86% of the lesions occurred in the approximal portion and 13% occurred in the occlusal portion (Table 2B).

Table 2. Restorations Replaced Due to Secondary Caries

Class of Restoration			%*
1			15
2	MO, DO	39	57
	MOD	18	
3			4
5			10
Complex			14

*Percentage of secondary caries subtotal
n = 1582 of which six were unspecified.

Table 2A. Location of Secondary Caries in Class 2 Restoration Replacements

Location		%
Occlusal		10.3
Proximal	54.1	89.5
Cervical	8.9	
Proximal-cervical angle	17.7	
Proximal-occlusal	7.8	
Proximal-cervical	.5	
Occlusal-cervical	.2	
Proximal-cervical angle-occlusal	.3	

n = 898 of which 12 were unspecified.

Table 2B. Location of Secondary Caries in Complex Restoration Replacements

Location		%
Occlusal		13.1
Proximal	37.1	86.9
Cervical	11.3	
Proximal-cervical angle	21.6	
Proximal-occlusal	8.5	
Proximal-cervical	3.8	
Occlusal-cervical	.9	
Proximal-cervical angle-occlusal	2.3	
Buccal/lingual	1.4	

n = 216 of which three were unspecified.

Amalgam restorations replaced because of "poor margins but no caries" (Table 3) were reported in the following cavity classifications: 28% (141) were class 1; 57% (288), class 2; 1% (6), class 3; 5% (25), class 5; and 9% (45) were identified as complex.

Table 3. Restorations Replaced Due to "Poor Margins" but No Caries

Class of Restoration			%*
1			28
2	MO, DO	40	57
	MOD	17	
3			1
5			5
Complex			9

*Percentage of poor margins subtotal
n = 506 of which one was unspecified.

Of the replacements due to isthmus fracture (Table 4), 7% (18) were class 1 restorations, 84% (302) were class 2. Fifty-nine percent of these were mesio-occlusal or distal-occlusal restorations, while 25% were mesio-occlusal-distal restorations. Isthmus fracture occurred in class 3 restorations in 1% (2) of the reported sample, and 7% (18) were in complex restorations.

Table 4. Restorations Replaced Due to Isthmus Fracture

Class of Restoration			%*
1			7
2	MO, DO	59	84
	MOD	25	
3			1
5			—
Complex			7

*Percentage of isthmus fracture subtotal
n = 244 of which three were unspecified.

For replacements necessitated by tooth fracture (Table 5), 12% (46) occurred around class 1 restorations, 42% (161) were associated with class 2, 2% (7) were class 3, 1% (3) were class 5, and 43% (162) of the fractures were in teeth with complex restorations.

Table 5. Restorations Replaced Due to Tooth Fracture

Class of Restoration			%*
1			12
2	MO, DO	30	42
	MOD	12	
3			2
5			1
Complex			43

*Percentage of tooth fracture subtotal
n = 383 of which four were unspecified.

A variety of other reasons accounted for the remaining replacements, such as "endodontics," "open proximal contact," and "overhangs" (Table 6). Twenty-eight percent (71) were class 1 restorations, 36% (92) were class 2, and 25% (64) were complex. Class 3 and class 5 restorations accounted for 3% (7) and 8% (20), respectively.

Table 6. Restorations Replaced for Other Reasons

Class of Restoration			%*
1			28
2	MO, DO	26	36
	MOD	10	
3			3
5			8
Complex			25

*Percentage of other reasons subtotal
n = 256 of which two were unspecified.

Table 7. Age of Restorations Replaced by Class (years)

	Class 1	Class 2	Class 3	Class 5	Complex	All Classes
Mean	11	11	12	10	10	11
SD	7	6	8	7	7	7
Range	1-35	1-42	1-32	0-30	0-50	0-50

n = 1683

The ages of the restorations replaced were reported in 1695 cases. The mean age, standard deviation, and range of the restorations as reported by class of replacement are shown in Table 7. Replaced class 1 restorations had an average age of 11 years (sd 7, range 1-35); class 2, 11 years (sd 6, range 1-42); class 3, 12 years (sd 8, range 1-32); class 5, 10 years (sd 7, range 0-30); and complex restorations, 10 years (sd 7, range 0-50). The mean age of serviceability for all classes was 11 years (sd 7, range 0-50). A review of the ages of all classes of restorations replaced for all reasons shows that 19% were replaced within five years following placement, 29% between 5 and 9 years, 25% between 10 and 14 years, 13% between 15 and 19 years, 9% between 20 and 24 years, and 5% were 25 years or older to a high of 50 years (Fig 2).

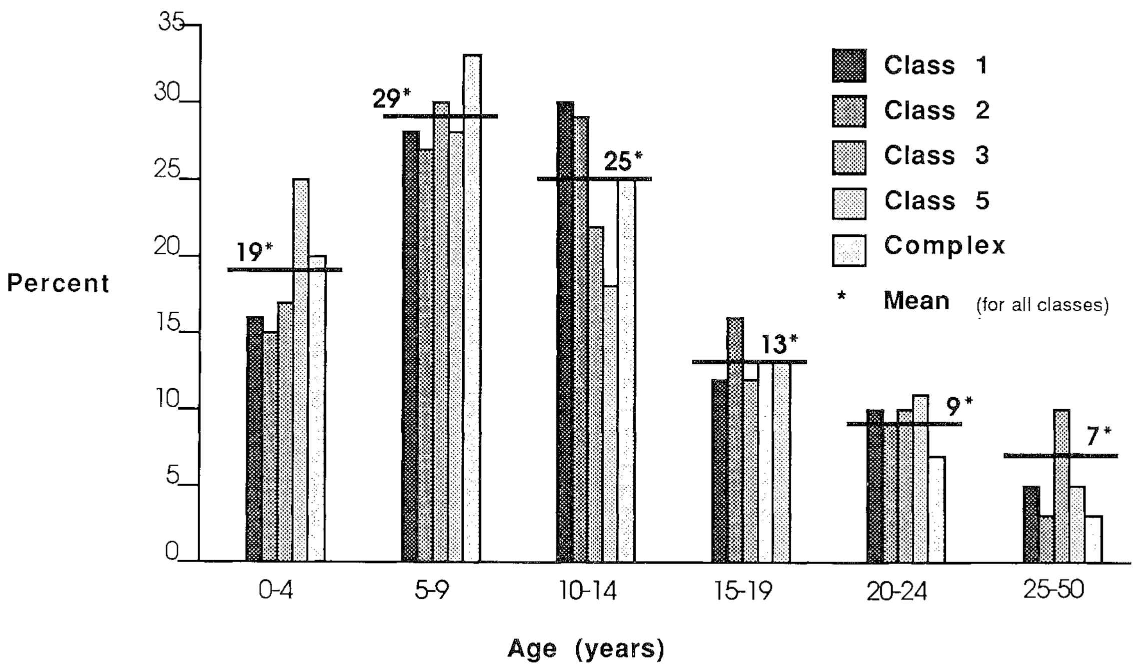

FIG 2. *Percentage of restorations by age at time of replacement for each class of restoration*

DISCUSSION

The response rate of 21% does not assure that the sample is representative of the survey group; however, the large number of cases reported encourages confidence in the results. It is assumed, however, that there is no relationship between the reasons for not responding to the survey and the characteristics of amalgam placement and replacement. The percentage of amalgam restorations placed for reasons of primary caries was 46% in the present study compared to 59% in the Michigan survey of Klausner and Charbeneau (1985) and 29% in the Mjör survey (1981). Of these, approximately one-half treated pit-and-fissure lesions. These data suggest a wide difference between Norway and the United States in the numbers of amalgam restorations placed due to primary caries, as high as 30%. This difference may be related to differences in caries prevalence or interception philosophies by respective practitioners within these countries.

Although specific criteria are set for the clinical diagnosis of pit-and-fissure lesions (Radike, 1972), the number diagnosed may be either inflated or deflated, depending upon the practitioner's understanding and application of these criteria. As reported by Marken (1962), there is wide variation in the diagnosis of primary caries by clinicians. Furthermore, changes in the epidemiology of coronal caries have made many practitioners more conservative in their approach to treating diagnosed, incipient lesions. This information, when coupled with this study's findings that 15% of diagnosed secondary caries necessitate the replacement of class 1 restorations and that 28% of "poor margin" replacements are class 1s, presents a strong argument in support of the recommendations of many that more consideration be given to a wait-and-watch philosophy or the use of pit-and-fissure sealants.

The mean reported age of replaced amalgam restorations for all classes was about 11 years, one-fifth being replaced within five years and one-half lasting less than 10 years. These data are consistent with those reported by others (Robinson, 1971; Allan, 1977; Mjör, 1981; Elderton, 1983).

A confounding variable in surveys is the subjective interpretation of guidelines that define failure and the need for replacement. As is the case with diagnosis of primary caries, variation accompanies the determination of the need to replace existing restorations (Merrett & Elderton, 1984). This variation may occur as a result of the subjective interpretation of failure and the need for replacement. Clearly there is a need to establish valid, reliable, and universally accepted guidelines, specific enough to minimize subjective interpretation, to assist the practitioner in making clinical judgments.

It must be recognized that these survey data regarding restoration serviceability and replacement emphasize restorations that were judged to be failures. One should not draw inappropriate conclusions regarding the average age at replacement, as many restorations not included in these data continue to be successful. More realistically one should develop an appreciation of the trends of serviceability for restorations placed by many clinicians in a large group of patients. In this survey, 29% of the replaced restorations reportedly lasted over 15 years with 19% lasting over 20 years before failure. More detailed analysis of restoration survival is needed to identify those factors which contribute to restoration durability.

