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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, book reviews, letters, and classified ads also are published.

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GUEST EDITORIAL

The Academy: A New Era

The launch of the Academy of Operative Dentistry in 1972 triggered a rapid, sustained growth in membership and early international recognition. In its twenty-sixth year, the Academy, with a 1200-strong membership, heralded a new era by making constitutional provision for international sections. A few months on, the European Section of the Academy (ESAOD) has been established, and promising symbiotic relationships are burgeoning across Europe.

Throughout Europe there is an enormous untapped wealth of experience and expertise. In addition, recent changes in the political map of Europe, including the former USSR, have created a unique challenge to organizations such as the Academy. How better to promote the aims and objectives of the Academy than by facilitating access to emerging knowledge and to share experience with colleagues previously deprived of such opportunity?

The newly formed European Section is being fashioned to complement the traditional activities of the Academy and to provide a pan-European organization for colleagues with interests in operative dentistry. Further purposes of the ESAOD will include a source of reference for matters pertaining to operative dentistry in Europe; the promotion of relevant education, training, and research; action to increase and give a wider geographical circulation to *Operative Dentistry* as the journal of the Academy; and to heighten the awareness of operative dentistry as one of the cornerstones of dentistry.

Regarding the arrangements for the running of the ESAOD, these are set out in detail in the bylaws prepared and approved as part of the application to the Academy to form the European Section. In short, elected officers and two members-at-large will be responsible for the affairs and activities of the ESAOD, with one of the office-bearers representing the European Section on the executive council of the Academy. Apart from an annual meeting of the ESAOD to be held in different venues around Europe, it is intended to establish a newsletter and to begin to compile a database on matters pertaining to operative dentistry in Europe. The activities of the European Section must be largely funded by ESAOD dues, but with initial pump-priming from the Academy.

The immediate priority of the new European Section is its inaugural annual meeting, which is being held 30 April through 2 May 1998 in association with the 1998 meeting of the Accademia Italiana di Conservativa (AIC) in Riva del Garda, Italy. In addition to a full-day program of presentations by international speakers, a poster session, and a gala dinner, delegates may attend two half-day sessions of the AIC meeting to be conducted in English.

Tentative plans have been made to hold the 1999 meeting of the ESAOD in Munich, and in 2000 the European Section plans to join forces with the French Society of Adhesive Dentistry, the German Society of Operative Dentistry, the Italian Academy of Conservative Dentistry, the Spanish Association of Operative Dentistry, the Swedish Cariology Association, and the Swiss Society for Preventive and Restorative Dentistry in running what may prove to be the largest-ever conference devoted to operative dentistry. This conference, "ConsEuro 2000: Today's Approach to Tomorrow's Challenges," is to be held 11-13 May 2000 in Bologna under the auspices of AIC.

It need hardly be said that the new European Section will flounder without members. All those in Europe with interests and responsibilities in the field of operative dentistry are therefore encouraged to join and contribute to the Academy and, in turn, ESAOD. Operative dentistry in Europe, as elsewhere in the world, lacks specialty status, and it is therefore all the more important that the discipline is coherent, focused, and determined to maintain its standing through education, training, and research. Operative dentistry will remain central to everyday clinical practice, and in the interests of the patients it serves and dentistry in general, the Academy and now its European Section must succeed in its mission. Such success is as much, if not more, in the hands of the members rather than the few who drive the administration of the organization. As a consequence, if you have concerns for operative dentistry, help to address these by membership and active participation in the Academy. For those resident in Europe the challenge is all the greater, with the new European Section of the Academy awaiting your support.

NAIRN H F WILSON
President-Elect, ESAOD

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ORIGINAL ARTICLES

Effect of Home-Use Fluoride Gels on Resin-modified Glass-Ionomer Cements

W A EL-BADRAWY • D McCOMB

Clinical Relevance
Resin-modified glass ionomers show improved resistance to APF gels when compared to conventional glass ionomers.

SUMMARY

Acidic fluoride gels have been found to significantly damage conventional glass-ionomer cements. In this study the effect of acidulated phosphate fluoride (APF) and neutral fluoride gels on the recently introduced resin-modified glass ionomers and a polyacid-modified composite resin (Variglass) was studied using scanning electron microscopy (SEM). Five materials were examined: Photac-Fil, Fuji II LC, Vitremer, Variglass, and Ketac-Fil (control). Groups of five specimens of each material were treated for 24 hours with one of the following: 1) distilled water, 2) neutral fluoride gel, 3) APF gel. Surface microstructure of treated specimens was examined using SEM, and microphotographs were evaluated using a three-point scale. APF was found to have a deleterious effect on all examined materials, while minimal effects resulted from the neutral fluoride gel compared to the control group.