In addition, other factors suspected to enhance durability need confirmation, including proper treatment planning, quality tooth preparation, properly manipulated restorative materials, well-isolated operating sites, and restoration recipients who demonstrate good oral hygiene and plaque control skills.

The most frequently cited reason for failure was secondary caries and the majority of these restorations were of class 2 design. Secondary caries accounted for 53% of the restorations in this national survey which is in keeping with the reports from other published studies (Healey & Phillips, 1949; Richardson & Boyd, 1973; Allan, 1977; Klausner & Charbeneau, 1985). The observation that nearly 90% of secondary caries found in class 2 restorations were located around the approximal boxes stresses the need for sound cavity preparation design features, adaptation of the amalgam to the cavity walls and margins during condensation, the re-establishment of physiologic contours, the smoothing and finishing of the restoration surface and margins, and continued emphasis on patient home care. This high incidence of failure in the approximal area should alert the dentist to the fact that close re-evaluation of the approximal margins is of paramount importance during recall examinations.

Removal of noncarious amalgam restorations because of poor margin integrity amounted to 17% of the replacements. Lack of margin integrity appears to be a common justification for replacement and may represent application of Ryge's "replace for prevention" criteria (Ryge & Snyder, 1973). Class 2 restorations were replaced at nearly twice the rate of class 1s. Correlation has been established between the clinical condition of margin degradation and "creep," a mechanical property associated with the higher γ-2 alloys (Mahler, Terkla, van Eysden & Reisbeck, 1970). Therefore, it may be presumed that older, higher γ-2-containing alloys may be responsible for a number of these failures and as the use of the high copper alloys becomes more prevalent, there will be a decrease in the number of restorations replaced as a result of poor margins. Clinical manipulation factors behind these failures are similar to those due to secondary caries and may include improper cavity preparation design at the tooth-restoration interface, lack of amalgam adaptation during condensation, and disruption of the reaction product matrix (AgSnHg) as a result of delayed carving or improper finishing.

Eighty-four percent of amalgams replaced as a result of isthmus failure occurred in class 2 restorations. Factors which may contribute to these failures are improper cavity design features, such as thin pulpal-occlusal section of amalgam (insufficient resistance form), faulty occlusion, and corrosion of the γ-2 phase in older alloys.

Tooth fracture accounted for 13% of the amalgam replacements. Forty-three percent of these occurred around complex restorations and 42% were associated with class 2s. These failures indicate a need for the consideration of alternative forms of cavity design or restorative materials during treatment planning. Where larger amalgam restorations must be placed, modification of the cavity design is required to remove all remaining tooth tissue which does not possess resistance form adequate to withstand the forces of mastication.

It is disappointing to find that 54% of the amalgam restorations are placed because of previous failures, that nearly 20% occurred within five years and 60% within 10 years of placement. In 1976 Elderton stated that: "Rather than the assumption engendered in textbooks that restorative treatment will normally be successful in the long term, it would seem that it might be more accurate to assume that every restoration stands a high chance of failing within a few years."

CONCLUSION

Results from this study present a distinct challenge to dental education, dental research, and each dental practitioner. We must continue to work to meet this challenge through (1) continued development and the more vigorous application of existing preventive measures related to both primary and secondary caries, (2) application of specific and well-defined criteria for diagnosis and treatment planning for primary and secondary caries, (3) development and application of specific and well-defined criteria for restoration replacement, (4) continued enhancement of the practitioner's clinical skills, and (5) more innovative restorative modalities.

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Comparison of Microleakage in Direct and Indirect Composite Resin Restorations in Vitro

P B ROBINSON • B K MOORE
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Summary

Changes in microleakage in direct and indirect composite resin MOD restorations placed in premolar teeth following thermocycling were investigated in this study in vitro. Marginal leakage was greater in thermally loaded direct restorations than in restorations made as inlays.

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INTRODUCTION

Polymerization contraction and a high coefficient of thermal expansion are thought to contribute to the failure of composite resin restorations (Bausch & others, 1982; Ortiz & others, 1979). Polymerization contraction may lead to poor adaptation of the resin to the walls and margins with subsequent microleakage. This problem can be reduced by enamel etching (Hembree, 1983; Monteiro & others, 1986). The high coefficient of thermal expansion, in relation to tooth structure, has been implicated in microleakage through marginal percolation (Nelsen, Wolcott & Paffenbarger, 1952) or through disruption of the marginal enamel etch bond, allowing microleakage in the space resulting from polymerization contraction (Eick & Welch, 1986).

This study investigated the relationship between microleakage, polymerization contraction, and the coefficient of thermal expansion in composite resin MOD restorations. Microleakage of restorations of cemented composite resin inlays made on stone dies was compared with that of directly placed resin restorations, before and after thermocycling. Prisma-Fine (L D Caulk Co, Milford, DE 19963) lightly filled composite resin (Ferracane, Matsumoto & Okabe, 1985) was selected for its properties of high polymerization contraction and a high coefficient of thermal expansion (Söderholm, 1984).

METHODS AND MATERIALS

Extracted human premolar teeth that were noncarious and shown to be clear of hairline cracks under a stereo microscope at a magnification of X10 were cleaned on a dental lathe with a slurry of flour of pumice and stored in water at 37 °C.

Forty class 2 MOD inlay cavities were prepared with gingival bevels. In these cavities one gingival wall was left level with the pulpal floor and the other was finished approximately 1 mm above the cementoenamel junction (Fig 1).

FIG 1. *Longitudinal mesiodistal section of prepared lesion restored with composite resin. Note shallow and deep cervical finishing of approximal boxes (X8).*

All preparations were made as uniform as possible in outline and depth. The cavities were prepared with a #169L plain tungsten carbide bur in a high-speed handpiece under water spray. A bur was discarded after three cavities were prepared. The bevel was placed with a #7901 plain tungsten carbide bur.

All cavities were washed with water, dried with compressed air, treated with 3% hydrogen peroxide for 20 seconds, rewashed, and redried. Twenty cavities were restored with Prisma-Fine according to manufacturer's instructions. An incremental layering technique was used, in which the resin was applied from the apical surface toward the occlusal surfaces. Prisma-Fine composite resin inlays, fabricated on stone dies (Silky Rock, Whip-Mix Corp, Louisville, KY 40217) made from impressions (Mirror 3, Kerr/Sybron, Romulus, MI 48174) and cured in the same incremental layering technique, were cemented into the 20 remaining cavities using Comspan composite luting cement (L D Caulk Co, Milford, DE 19963). All restorations were finished with disks (Sof-Lex, 3M Dental Products, St Paul, MN 55144) 20 minutes after insertion.

The restored teeth were stored in water at 37 °C for four weeks. During that time, half of the directly restored premolars (10 teeth) and half of the premolars restored with composite resin inlays were subjected to 2500 thermocycles at 15 and 55 °C. At the end of the storage period the seal of the cavity was assessed by the radioisotope technique (Swartz & Phillips, 1961). The teeth were sealed with a combination of nail varnish enamel and tin foil so that only the area of the restoration and a 1 mm wide band of surrounding tooth surface were exposed. They were then immersed for two hours in calcium chloride ($Ca^{45}Cl$) solution pH 7.2 with a concentration of 0.1 mCi/ml. Following removal from the isotope, the teeth were rinsed in water for two hours. The foil was removed and the teeth sectioned longitudinally with a diamond disk on a sectioning machine. The tooth sections were dried and placed on dental x-ray film for production of the autoradiographs.

Autoradiographs depicting five distinct degrees of leakage were chosen from the 40 autoradiographs of the restorations to serve as standards for ranking the degree of leakage (Fig 2). The autoradiographs were assigned random code numbers to allow blind evaluation. Three evaluators scored the coded autoradiographs independently and assigned leakage values. The code was not broken until all the evaluations were complete.

There was no difference between the evaluations of the autoradiographs. Ridit analysis was then performed to determine the population

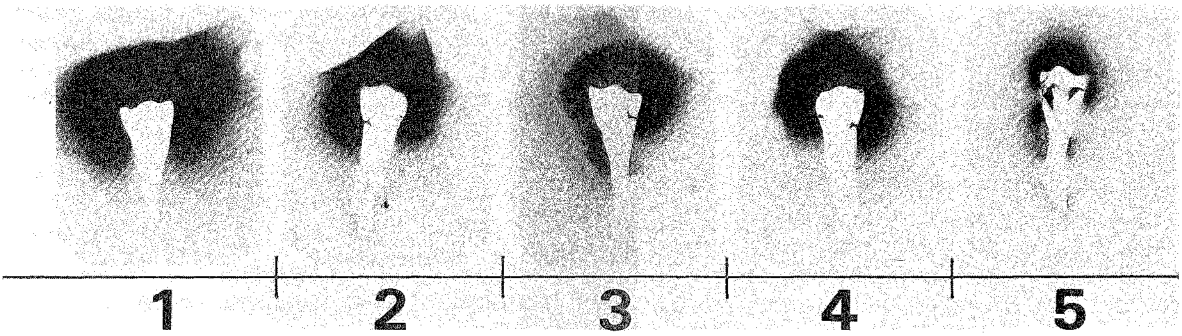

FIG 2. *Standard series of autoradiographs used for grading leakage of MOD restorations. A dark line along the restoration tooth interface is a result of radioisotope penetration.*

ridit values. Ridit means and standard deviations were calculated. Since Bartlett's chi-square test showed a lack of homogeneity of the variance, the Welch test was used instead of the one-way analysis of variance. The Newman-Keuls sequential range test was used for comparing any two groups.

RESULTS

As shown in the table, the directly placed MOD composite resin restorations showed the most leakage ($P < 0.01$). Ridit analysis demonstrated that the leakage pattern in this group more often matched the microleakage shown in autoradiograph 4 in the standard series (Fig 2). There was no significant difference between microleakage patterns of the direct and indirect resin restorations maintained at 37 °C (uncycled) and the indirect inlay thermocycled group. Marginal leakage at the cervical margin of only one box was not recorded in the direct thermocycled resin restorations. For those restorations in which microleakage at the cervical margin was found in only one box (10 of 13 cases), leakage was found only in the deep box. Where there was leakage on the cervical margin of only one box in the other groups of restorations, the following results were recorded at these sites: direct uncycled, 0 shallow side, 5 deep side; indirect uncycled, 2 shallow side, 3 deep side; indirect thermocycled, 1 shallow side, 2 deep side.

Leakage Comparisons

Group	Ridit Mean	SD
Direct (uncycled at 37 °C)	0.39	0.204
Direct (thermocycled)	0.86*	0.084
Indirect (uncycled at 37 °C)	0.39	0.204
Indirect (thermocycled)	0.34	0.217

*Significantly different from other groups ($P < 0.01$)

DISCUSSION

These results confirm that microleakage may occur within the polymerization contraction gap between resin and cavity wall of MOD restorations. Since the coefficients of thermal expansion of composite resin and a tooth are different, thermocycling of the direct restorations probably disrupts the marginal seal, allowing leakage into the space caused by polymerization contraction. There is more microleakage at the cervical aspect of the deep box of the MOD restoration than on the shallow side, probably because of a greater volume of composite resin (Söderholm, 1984). Also Gwinnett (1967) has shown in a scanning electron microscope study that the cervical enamel of human teeth possesses an irregular prismatic pattern which may also result in poor bonding. Cemented composite restorations made indirectly as inlays showed less leakage than the direct-filled thermocycled group. This study supports the theory that polymerization contraction, rather than differences in the coefficients of thermal expansion between tooth and resin, is the major cause of microleakage.

CONCLUSION

Directly placed MOD composite resin restorations showed greater microleakage than did the cemented composite resin inlays made indirectly as inlays. Also there was increased microleakage shown for the larger of the proximal boxes of the direct composite resin restorations.

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CLINICAL REPORT

Guide Wire for Parallel Pin Castings

DAVID E SNYDER

Summary

A technique is presented for preparing parallel pin channels without the use of a paralleling device. This technique, guided by three simple principles, uses a commercially available pin kit and a few materials found in most dental offices.

Introduction

Parallel pin castings have certain definite advantages in selected cases. Unfortunately, some dentists may avoid them because of the difficulty of preparing parallel pin channels. Mann, Courtade and Sanell (1965) have published an article about the preparation of parallel pin channels without the use of a paralleling device. Although there are many paralleling devices, their cost and complexity may be a deterrent to use. Courtade and Timmermans (1971) have written an exhaustive text covering many pin techniques. The literature, however, may present a discouraging amount of studying for the preparation of a few pin castings.

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The increase in the number of full-coverage restorations may be a result of the supposed complexity of specialized preparations. Many pins are used for amalgam restorations; however, not nearly as many pins are used for cast procedures. Since the cast pins must be parallel with the line of draw, the apparent difficulty associated with preparing parallel pin channels may be the reason dentists are reluctant to use them. Actually, the parallelism of pins provides a better means of visualization than do the axial walls of preparations. The author has instructed students in the simplified technique described below for 11 years and has found no difficulty in acquainting them with the concept.

To use pins with cast restorations, the placement of pin channels must be parallel to the line of draw of the preparation. This technique involves the guide wire concept, which depends on three simple fundamentals.

1. The parallelism of straight-line objects must be easily seen.
2. A side view must be provided, achieved by a mirror held at a 45° angle.
3. A guide to the direction of draw is required, provided in this instance by a small wire

held in place with tacky wax.

In the technique presented — see Figures 1-13 — a short piece of wire is used, such as a piece of paper clip or orthodontic wire. It is attached with sticky peripheral wax to the tooth being operated upon or to the tooth immediately adjacent. The VIP Pin Kit (Whaledent International, 236 Fifth Ave, New York, NY 10001) is used in this technique.

FIG 1. *This rather short, broken-down tooth is a good candidate for pins.*

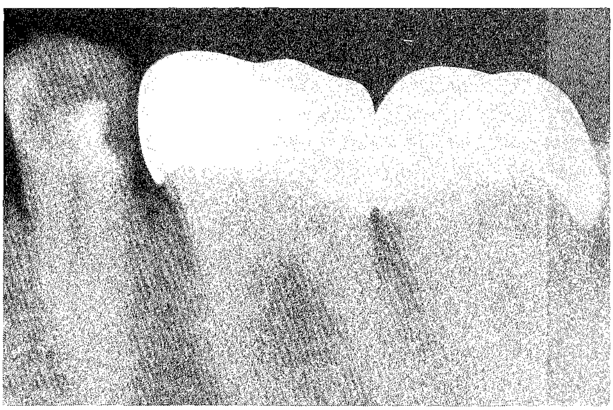

FIG 2. *An x-ray reveals pulp and periodontal anatomy to aid in planning pin placement.*

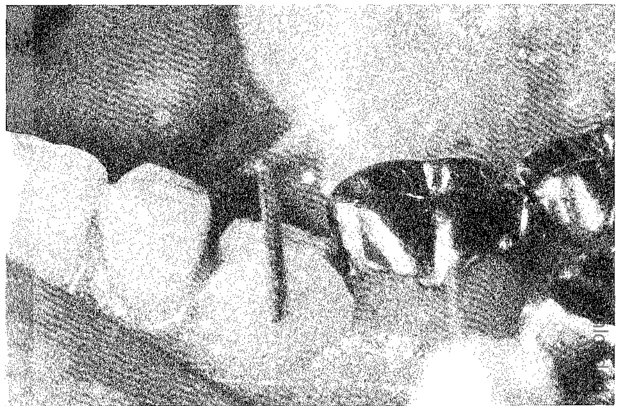

FIG 3. *A guide wire may be placed with a sticky peripheral wax to show the path of insertion of the casting.*

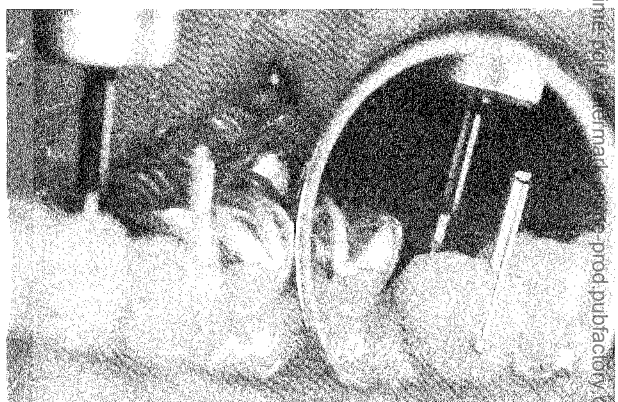

FIG 4. *With a mirror held at about a 45° angle in the buccal vestibule, the operator can see two views of the guide wire and the twist drill. Since both views are always presented, minor corrections in drill alignment are easily made.*

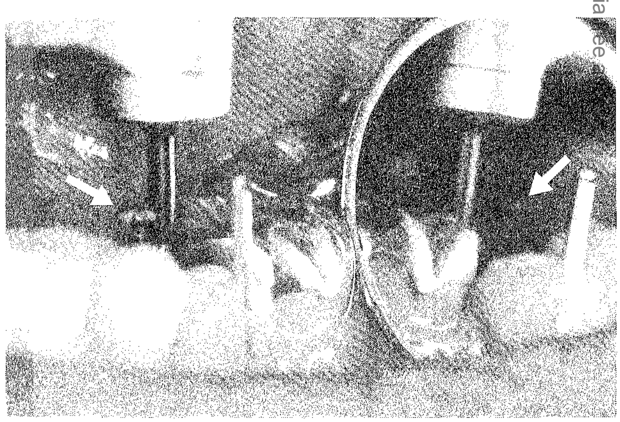

FIG 5. *After one channel has been drilled, an impression pin can be placed (arrows). This allows a further check on alignment, since it is easier to notice the parallelism with additional straight line objects.*

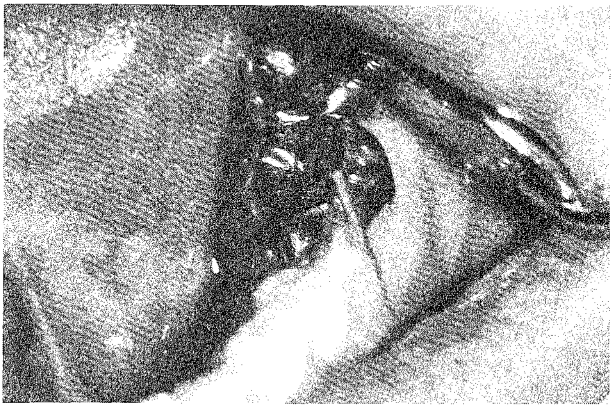

FIG 6. *With both impression pins in place, the operator can recheck the parallelism.*

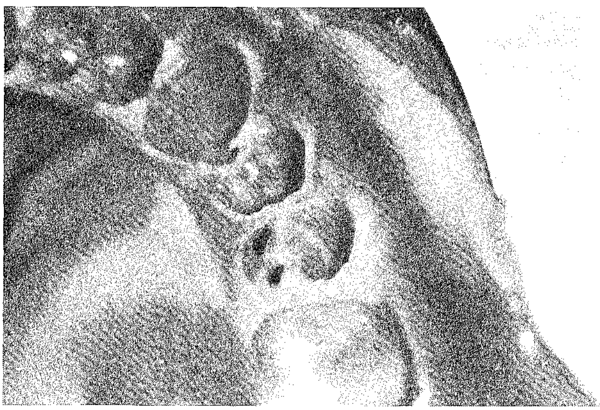

FIG 7. *Either hydrocolloid or one of the elastomers may be used to take the impression. The impression pins are retained in the impression.*