Although showing greater resistance to the APF gel than conventional glass-ionomer cements, resin-modified glass-ionomer materials revealed characteristic immersion and erosion behavior, substantiating their differentiation from a hybrid material containing a preponderance of resin.

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INTRODUCTION

Glass-ionomer cements are clinically accepted preventive restorative materials. First introduced as a direct restorative material in 1972 by Wilson and Kent, they provide a tooth-colored, fluoride-releasing material that bonds chemically to both enamel and dentin (Thornton, Retief & Bradley, 1986; Powis & others, 1982). Such properties, combined with caries inhibition, have made glass-ionomer cements particularly useful where cariostatic action is needed clinically, i e, in the caries-prone patient and in the treatment of root decay. Conventional glass-ionomer restorative materials are, however, still essentially cements and as such have several inherent shortcomings: 1) They have a short working time and a long setting and maturation time; 2) They show consistent sensitivity to dehydration, especially before maturation; 3) They are susceptible to early moisture contamination; and 4) They show brittle behavior. However, with knowledgeable handling, good longevity has been documented (Teo, 1986; Walls, Murray & McCabe, 1988; Knibbs, 1987 & 1988).

The recent introduction of resin-modified glass ionomers by Antonucci and Stansbury (1989) and

their further development by Mitra (1991) have overcome many of these shortcomings. Some of these new materials involve novel polyacrylic (polycarboxylic) acid polymer chains grafted with pendant methacrylate groups. Improved physical properties and photopolymerization capabilities have led to increasing clinical acceptance of resin-modified glass-ionomer materials in recent years (Chen, 1993; Kitamura, Aoyama & Miyazaki, 1993; Nathanson & Buithieu, 1993). They have shown less gap formation in vitro than conventional glass ionomers and better adaptation and adhesion to dentin (Sidhu, 1994; Pierik, Gartner & Mitra, 1993; El-Badrawy & McComb, 1993; Tosaki & Hirota, 1994). The pattern of fluoride release has been found to be equivalent in both true resin-modified and conventional glass ionomers (Seppa, Korhonen & Nuutinen, 1995; Momoi & McCabe,1993; Griffin, Donly & Erickson, 1992). Little research has been done, however, to investigate their resistance to dissolution.

In a recent clinical study that used conventional glass-ionomer cements for treatment of postradiation caries, restorations showed evidence of degradation within 6 months when using a mildly acidic (pH 5.8) home-use sodium fluoride gel as a preventive measure (Wood, Maxymiw & McComb, 1993). El-Badrawy, McComb, and Wood (1993) studied the effect of different home-use fluoride gels on conventional glass ionomers in vitro and reported significant surface disintegration with the acidulated gels. Neutral gels showed little effect in this in vitro model. Kramer and others (1986) also reported that APF caused the greatest conventional glass-ionomer dissolution compared to other fluoride gels. When Akselsen, Afseth, and Rolla (1987) and Billington, Williams, and Strang (1987) examined the effect of 2.0% neutral sodium fluoride on two conventional glass-ionomer cements, their results were equivocal. Akselsen and others (1987) reported visual disintegration of two of the materials, while Billington and others (1987) reported no visual disintegration on the same glass-ionomer cements.

The purpose of this study was to investigate the resistance to dissolution by two home-use fluoride gels on restorative materials that combine resin and glass-ionomer technology. In order to further characterize these novel materials, erosion behavior was compared qualitatively and quantitatively with that of a conventional glass-ionomer restorative material.

METHODS AND MATERIALS

The fluoride gels used in this study were: Neutragel (Germiphene Corp, Brantford, Ontario, Canada), a neutral sodium fluoride 0.5%, and Karigel (Lorvic, St Louis, MO 63134) an acidulated phosphate fluoride (APF) 0.5%.

Glass-Ionomer Cements and Polyacid-modified Composite Resin Used in the Study

Brand Name	Code	Manufacturer
Ketac-Fil	KT	ESPE, Seefeld/Oberbay, Germany
Photac-Fil	PH	ESPE
Fuji II LC	FJ	GC Corp, Tokyo, Japan
Variglass	VR	L D Caulk/Dentsply, Milford, DE 19963
Vitremer	VT	3M Dental Products, St Paul, MN 55144