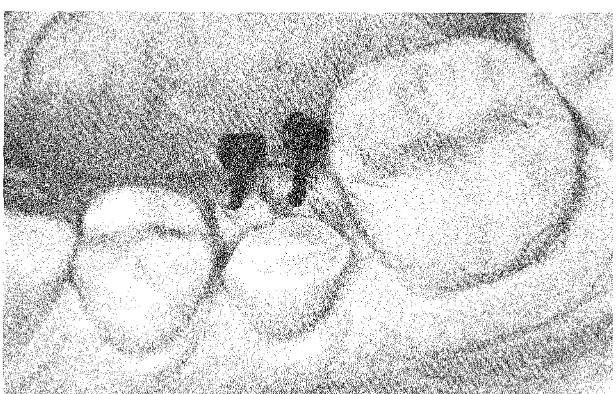

FIG 8. *The cast is poured and when the impression materials are removed the pins frequently remain in the cast.*

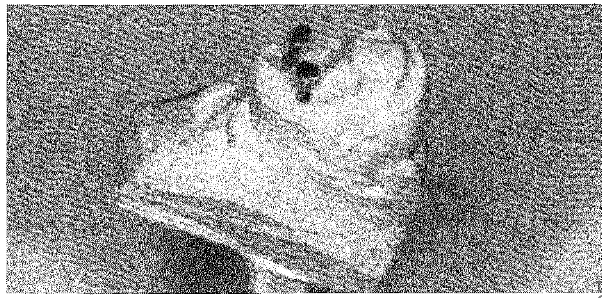

FIG 9. *Metal casting pins (Whaledent VIP Kit) are placed in the pin channels of the trimmed die.*

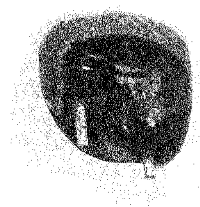

FIG 10. *The waxing of the case should be done carefully so that the wax does not flow down the pin. In this case, the wax was inadvertently allowed to run down the pin.*

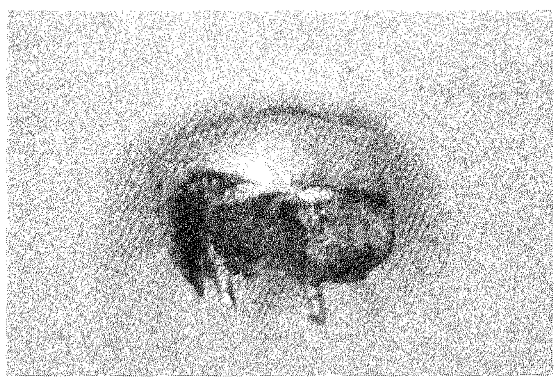

FIG 11. *Casting demonstrates pins in place*

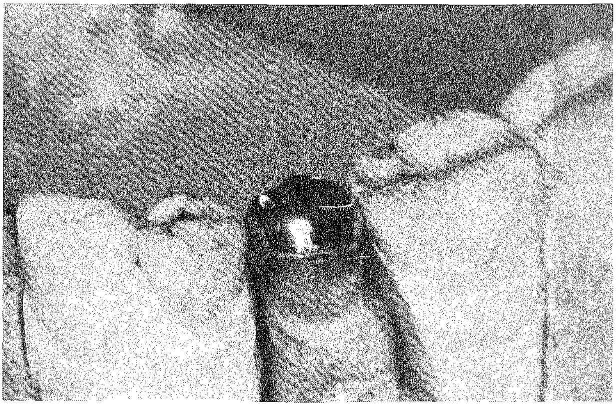

FIG 12. *Casting fitted to the die*

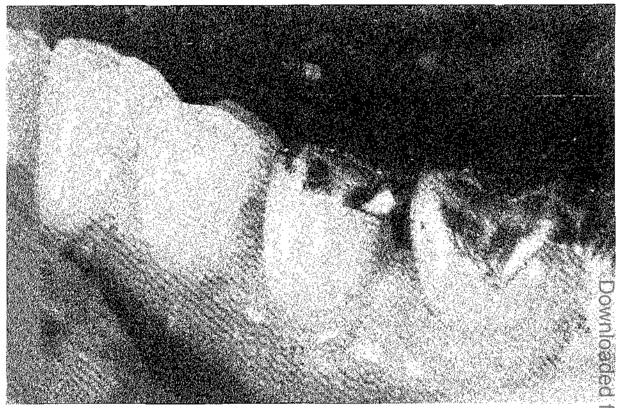

FIG 13. *Cemented casting in the mouth*

Discussion

This parallel pin concept is based on the constant monitoring of the drilling procedure to ensure the resulting pin channels are parallel. However, since even the best of operators and techniques sometimes fail, a few easy solutions are available if the pin channels are not parallel. One advantage is that the cast pin is smaller than the drilled hole, allowing some slight compensation for error. Courtade (1971) claims up to 8° off of parallel can be tolerated. If the error in parallelism is discovered before taking the impression, the channel or channels can be redrilled with the next size larger drill. If the error is discovered after the casting has been produced, it is possible to shorten the pin — to about 1 mm in length to maintain its resistive feature — if the other pins and retentive features are adequate. Minimal adjustment of the axial wall of the pin does not appear to affect the resistance and retention required.

Conclusion

The technique presented here is simple and requires only readily available materials to implement. Many cases requiring additional resistance and retention would be enhanced by use of a guide wire to facilitate placement of parallel pin channels for the cast restorations.

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PRODUCT REPORTS

Evaluation of the Dispersalloy Caplet System

W J DONAHUE • R L COOLEY

Summary

This report is an evaluation of the Caplet system which is a new and unique method of dispensing mercury and amalgam alloy. Advantages and disadvantages of this system in relation to mercury hygiene are compared to pre-encapsulated disposable capsules and reusable capsules loaded from bulk supplies. Mercury leakage, amalgam retention, and capsule degradation are evaluated and discussed.

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The views expressed herein are those of the authors and not necessarily those of the United States Air Force or Department of Defense.

INTRODUCTION

A new and innovative method of dispensing mercury and alloy has been introduced. It is being promoted under the name Caplet (Johnson & Johnson Dental Products, East Windsor, NJ 08520) and is basically a plastic pouch made of Surlyn that contains both the premeasured mercury and alloy tablet. The mercury and alloy are separated by a membrane until trituration, at which time the plastic pouch separates, allowing the mercury and alloy to mix. The plastic pouch is disposable and can be removed from the amalgamator capsule after trituration.

A newly designed Caplet amalgamator capsule is supplied with every unit of 100 Caplets (Fig 1). The manufacturer recommends that this capsule be used only 100 times and then discarded, due to the wear created by trituration. No reference could be found in which any other manufacturer recommended a limited number of uses for a reusable capsule. The Council on Dental Materials, Instruments, and Equipment of the American Dental Association (*ADA News*, 1981) has not made recommendations on the number of times that a capsule should be used, but has recommended that

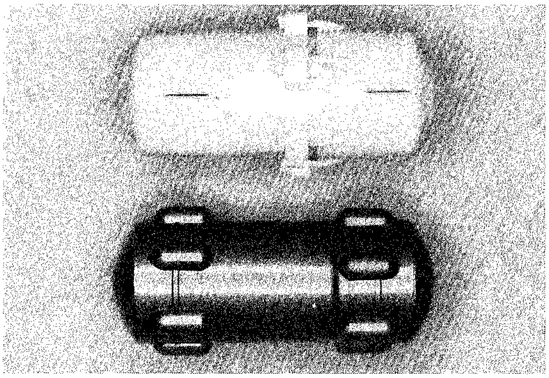

FIG 1. *The newly designed Caplet capsule (top) can be compared to the older Johnson & Johnson friction lock capsule (bottom).*

amalgamator capsules be checked for leaks and replaced, if necessary.

The Caplet amalgamator capsule has a locking device (Fig 2) that keeps the two halves

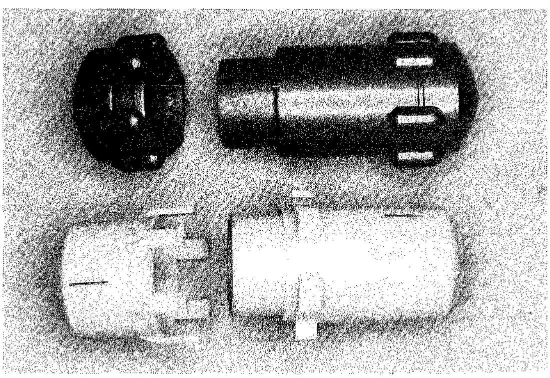

FIG 2. *Locking device on the Caplet capsule (top) consists of a set of arms that engage braces on the other capsule half. The reusable capsule (bottom) is held together by friction of the two capsule halves.*

sealed during trituration, in addition to a secondary seal that is said to virtually eliminate mercury leakage. Previous studies have found that reusable capsules allow mercury leakage and this leakage increases with use (Cooley & Barkmeier, 1979; von der Lehr & Capdeboscq, 1979; Capdeboscq & van der Lehr, 1979; Barkmeier & Cooley, 1981).

The purpose of this study was to evaluate the Caplet amalgamator capsule for mercury leakage and compare it to a reusable capsule and a pre-encapsulated disposable capsule made by the same company. Most studies of capsule leakage have used the weight loss method (weighing the capsule before and after trituration) to detect mercury loss. It has been shown, however (Barkmeier & Cooley, 1982), that capsules wear during trituration and experience a weight loss during this process. To avoid this variable, this study used tape to trap any expelled mercury and a mercury vapor analyzer to detect mercury on the tape.

MATERIALS AND METHODS

Two types of capsules, reusable and preloaded, were compared to the Caplet capsule. All the capsules were made by the same manufacturer (Johnson & Johnson Dental Products). The pre-encapsulated capsules (Dispersalloy double dose, 600 mg) were used through one trituration cycle, evaluated for mercury leakage, and then discarded. The Caplet capsule and the J & J reusable capsule were placed through 50 trituration cycles in a Caulk Vari-Mix (L D Caulk Co, Milford, DE 19963) amalgamator. Both capsules were triturated for 18 seconds; however, the Caplet capsules were tested at the manufacturer's recommended M-3 setting while the reusable and the pre-encapsulated capsules were tested at an M-2 setting.

The Caplet capsules were tested with a double-dose Caplet (600 mg Dispersalloy/592 mg mercury), the pre-encapsulated with 600 mg Dispersalloy, while the reusable capsules contained two Dispersalloy pellets and two drops of mercury from a dispenser (L D Caulk Co, Milford, DE 19963) with an E plunger.

A strip of masking tape was placed around the interface of the two capsule halves prior to trituration to capture the mercury being expelled during trituration. Mercury escaping from the capsule would be trapped on the adhesive surface of the tape.

A Jerome Mercury Vapor Analyzer (Model 401, Jerome Instruments, Jerome, AZ 86331) was used to detect and measure the mercury which was captured on the tape. This analyzer was used because it is a very accurate instrument for measuring mercury levels. It has only one known interference (hydrogen sulfide) and there is a filter to remove this substance. This instrument uses a thin gold film to detect and measure mercury vapor. When mercury vapor passes over the gold film it adsorbs on the surface, which changes the electrical resistance of the film. This change in resistance is converted by a microprocessor to milligrams of mercury per cubic meter (mg Hg/m^3). The analyzer's probe was placed one-half inch above the surface of the tape. Measurements were taken after each trituration cycle up to the tenth, and thereafter at intervals of five cycles up to 50.

Mercury accumulation within the capsule following trituration during multiple uses was determined indirectly by measuring the mercury vapor concentration within the capsule following trituration. The probe tip of the Jerome Mercury Vapor Analyzer was placed one-quarter inch inside the opening of the capsule for this measurement.

Integrity and degradation of the capsule during reuse was determined by visual examination following each use, concentrating on two areas: (1) fracture, chipping, or other defects, and (2) roughening of the internal capsule surface and retention of amalgam on roughened surfaces.

RESULTS

Mercury Expelled during Trituration

Results of mercury vapor measurements obtained from the tape placed around the interface of the two capsule halves during trituration are shown in Table 1. It can be seen that

Table 1. Mercury Vapor Expelled during Trituration (mg Hg/m^3)

Mix Number	Caplet Capsules		Reusable Capsules		Pre-encapsulated Capsules*
	#1	#2	#1	#2	#1 - 15
1	0.021	0.010	0.020	0.020	0.00
2	0.014	0.020	0.030	0.028	
3	0.022	0.024	0.030	0.046	
4	0.005	0.017	0.020	0.080	
5	0.022	0.028	0.025	0.040	
6	0.010	0.029	0.025	0.046	
7	0.080	0.034	0.040	0.048	
8	0.020	0.030	0.040	0.050	
9	0.022	0.028	0.045	0.052	
10	0.025	0.028	0.050	0.051	
15	0.045	0.030	0.050	0.047	
20	0.065	0.048	0.050	0.078	
25	0.070	0.072	0.070	0.097	
30	0.085	0.094	0.070	0.098	
35	0.130	0.155	0.080	0.090	
40	0.210	0.185	0.080	0.130	
45	0.260	0.230	0.080	0.180	
50	0.260	0.220	0.100	0.220	

*The 15 preloaded capsules were triturated and discarded.

mercury vapor levels increased with increased use of both the Caplet capsules and the reusable capsules. When this data was subjected to statistical analysis using the least squares linear regression out to 50 mixes, there was a significant increase in the slope of the leakage graph for both capsules as indicated by the F Test for regression ($P < .001$). As the pre-encapsulated capsules were only used once, the mercury measurements were to be averaged for 15 capsules; however, there was so little mercury that the instrument did not register on the lowest scale.

Mercury Vapor Measurements in Capsules

Measured levels of mercury vapor obtained within the capsules following trituration and removal of amalgam are shown in Table 2. Levels reached 5 mg of mercury per cubic meter after eight cycles of the Caplet capsule and five cycles of the reusable capsule. Additional readings were not taken after the five milligram level was reached, as this represents the maximum reading obtainable with the Jerome Mercury Vapor Analyzer. Again, the pre-encapsulated capsule measurements were averaged as they were only used once. The average for the 15 preloaded capsules was 1.23 mg Hg/m^3 with a range from 0.8 to 1.7 mg Hg/m^3.

Visual Examination

Visual examination of all the capsules following trituration did not reveal any fractures or mechanical defects. The interior of both the Caplet and reusable capsule, however, showed considerable roughening of the internal surfaces due to repeated contact of the metal pestle with the interior surfaces during trituration. This roughening caused the retention of small amounts of scrap amalgam within the capsule following the removal of the amalgam mix. Surface roughening and amalgam retention appeared to worsen with increased uses of the capsule. A slight build-up of amalgam at the interface of the two capsule halves was noted and appeared to increase with increased use of the capsules. Another finding was that the plastic pouch did not always come out with the mixed amalgam and had to be manually removed.

Table 2. Retained Mercury Vapor Levels in Capsules (mg Hg/m^3)

Mix Number	Caplet Capsules #1	Caplet Capsules #2	Reusable Capsules #1	Reusable Capsules #2	Pre-encapsulated Capsules* #1 - 15
1	2.0	2.8	3.5	3.6	1.23
2	2.5	3.0	3.6	3.4	
3	2.7	3.0	5+	4.5	
4	3.8	3.8	4.8	5+	
5	3.9	4.8	5+	5+	
6	2.8	4.85	5+		
7	4.0	4.95			
8	5+	5.0			
9	5+	5+			
10	5+	5+			

+ indicates that the levels were too high to measure with the Jerome Model 401 Vapor Analyzer.

*The 15 preloaded capsules were triturated once and discarded. This is the average mercury vapor level for the 15 capsules.

DISCUSSION

One of the primary goals of this test was to determine if mercury leakage increased with an increase in usage of the Caplet capsule. To detect for measurement errors in each group, a second capsule was evaluated as a test of agreement. A paired *t*-test analysis of the data indicates that there was no significant difference in mercury loss between the Caplet capsules; however, there was a significant difference between the two reusable capsules ($P = .0036$). In addition, the sample size in this study is similar to some previous studies (von der Lehr & Capdeboscq, 1979; Capdeboscq & von der Lehr, 1979). A study performed by the manufacturer using a large number of capsules found little variance among the Caplet capsules with few losing weight when triturated only once (Subelka, 1985). In that study, 50 Caplet capsules were triturated one time and 42 did not show any evidence of mercury loss using the "weight loss" method. The highest weight loss value was 0.2 mg for four of the capsules.

Although none of the capsules tested exhibited significant expulsion of mercury during trituration, or emitted mercury levels in high enough concentrations to be of concern, there were differences in the three systems tested.

Reusable capsules utilizing bulk mercury dispensers (having only the friction lock design) and the Caplet system (having both friction lock and mechanical locking properties) exhibited significantly higher levels of mercury expulsion during trituration than did the pre-encapsulated capsules (which had no detectable mercury loss). The amount of mercury expulsion during trituration continued to rise as the capsules were reused. This rise can partly be attributed to the build-up of scrap amalgam noted at the closure interface of the two capsule halves in both systems (Figs 3 & 4). This build-up continued to increase as the capsules were reused and correlated positively to the rise in measured mercury expelled from the capsules as the number of uses increased. Another possible reason for the increase in mercury expulsion is the repeated opening and closing of the capsules causing continual wear of the capsule mating surfaces, and therefore lessening the friction lock seal between the two capsule halves. The pre-encapsulated capsules showed virtually no detectable mercury expulsion during trituration and are considered superior in this respect to both the reusable and the Caplet system.

Both the reusable and Caplet systems make use of metal pestles inside the plastic capsule during trituration. The weight of the metal pestle causes considerable roughening of the internal surfaces, especially at the ends of the capsule, and increases as the capsules are reused. Triturated amalgam adheres to these roughened surfaces, and small amounts are retained following removal of the mix. This retained amalgam is contacted by the metal pestle during the trituration of the next mix and portions of the previously set amalgam may break free, contaminating the mass being triturated. Such contamination may alter the physical properties of the new mix. The weight of the metal pestles might also contribute to the increased mercury vapor noted within the reused capsules by forcing mercury into the capsule walls during trituration.