The materials tested are listed in the table. Seventy-five class 5 cavity preparations, each measuring 2 x 3 mm x 1.5 mm in depth, were prepared in extracted permanent teeth. They were washed, lightly dried, and groups of 15 randomly chosen preparations were restored with the test materials. For all materials proportioning and mixing were completed according to the manufacturers' instructions. The restorative material was applied using a syringe in order to minimize air entrapment. For the photopolymerized materials each restoration was cured for 40 seconds using a light-curing unit (Heraeus Kulzer Inc USA, Irvine, CA 92718). Finishing was performed with multifluted #7901 burs and polishing was carried out using Sof-Lex disks (3M Dental Products), keeping the restoration surface wet. Specimens were then stored in water for 24 hours at 37 °C. The Ketac-Fil control group preparations were restored utilizing a precontoured aluminum cervical matrix and left undisturbed for 8 minutes. Following removal of the matrix the restoration surface was protected using the manufacturer's recommended varnish (ESPE varnish). Finishing and polishing for this group was carried out after 24 hours using the above armamentarium.

Each of the above groups was further subdivided into three groups of five teeth each. One subgroup was stored in distilled water as a control. The other two subgroups were treated by immersion in one of the above two fluoride gels. The treatment was carried out for 8 hours daily for a total of 3 days, which is equivalent in time to 1 year of 4 minutes of daily patient use. Each tooth was treated with 20 ml of gel in a separate plastic bottle. At the end of each day, specimens were taken out, rinsed under running water for 1 minute, patted dry, and placed in bottles containing 20 ml distilled water. Throughout the

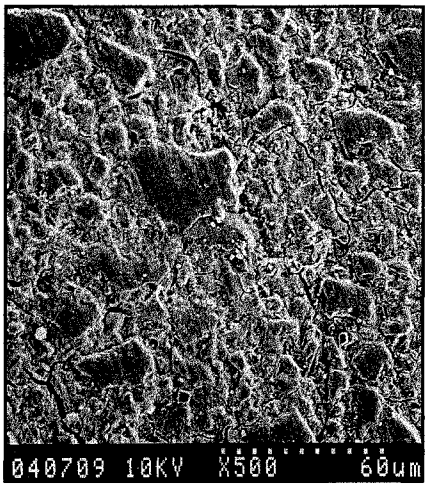

Figure 1A. Ketac-Fil control stored in distilled water

Figure 1B. Ketac-Fil stored in Neutragel

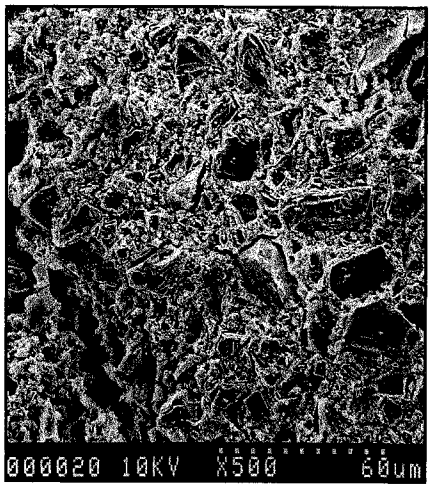

Figure 1C. Ketac-Fil stored in APF

treatment period, teeth stored in gel were manually shaken every hour in order to prevent chemical equilibrium around the restoration surface. Upon completion of the treatment, all specimens were washed, dried, gold sputtered, and examined using scanning electron microscopy. A representative image was collected from each of the different specimens at X500 and X1000 magnification.

SEM micrographs of the restoration surface were rated by two evaluators. Any visual degradation of the glass particles was rated according to the same criteria used in a previous study (El-Badrawy & others, 1993), with the addition of a new category (0.5): (0) particles appear intact with no visible etched surface; (0.5) mild effect with minimal surface pitting; (1) moderate pitting and slight cracking of the glass particles; (2) severe cracking and pitting present. The rating for the glass-ionomer matrix was carried out as follows: (0) surface appears undisturbed, glass particle level with and embedded in matrix; (0.5) mild degradation with disturbed matrix and minimal changes; (1) moderate degradation with irregular surface, particles partially protruding and a limited number of voids present; (2) severe degradation with little or no matrix around particles and a considerable number of voids present.

Statistical analysis for the resulting nonparametric data was carried out using the Kruskal-Wallis one-way ANOVA and the Mann-Whitney rank test.

RESULTS

Figure 1 shows typical micrographic representations of the effect of the three different treatments

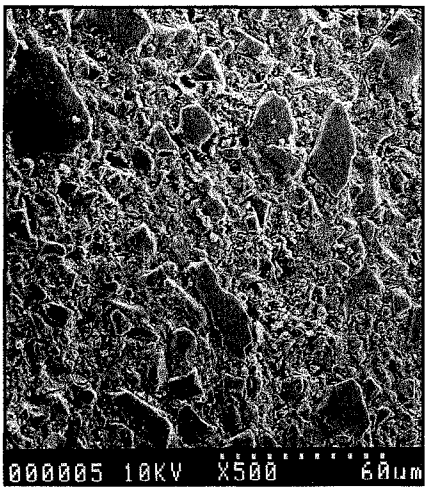

Figure 2A. Photac-Fil control stored in distilled water

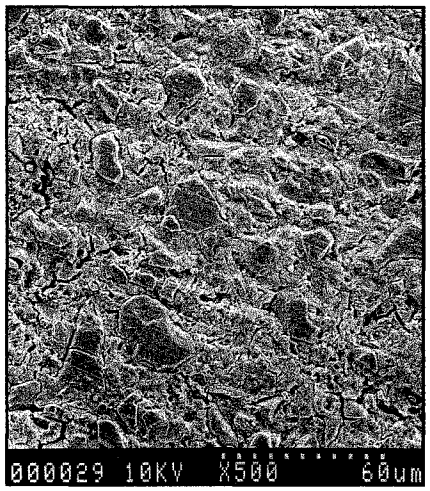

Figure 2B. Photac-Fil stored in Neutragel

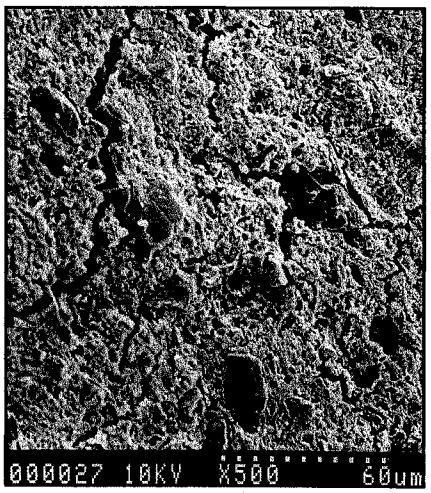

Figure 2C. Photac-Fil stored in APF

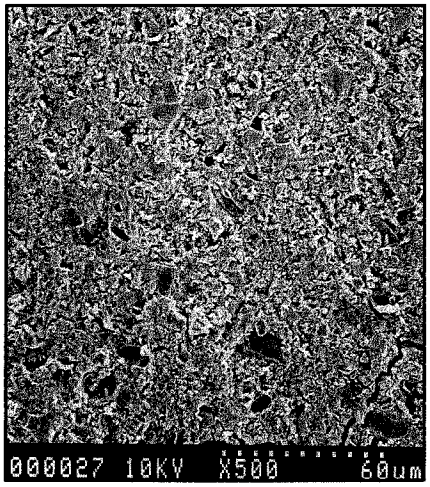

Figure 3A. Vitremer control stored in distilled water

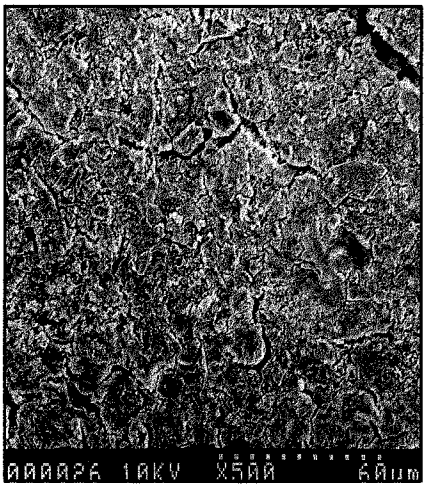

Figure 3B. Vitremer stored in Neutragel

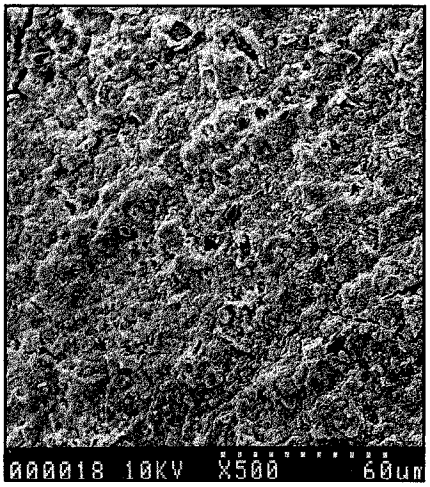

Figure 3C. Vitremer stored in APF

on Ketac-Fil. Figure 1A shows the effect of storage in distilled water. The surface was smooth and intact and the matrix was undisturbed, except for dehydration cracks that ran through the matrix and alongside the larger glass particles. Ketac-Fil restorations treated with Neutragel showed minimal evidence of change (Figure 1B), whereas Ketac-Fil restorations treated with APF gel (Figure 1C) revealed protruding particles and voids as a result of matrix dissolution. Particles were also irregularly pitted and etched. Kruskal-Wallis one-way ANOVA confirmed that Ketac-Fil matrix degradation with APF was statistically significant, while Neutragel effect was not significantly different from that of water ($P = 0.008$). The effect of different solutions on Ketac-Fil particles was not significant ($P = 0.37$).