The plastic pouch containing the premeasured amalgam and mercury in the Caplet system bursts during trituration, releasing the amalgam and mercury. Following trituration, the pouch does not always come out of the capsule with the amalgam mix, making it necessary to manually remove the retained pouch prior to reloading the capsule for the next mix. The manufacturer's instructions direct the user to tap the capsule on the counter top to remove the pouch if it is retained within the capsule. Although this action would remove

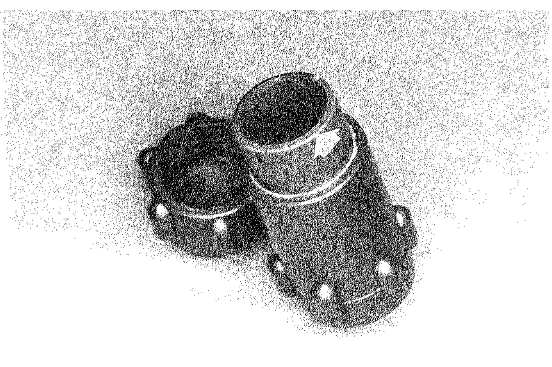

FIG 3. *Build-up of amalgam at the mating surfaces of the two halves of the reusable capsule.*

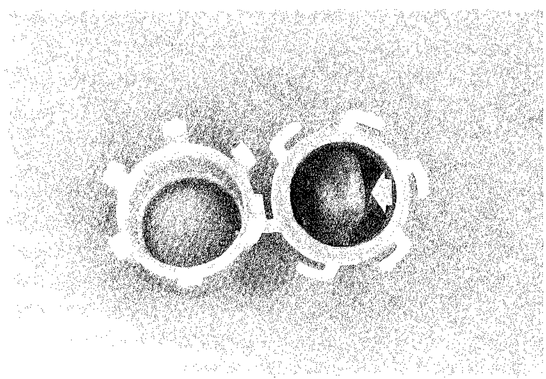

FIG 4. *Build-up of amalgam at the mating surfaces of the Caplet capsule. Also, the plastic pouch can be seen in the right half as it failed to come out with the amalgam mix.*

the pouch, it would also dislodge the retained amalgam particles and deposit them on the counter. Unless meticulously cleaned, the counter top could then become contaminated and be a source of mercury vapor, potentially harmful to patients and staff. A more hygienic method would be the use of cotton pliers to remove the plastic pouch.

The packaging of the Caplet system offers some significant advantages, as do all pre-encapsulated systems, over reusable capsules which utilize bulk mercury dispensers. When mercury and amalgam are premeasured and sealed within the plastic pouch, the potential for a catastrophic mercury spill that may occur with bulk mercury dispensers is eliminated. This system would also eliminate smaller spills that may occur when mercury is released from the dispenser into the capsule. The premeasured dosages present within the Caplet offer the potential for more consistent amalgam mixes, and resultant higher quality restorations. In addition, the cost of the Caplet system is significantly reduced from the pre-encapsulated disposable system since the capsule price is not included in the dose price of the system.

CONCLUSION

Both bulk dispensing systems and the Caplet system utilize reusable capsules with metal pestles. Both systems exhibit mercury expulsion from the capsule during trituration which increases with the number of capsules used. Both systems also exhibit retained amalgam scrap within the capsule, which has the potential to contaminate subsequent mixtures of amalgam triturated within the capsule. This retained amalgam as well as mercury driven into the capsule walls causes mercury vapor levels within the capsules to increase with the number of reuses. The pre-encapsulated capsule system exhibits neither of these disadvantages and is significantly better than either the bulk dispensing system or the Caplet system when viewed in terms of mercury hygiene.

The Caplet system eliminates the possibility of catastrophic mercury spills, but retains the problems of retained amalgam scrap within the capsule, and expulsion of mercury from the capsule during trituration associated with the reusable capsule systems. For practitioners currently using bulk mercury dispensers in their practice, a switch to the Caplet system would eliminate the possibility of a catastrophic mercury spill with a negligible increase in cost. The best mercury hygiene, however, is available only with the use of disposable predosed capsule systems.

Acknowledgments

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Bond Strengths of Repaired Composite Resins

B POUNDER • W A GREGORY
J M POWERS

Summary

The wide use of composite resins in dentistry has necessitated repair of fractured, discolored, and worn restorations. Laboratory investigations have demonstrated that new composite resin can be bonded to previously cured composite resin. This study examined the bond strength of three commercial composites, from one manufacturer, used in repair procedures with three corresponding commercial bonding agents. No combination of primary resin, repair resin, and bonding agent consistently developed highest bond strengths. Tensile bond strengths equal to diametral tensile strengths of repaired microfilled and conventional composites or resin/etched enamel bond strengths, of the commercially available products, were not attained.

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INTRODUCTION

The combination of the acid-etch technique for increasing the adhesion of acrylic filling materials to enamel (Buonocore, 1955) and the bis-GMA composites (Bowen, 1962) has extended the use of resin restorative materials from simple class 3 lesions to those of greater complexity and size.

Composite resins are currently used to restore class 1, 2, 4, and 5 defects, to resurface crown and bridge facings, to attach orthodontic brackets, to splint periodontally compromised teeth, and as a direct veneer material necessitating repair as a result of failed bonds, color changes, and loss of surface through chemical and mechanical deterioration.

Techniques for the mechanical preparation of fractured surfaces to enhance retention of new composite resin to old and optimize the success of repairs have been widely evaluated and reported (Caspersen, 1977; Gwinnett & Matsui, 1967; Retief, 1978; Boyer & Hormati, 1980; Boyer, Chan & Torney, 1978).

The opportunity for chemical bonding has been studied (Vankerckhoven & others, 1982). Measurements of residual unreacted methacrylate groups in composite resin after cure showed microfilled and large-particle products to be 40% and 57% unsaturated. Therefore, chemical bonding of new resin to previously polymerized resin could be expected.

Diametral tensile strengths of typical large-particle composite resins have been reported to be in the 35 to 55 MN/m^2 range and that of microfilled resins in the 30 to 36 MN/m^2 range (Craig, 1981). Tensile bond strengths of resin to enamel of 15 to 30 MN/m^2 are reported to be clinically functional (Causton, 1975). Several laboratory investigations have demonstrated that surface preparation of old composite by mechanically roughening the surface, cleansing with 30 to 50% phosphoric acid, and treating with unfilled bonding agent optimized the repair bond (Boyer & others, 1978; Boyer, Chan & Reinhardt, 1984; Söderholm, 1985). This study addressed the clinical question of the repair of "unknown" composite resin. Composites of different composition and filler particle size, from a single manufacturer, were repaired with like and unlike materials using different bonding agents.

MATERIALS AND METHODS

A large-particle composite resin, chemically cured (Concise, batch #1925), a microfilled composite resin, also chemically cured (Silar, batch #8601, 8602), a microfilled composite resin, light cured (Silux, batch #5501ME), and three bonding agents (Enamel Bond, batch #1272 P1 [Resin A], 2E1 [Resin B]; Scotchbond Lightcured, batch #5P1; and Scotchbond, chemically cured, batch #4L1) were used in this study. All composite resins were manufactured by the 3M Company (3M Dental Products, St Paul, MN 55144). Sample combinations of original and repair composites and bonding agents are shown in Table 1.

Forty-five cone-shaped samples, 4 mm thick, of each of the three composite resins were developed in a split-ring mold, using Teflon filling instruments. The samples that were chemically cured (Concise and Silar) were mixed according to manufacturer's instructions and allowed to cure for 20 minutes at 37 °C before removal from the forms. The resin samples that were light cured (Silux) were developed in three increments and cured at each step for 20 seconds with a commercial dental curing light (Translux, Kulzer, Inc, Irvine, CA 92718).

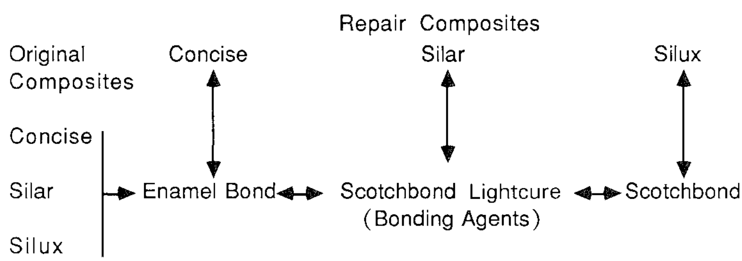
Two hours after cure the repair process was initiated.

Five samples of each of the three composite resins were repaired, with each of the three composite resins using each of the three bonding agents for a total of 27 combinations and 135 tests.

The small end of the cone-shaped samples were polished flat with 600-grit silicon carbide paper and cleaned with 37% phosphoric acid gel (3M Dental Products, St Paul, MN 55144), rinsed vigorously for 60 seconds with tap water, and dried with oil-free compressed air before repair. Bonding agent was applied according to manufacturer's instructions with a brush and the excess blown off with a gentle stream of compressed air. A Teflon ring, 5 mm internal diameter, was held against the primary sample with a clamp and the repair composite was applied and cured as described above. The repaired samples were stored in 37 °C water for 24 hours before the tensile bond strength was determined on a testing machine (Model TT-BM, Instron Corp, Canton, MA 02021) at a head speed of 0.05 cm/min.

The means and standard deviations for the samples were determined. The data were analyzed by analysis of variance using a factorial design (Dalby, 1968). Means were ranked by a

Table 1. Combinations of Original and Repair Composites and Bonding Agents



Tukey interval (Guenther, 1964) calculated at the 95% level of confidence. Differences between two means that were larger than the Tukey interval were statistically significant.

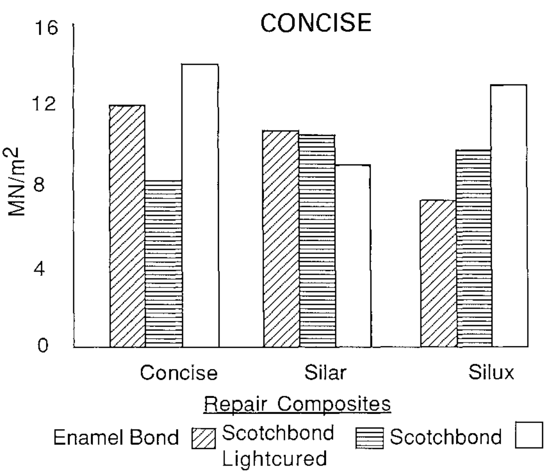
RESULTS

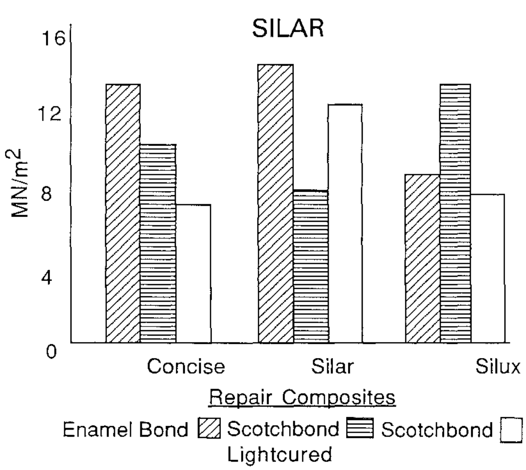
The figure shows the bond strength of each of the composite resins when repaired with Concise, Silar, and Silux, and the three respective bonding agents.