Figure 2A shows a representative micrograph of Photac-Fil stored in distilled water. Particles showed morphological similarity to those of Ketac-Fil, whereas the matrix showed less susceptibility to dehydration. Photac-Fil treated with Neutragel (Figure 2B) was essentially comparable to the control specimens except for the presence of some crazing. Figure 2C is a micrograph of a Photac-Fil restoration treated with APF gel. The matrix was distinctly altered and appeared swollen with numerous voids and cracks. The qualitative ranking of the matrix changes in the APF group was significantly different from those of both the Neutragel and the control ($P = 0.04$). Statistical analysis showed no significant difference in particle degradation among the three groups ($P = 0.31$).

Vitremer specimens stored in water revealed a flat surface with minor dehydration cracks (Figure 3A). The matrix of Vitremer specimens treated with Neutragel was uneroded, but the surface showed more dehydration cracks than the control (Figure 3B). A trend for mild matrix expansion with Neutragel was observed, but was not statistically significant using a qualitative rating scheme. The treatment with APF gel caused swelling of the Vitremer matrix as shown by the irregular surface with rounded contours and submerged and/or enveloped particles (Figure 3C). Higher magnification revealed that the particles were loosely attached, partially covered, and held by the elevated matrix (Figure 4). This effect of APF gel on the Vitremer matrix was significantly different from that of both Neutragel and water ($P = 0.02$). The effect of the three treatments on the filler particles was not statistically different.

Fuji II LC specimens treated with Neutragel (Figure 5B) showed significant matrix changes ($P = 0.03$), as well as slight particle changes when compared with the control group (Figure 5A). Specimens treated

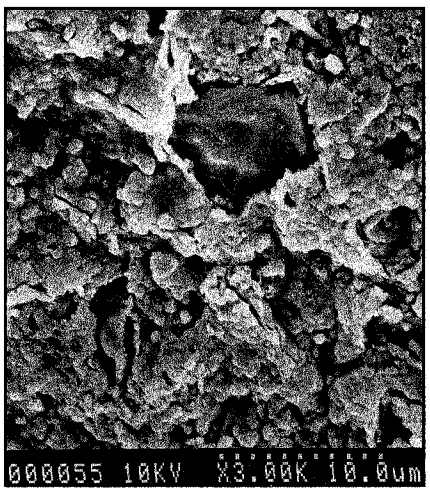

Figure 4. Example of matrix swelling following immersion in APF gel

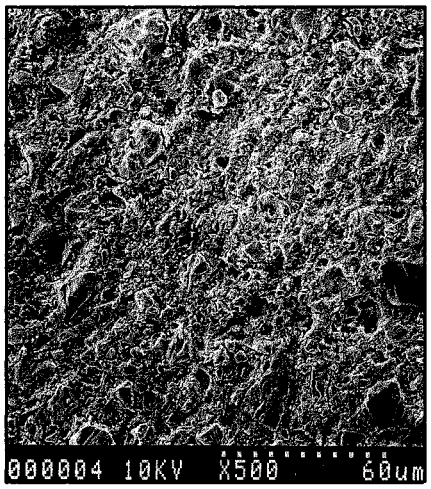

Figure 5A. Fuji II LC control stored in distilled water

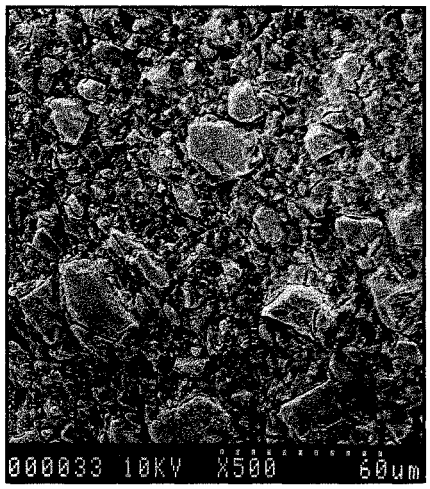

Figure 5B. Fuji II LC stored in Neutragel

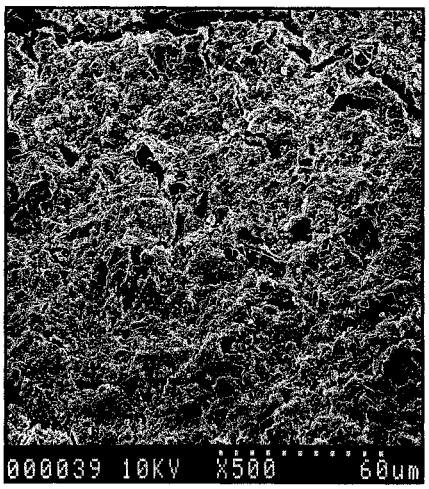

Figure 5C. Fuji II LC stored in APF

with APF gel showed two different surface phenomena, the first being a mildly affected surface (Figure 5C) similar to changes shown with Vitremer. The second phenomenon was referred to as "selective degradation" and was observed only in this group. "Selective degradation" was used to describe discrete, markedly eroded patches present on the otherwise more mildly affected surface, as shown in Figure 6. These changes, which were difficult to rank qualitatively, were also significantly different from the control at the same level of significance as Neutragel treatment. The effect of the neutral fluoride gel on the glass particles showed marginal statistical significance from that of water ($P = 0.05$).

Unlike the other materials, Variglass specimens stored in water showed a relatively smooth surface free from dehydration cracks (Figure 7A). Neutragel had no significant effect ($P = 0.12$) on the erosion of Variglass matrix (Figure 7B). Following treatment with APF gel, a honeycomb appearance of a flat matrix full of voids was evident. Small glass particles had been totally eroded and larger glass particles were etched and cracked (Figure 7C). The glass particles seemed to be affected more than the matrix in this material. This particle degradation resulting from both APF gel and Neutragel treatment was significant compared to the control group ($P = 0.001$).

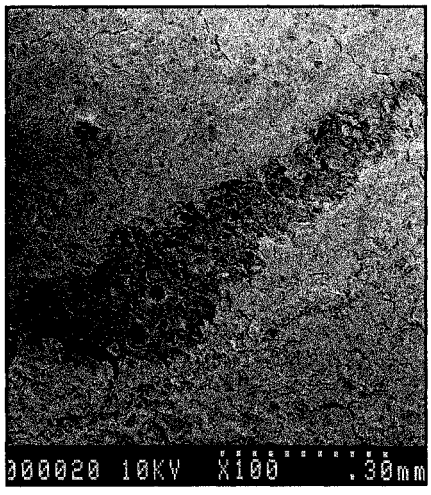

Figure 6. Fuji II LC showing an area of "selective degradation"

DISCUSSION

The trend demonstrated by APF gel in this study confirms the results of a previous study conducted on conventional glass-ionomer cements (El-Badrawy & others, 1993). Both studies indicate that APF has the most damaging effect of the studied solutions on all experimental materials. However, in the present study, the effect of APF gel on resin-modified glass-ionomer cements manifested itself in a new pattern. That is :

a) Matrix dissolution, which was detected peripheral to the glass particles, leading to a "halo" appearance surrounding the glass particles (Figures 8A,B). It is believed that this "halo" effect could be due to dissolution of the siliceous hydrogel layer. It has been reported that in the final set structure of conventional glass ionomers the glass particles are sheathed by a siliceous hydrogel layer (Smith, 1994; Mitra, 1994). Since true resin-modified glass ionomers are purported to undergo an acid-base reaction as well as photopolymerization (Mitra, 1994), a siliceous hydrogel layer or reaction zone would be expected to a greater or a lesser extent sheathing the glass particles. In some of the commercially available resin-modified glass-ionomer systems, the glass-ionomer