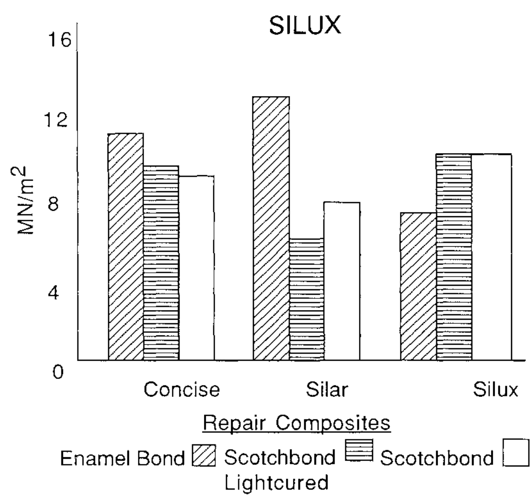
The mean values of bond strengths of composite Concise are shown. Bond strengths ranged from 7.2 to 14.0 MN/m² with the best bond obtained with repair resin Concise and bonding agent Scotchbond. The lowest bond strength was obtained with repair resin Silux and bonding agent Enamel Bond. The highest value of combination bond strength was significantly higher than the values obtained from all but two of the other eight combinations.

The mean values of bond strengths of the composite Silar repaired with Concise, Silar, and Silux, and with each bonding agent are found in the figure. Bond strengths ranged from 7.0 to 13.9 MN/m² with the best bond obtained with repair resin Silar and bonding agent Enamel Bond. The lowest bond strength was obtained with repair resin Concise and bonding agent Scotchbond. The highest bond strength combination value was significantly higher than the values obtained from all but three of the other eight combinations.

The figure also shows the mean values of bond strengths for the composite Silux repaired with Concise, Silar, and Silux and with each bonding agent. Bond strengths ranged from 5.7 to 12.5 MN/m², with the best bond obtained with repair resin Silar and bonding agent Enamel Bond. The lowest bond strength was obtained with repair resin Silar and bonding agent Scotchbond Lightcured. The highest bond strength combination value was significantly higher than the values obtained from all but one of the other eight combinations.







Bond strength of Concise, Silar, and Silux repaired with Concise, Silar, and Silux and three bonding agents, respectively.

Table 2 shows the means (n = 5) of composite resin repair bond strengths of each of the three primary composites of the three repair composites by bonding agent.

DISCUSSION

The strength at the bond interface determines the ultimate success or failure of repairs of composite resin. The wetting of the surface to be repaired by a bonding agent to allow optimal adaptation of the repair composite has been shown to be integral to the development of a high bond strength (Causton, 1975; Boyer & others, 1984).

The tensile bond strengths of repairs of composite resins obtained in this study indicate that the bond strength cannot always be predicted on the basis of the repairing resin and bonding agent alone. Combinations did not uniformly produce the best or the worst bond strengths. Highest bond strengths were obtained when Concise and Silar were repaired with Concise and Silar, but not when Silux was repaired with Silux. The bonding agent marketed with the primary resin did not develop highest bond strengths in any of the test combinations. Combinations of repair materials (composite plus bonding agent) resulted in bond strengths of similar rank order when Silux and Silar were repaired by Concise, but not so for Concise repaired by Concise. The same ranking result was found for either Silux or Silar repaired by Silar with any of the bonding agents, and again the ranking of Concise repaired by Silar was different. There was no similarity in bond strength ranking among any of the primary resins when Silux was the repair material.

When Concise was used as the repair material for any of the three primary composites, no single bonding agent resulted in a stronger bond in all combinations. When Silux was used as the repair material, there was no single bonding agent of choice. When Silar was used as the repair material, Enamel Bond was the

Table 2. Composite Resin Repair Bond Strengths by Bonding Agents

	REPAIR RESIN					
	CONCISE		SILAR		SILUX	
Primary Resin	Mean	SD	Mean	SD	Mean	SD
			ENAMEL BOND			
Concise	11.9	5.8	10.7	3.7	7.2	4.6
Silar	13.1	4.5	13.9	7.6	8.4	2.9
Silux	10.7	6.7	12.5	6.9	6.9	3.2
			SCOTCHBOND LIGHTCURED			
Concise	8.4	2.4	10.5	4.7	9.7	2.4
Silar	10.0	5.6	7.8	2.6	13.0	5.6
Silux	9.3	2.1	5.7	1.6	9.7	1.8
			SCOTCHBOND CHEMICALLY CURED			
Concise	14.0	3.8	9.0	2.6	13.0	1.3
Silar	7.0	2.2	12.3	3.9	7.6	1.9
Silux	8.7	1.3	7.6	1.6	9.7	1.7

Mean is of five replications with standard deviation.
Tukey interval, 2.1 MN/m^2.

most effective bonding agent. Lowest bond strength values did not correlate with any one bonding agent in combination with any of the three repair materials.

The repair bond strengths demonstrated in these combinations ranged from less than one-half (6.9 MN/m^2) to almost equal (13+ MN/m^2) to the lower level of clinically acceptable bond strengths (15-30 MN/m^2) on composite to enamel as determined by Causton (1975). None of the repairs demonstrated bond strengths near the diametral tensile strength reported for large-particle and microfilled composite resins (Craig, 1981).

CONCLUSIONS

1. Highest tensile bond strength of repaired composite resins after surface preparation resulted from no single combination of bonding agent and repair resin or from the composite resin repaired.
2. Bond strength of repaired composite resins after surface preparation did not approach the diametral tensile strength of large-particle or microfilled composite resins.
3. Bond strengths of repaired composite resins after surface preparation did not reach the clinically functional strength associated with composite resin/enamel bonds.
4. Repair material of like composition or the bonding agent marketed with the repair resin did not always produce highest bond strengths.

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DEPARTMENTS

Book Reviews

JOHNSTON'S MODERN PRACTICE IN FIXED PROSTHODONTICS
Fourth Edition

Roland W Dykema, Charles J Goodacre, and Ralph W Phillips

Published by W B Saunders Company, Philadelphia, 1986. 460 pages, 600 illustrations, indexed. $42.95

This is a fourth edition of the classic 1971 text, *Modern Practice in Crown and Bridge Prosthodontics,* by John F Johnston, Ralph W Phillips, and Roland W Dykema. It has been appropriately shortened by some 200 pages and revised to reflect current, but conservative, philosophies of fixed prosthodontic techniques necessitated by changes in materials and/or procedures.

The purpose of this edition is similar to that stated in the first: "to be comprehensive but not encyclopedic in scope and to present basic knowledge and accepted techniques in a manner which will enable the student, or practitioner, to assimilate and apply them clinically. The clinical operations set forth are intentionally conservative so that the student will follow a plan designed to help avoid difficulties. The experienced clinician will broaden the application of many principles with complete success, at the same time observing the fundamentals."

The authors achieve this purpose to the extent that the text covers a broad range of topics but is not encyclopedic in scope. The chapters on dental ceramics have been extensively revised and concentrate on various ceramic restorations of anterior teeth. There is a new chapter on color and shade selection and an excellent chapter on esthetics in ceramic restorations. New chapters have also been added on resin restorations, resin bonding, and resin-bonded prostheses. Chapter 32 on occlusion, as authored by George W Simpson, DDS, is very well done and is nicely augmented by some of the best illustrations in the text.

Although the practice of dentistry has changed dramatically in 15 years, some aspects of tooth preparation, especially those for partial veneer crowns, have changed little and these fundamentals have been well covered in the early chapters of the text. However, the opportunity to address other techniques, such as all-ceramic crowns for posterior teeth, has not been taken and these authors certainly have the expertise to address this issue quite capably.

There are also a number of pearls buried in the chapters of this book that are not well presented. Cautions and limitations as well as distinct advantages of certain procedures are well camouflaged in the small print of the existing outline, which is indeed unfortunate. In fact, there is a definite monotony in the size of the black and white prints and in the presentation of the printed text. The chapter on esthetics in ceramic restorations could have benefited nicely from some color prints emphasizing the authors' points, much more so than from the color plate on page 331 relative to Munsell's color chart. In leafing through the book, there is simply no inspiration to get out one's checkbook.

The authors have indeed achieved their intent to present operations that are intentionally conservative. But in doing so, they have missed a ripe opportunity to share their considerable knowledge in a reference text that could be easily scanned and that would be very useful to many clinicians. It would be nice if the fifth edition would appear soon in a much more modern and presentable format.

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AN INTRODUCTION TO DENTAL ANATOMY AND ESTHETICS

Robert P Renner, DDS

Published by Quintessence Publishing Co, Inc, Chicago, 1985. 286 pages, illustrated. $48.00

This textbook is designed to assist the dental student and other dental paraprofessionals in understanding and interpreting the fundamentals of dental anatomy and esthetics. The book itself is beautifully produced, with large, easy-to-read print on heavy glossy paper and numerous photographs both in color and black and white. The photographs and line drawings serve to enhance the reader's understanding of arch form, tooth position, and axial inclinations of teeth in their respective arches.