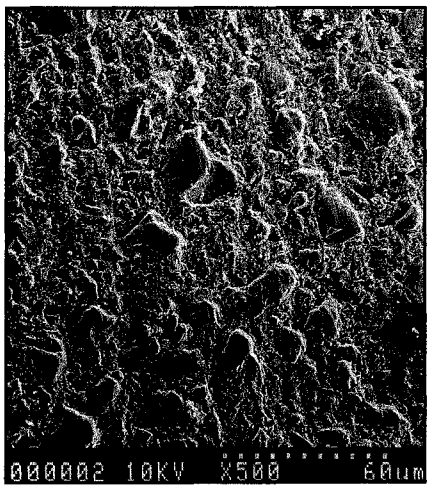

Figure 7A. Variglass control stored in distilled water

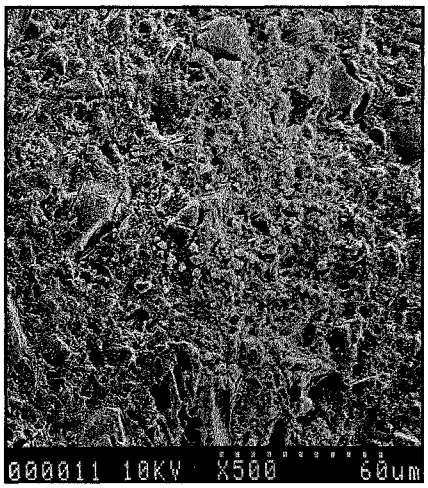

Figure 7B. Variglass stored in Neutragel

Figure 7C. Variglass stored in APF

component is limited and the glass particles act as fillers only, with little acid-base reaction taking place. The closer the system is to a true glass ionomer the more particle involvement in the reaction (Gasser, 1994). In fact, the presence of a "halo" in this study can be considered proof of the acid-base reaction taking place in the resin-modified glass-ionomer materials that exhibited this finding. Although the siliceous hydrogel layer is present in the conventional glass-ionomer cements, the "halo" appearance was not very obvious in the APF-treated group due to the generalized dissolution of the matrix. Because of the improved resistance of the resin-modified glass-ionomer resinous matrix to dissolution and solubility, the siliceous hydrogel layer was the first to erode, leading to the "halo"-like appearance in this experiment; it can be considered the weakest link in the system.

b) Generalized matrix changes that resulted in a swollen or expanded matrix appearance were detected in all of the resin-modified glass ionomers, with variable degrees of severity, except for the polyacid-modified composite resin,Variglass. Figure 4 shows this swelling in detail at a higher magnification. This is in agreement with Nicholson, Anstice, and McLean (1992), who reported that light-cured glass ionomers prepared with HEMA copolymers behave like hydrogels, and absorb water. In this study all the examined resin-modified glass-ionomer cements contained polyacrylic acid and HEMA (2-hydroxyethyl methacrylate), a hydrophilic monomer, which acts as a solvent and a polymerizable monomer. Nicholson

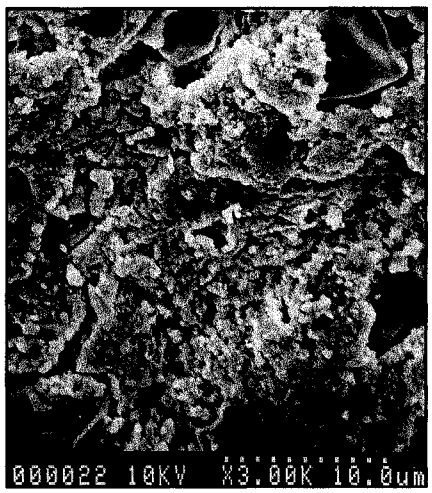

Figure 8A. Example of a halo-like appearance around glass particles of Fuji II LC treated with APF

Figure 8B. Example of a halo-like appearance around glass particles of Vitremer treated with APF

and Anstice (1994b) reported that because of the contrasting nature of these liquid components, there is a natural tendency for resin-modified glass ionomers to undergo phase separation while still liquid. This tendency for phase separation increases as the setting reaction proceeds, i e, as HEMA undergoes polymerization, it ceases to be water-soluble, which causes it to separate from the aqueous part of the formulation. In addition, as the acid-base reaction proceeds and the acid becomes more neutralized, more hydrophobic organic species become less soluble in the aqueous phase. Therefore the set product is expected to contain domains of different phases in its microstructure. Nicholson and Anstice (1994a) also reported that almost certainly the sites of these hydrophilic domains are the centers to which water migrates as it is absorbed.

Water uptake was also reported by Yap and Lee (1995) when negative values for water solubility were determined for resin-modified glass ionomers, compared to composites and conventional glass ionomers, implying an uptake of water into cement structure. Nicholson and others (1992) also reported that light-cured glass ionomers stored in water showed lower compressive strength and a change in their mode of failure. It is likely that the swollen appearance detected in this study was an early form of matrix degradation, which, when combined with aggravating factors such as a void or surface disturbance, could explain the "selective degradation" pattern mentioned above. The fact that controls of the resin-modified glass ionomer showed less expansion or swollen appearance was surprising, but this could be more evident with time. Nicholson and others (1992) reported that the weight increase due to water absorption was progressive with time.