The author begins with a good general description of the entire masticatory process and rapidly moves to a detailed description of its component parts.

A precise account of the temporomandibular joint's anatomy, function, and importance to the entire dental-facial complex is presented. A considerable portion of the text describes the intricacies of jaw movement and its relationship to the teeth. In addition to descriptions of the envelope of motion, articulation, and occlusal contacts in intercuspal position, Dr Renner includes a table of the muscles of mastication, highlighting muscle action and nerve supply — helpful to any student of anatomy of the oral apparatus. However, I found myself wanting a better diagrammatic view of their location than the illustration provided on page 37. Regional anatomy with descriptions of the oral mucosa, salivary glands, and tongue are well presented with good reference tables, clinical photographs, and pictures of histological sections.

A major part of the book is devoted to the individual characteristics of the teeth which are depicted in detail from all views. A full page of photographs and illustrations lies adjacent to the text, enabling the reader to immediately look at what is being described. However, additional diagrammatic labeling emphasizing important anatomical landmarks superimposed on the photographs or accomplished with larger drawings would have been helpful. Variations of individual occlusal anatomy, root and pulp morphology are not approached in this publication.

The midsection of the book is devoted to the development of the teeth and supporting structures. Excellent illustrations of histological sections, electron micrographs, and pictures of clinical x-rays help relate the development of the dentoalveolar complex to everyday clinical practice. The static and dynamic occlusal contacts for Class I occlusions for the individual with natural dentition are addressed as are normal genetic variations of malocclusion. Dr Renner appropriately presents a variety of differing opinions regarding the significance of various theories of occlusion.

In the concluding chapter on dental esthetics, the author states that "this material is the stepping stone on which the student can learn to perceive applied dental anatomy and use it to improve patient treatment." To that end, the author succeeds quite well. Too often in dental education we are trained to focus on the minutia of our operating field at the exclusion of the broader, more important perspective. The final chapter in this book is devoted to helping the student to orchestrate much of what has been learned in prior chapters and to help him/her to see oral, dental, and facial anatomy as a harmonious and beautiful composition.

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9618 59th Avenue SW
Tacoma, WA 98499

Textbook Available from New Source

The textbook *Advanced Restorative Dentistry* (1987, second edition, second printing) by Lloyd Baum and Richard B McCoy, co-editors, is no longer being published by W B Saunders Co. It may be ordered from the Dental Center, P O Box 7067, Loma Linda, CA 92354, at a price of $25.00.

Announcements

NOTICE OF MEETINGS

Academy of Operative Dentistry

Annual Meeting: 18 - 19 February 1988
Westin Hotel

American Academy of Gold Foil Operators

Annual Meeting: 8 - 9 October 1987
University of Colorado
Denver, Colorado

The annual meeting of the American Academy of Gold Foil Operators, to be held this year at the University of Colorado, promises to be outstanding. Clinical demonstrations of a variety of cavity classifications will be demonstrated by the members. The theme for the lecture series is "The Development of Excellence in Dentistry." Entertainment and good fellowship is to be the key for the Thursday evening banquet.

This meeting promises to be one of the best. Plan now to attend and make your reservations early. For more information about the meeting and registration procedures please contact:

Dr Ralph A Boelsche
Secretary-Treasurer
American Academy of Gold Foil Operators
2514 Watts Road
Houston, TX 77030

Silver Anniversary for George M Hollenback Seminar

The George M Hollenback Operative Dentistry Seminar celebrated its 25th anniversary at Beckley, West Virginia, in a three-day meeting, April 30, May 1 and 2, 1987.

Honored guests were Drs Nelson Rupp and Fred Eichmiller, both of the National Bureau of Standards, Bethesda, Maryland, and Rear Admiral Julian J Thomas (DC) USN (ret), chairman of the Department of Operative Dentistry, Northwestern University, Chicago.

As founders of the Seminar, Drs José E

Medina, D E Neil, and Paul H Loflin were honored during the Friday banquet with Revere silver bowls. They were also presented with lapel pins by Dr David Bridgeman, who had made them, using as his model the American Academy of Gold Foil Operators Key.

Current officers of the Seminar are: president, Glenn Birkitt (Leesburg, Va); secretary-treasurer, Joel M Wagoner (Beckley, WVa); director, José E Medina (Gainesville, Fla); and assistant director, Paul H Loflin (Beckley, WVa).

Clinical operations featuring compacted gold and cast gold restorations comprised the theme of this year's meeting.

Symposium: "Criteria for Placement and Replacement of Dental Restorations"

An international symposium sponsored by the University of Florida, chaired by Drs Ken Anusavice and Ivar Mjör, will be held at Lake Buena Vista, Florida, October 19-21.

The objective of the symposium is to assess existing research data to develop guidelines for the standardization of clinical decisions with respect to preventive therapy, diagnosis of caries associated with restorations, analysis of caries progression, and management of defective restorations. Topics will include reliability of caries diagnosis, bacterial leakage vs microleakage, classification of patient risk, variability of the decision-making process, pulpal response to dental materials and micro-organisms, material allergies, assessment of restoration quality, criteria for selection of dental materials, insurance considerations, and an analysis of cost vs longevity of sealants, preventive resins, composites, amalgams, cast prostheses, resin-bonded bridges, and PFM units. A quality evaluation plan of the California Dental Association will be considered as a potential model for establishing preventive and restorative criteria.

There will be 25 internationally recognized speakers presenting 30-minute review papers followed by a 10-minute discussion period.

For more information concerning fees and registration contact:

Dental Continuing Education
University of Florida
Box J-417, JHMHC
Gainesville, FL 32610

Clinical and Oral Examinations: The American Board of Operative Dentistry

The annual clinical and oral examinations for candidates being examined by the board will be held in Seattle, Washington, from 14 - 16 September at the University of Washington. Candidates, having previously had their credentials approved and having successfully completed the written examination, upon submission of their clinical cases are eligible to challenge the clinical and oral examinations.

Upon the successful completion of all phases of the examination process, the candidate achieves the status of board certified.

All correspondence related to applications, dates, sites, and time of examinations, as well as general inquiries and completed applications, should be addressed to:

Dr James V Gourley
Secretary-Treasurer
12238 Olympic View Road N W
Silverdale, WA 98383

Annual World Dental Congress Federation Dentaire Internationale

October 24 - 30, 1987
Buenos Aires Sheraton Hotel
Buenos Aires, Argentina

For information concerning this meeting, its program content, the opportunity to present, registration, and other matters please contact:

FDI Secretariat
Meon House, Petersfield
Hampshire, GU 32 3JN
United Kingdom

Call for Papers

The Scientific Session of the Academy of Dental Materials welcomes poster presentations for interested participants on all areas of dental materials research. The European-style poster session is planned as an afternoon event during the Academy's annual meeting in Chicago on 19 February 1988.

For information on the meeting and papers, call 312-908-6887 or 312-647-9570.

INSTRUCTIONS TO CONTRIBUTORS

Correspondence

Send manuscripts and correspondence about manuscripts to the Editor, David J Bales, at the editorial office: OPERATIVE DENTISTRY, University of Washington, School of Dentistry SM-57, Seattle, WA 98195, USA.

Exclusive Publication

It is assumed that all material submitted for publication is submitted exclusively to *Operative Dentistry.*

Manuscripts

Submit the original manuscript and one copy; authors should keep another copy for reference. Type double spaced, including references, and leave margins of at least 3 cm (one inch). Supply a short title for running headlines. Spelling should conform to *Webster's Third New International Dictionary,* unabridged edition, 1971. Nomenclature used in descriptive human anatomy should conform to *Nomina Anatomica,* 5th ed, 1983; the terms 'canine', 'premolar', and 'facial' are preferred but 'cuspid', 'bicuspid', and 'labial' and 'buccal' are acceptable. SI (Système International) units are preferred for scientific measurement but traditional units are acceptable. Proprietary names of equipment, instruments, and materials should be followed in parentheses by the name and address of the source or manufacturer. The editor reserves the right to make literary corrections.

Tables

Submit two copies of tables typed on sheets separate from the text. Number the tables with arabic numerals.

Illustrations

Submit two copies of each illustration. Line drawings should be in india ink or its equivalent on heavy white paper, card, or tracing vellum; any labeling should be on an extra copy or on an overleaf of tracing paper securely attached to the illustration, not on the illustration itself. Type legends on separate sheets. Photographs should be on glossy paper and should be cropped to remove redundant areas. For best reproduction a print should be one-third larger than its reproduced size. Maximum size of figure is 15x20 cm (6 x 8 inches). The cost of color plates must be met in full by the author. On the back of each illustration, near the edge, indicate lightly in pencil the top, the author's name, and the number of the figure. Type legends on a separate sheet. Where relevant, state staining techniques and the magnification of prints. Obtain written consent from holders of copyright to republish any illustrations published elsewhere.

References

Arrange references in alphabetical order of the authors' names at the end of the article, the date being placed in parentheses immediately after the author's name. Do not abbreviate titles of journals; write them out in full. Give full subject titles and first and last pages. In the text cite references by giving the author, and, in parentheses, the date, thus: Smith (1975) found . . .; or, by placing both name and date in parentheses, thus: It was found . . . (Smith & Brown, 1975; Jones, 1974). When an article cited has three authors, include the names of all of the authors the first time the article is cited; subsequently use the form (Brown & others, 1975). Four or more authors should always be cited thus: (Jones & others, 1975). If reference is made to more than one article by the same author and published in the same year, the articles should be identified by a letter (a, b) following the date, both in the text and in the list of references. Titles of books should be followed by the name of the place of publication and the name of the publisher.

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