The Variglàss matrix, on the other hand, did not show any signs of swelling, which could be due to the absence of HEMA from its liquid. Variglass liquid contains polyacrylic acid, VLC monomers, and PENTA (a polymerizable phosphoric acid ester). In fact, the absence of cracking from the Variglass matrix and the honeycomb appearance shown in Figure 7C following APF treatment was similar in appearance to that demonstrated by a composite resin used in our previous study (El-Badrawy & others, 1993). This verified that Variglass is a closer material to composite resins than to glass-ionomer cements. Burgess, Norling, and Summit (1994) also reported that Variglass relied primarily on photopolymerization to produce a usable material. For all these reasons Variglass is best categorized as a polyacid-modified composite resin, as suggested by McLean, Nicholson, and Wilson (1994).

It is important to acknowledge that solely visual examination may not fully reveal the extent of the changes occurring, which could affect the clinical integrity of the material in the oral milieu. Altered surfaces may be softened and more readily eroded under intraoral chemical and physical conditions with far more profound consequences in vivo.

CONCLUSIONS

1. Neutral sodium fluoride gel had little effect on the surface integrity of resin-modified glass-ionomer restorations under the conditions of this test.
2. Resin-modified glass-ionomer materials showed some improved resistance to APF gel over conventional glass ionomer; however, a specific pattern of erosion susceptibility was identified.
3. Resin-modified glass ionomers showed a tendency to absorb water and swell. This was particularly evident with APF gel, but was observed to a lesser extent with Neutragel.
4. A pattern of erosion behavior resembling that of resin composite was shown by the polyacid-modified composite resin, Variglass.

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A Study on the Radiopacity of Different Shades of Resin-modified Glass-Ionomer Restorative Materials

N MAROUF • S K SIDHU

Clinical Relevance
No significant difference in radiopacity was found among the various shades within three resin-modified glass-ionomer restorative materials.

SUMMARY

There are several resin-modified glass-ionomer restorative materials available to the dental profession today. The commercially available brands are presented in a range of shades. There is little information on their radiopacity and whether this varies with differences in shade. While the general radiopacity of various products may have been studied, only assumptions are available regarding their consistency between shades. The purpose of this study was to investigate if there were any significant differences in the radiopacity of the shades available within each commercial product. The products evaluated were Fuji II LC, Vitremer, and Photac-Fil. The optical densities of standardized radiographs of samples of these materials were determined and radiopacity values of materials expressed in millimeter equivalents of aluminum.

Of the three resin-modified glass-ionomer restorative materials tested, Fuji II LC was the most radiopaque and Photac-Fil the least. Fuji II LC and Vitremer showed radiopacity values equivalent to >2.5 mm and >1.5 mm aluminum respectively; Photac-Fil demonstrated very low radiopacity values (equivalent to <0.6 mm aluminum). Statistical analysis revealed that there was no significant difference in radiopacity among the shades within each of these brands.

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INTRODUCTION

Glass-ionomer cements were developed for dental use in the early 1970s (Wilson & Kent, 1972). Developments have led to the introduction of hybrid versions of this material that are light cured (Antonucci, McKinney & Stansbury, 1988; Mitra, 1988). These resin-modified cements are materials of conventional glass ionomer with a small addition of light-curing resin (Sidhu & Watson, 1995). Their advantages include a command set that enables easy clinical use, and good esthetic results. In addition, their fluoride-release property is a significant

characteristic that is beneficial for patients in the high-caries-risk category.

It is essential that restorative materials have appropriate radiopacity values in order to enable the operator to radiographically establish the contour of the restoration, its contact with adjacent teeth, marginal adaptation, interfacial gaps, and for detection of recurrent caries. In addition, adequate radiopacity aids in distinguishing normal tooth structure from the restorative material. According to the International Organization for Standardization (ISO) draft proposal on resin-modified cements (1994), if a manufacturer claimed that such a material was radiopaque, its radiopacity, as determined by a standard testing procedure, should be at least twice the same thickness of aluminum and not more than 0.5 mm below the value claimed by the manufacturer. Metal-based materials often show excellent radiopacity and are easily detected on radiographs. Polymeric materials, however, are often radiolucent, making them difficult to detect on radiographs, but the addition of fillers or use of radiopaque compounds improves this. In the glass-ionomer materials, the radiopacity can be achieved by the incorporation of elements such as strontium, barium, and zirconium (Smith, 1990). Unfortunately, reports on their radiopacity are lacking in the dental literature.

As with most other esthetic restorative materials, the resin-modified glass-ionomer cements are available in a variety of shades. These materials are presented mostly in shades based on the Vita (Vita Zahnfabrik, Bad Säckingen, Germany) shade guide system. A previous study showed that there was considerable variation in general radiopacity values between the different resin-modified cements tested (Sidhu & others, 1996). However, differences in the radiopacities of various shades within the same resin-modified glass-ionomer material have not been established. It is not known if the pigmentation used to produce the various shades results in significant differences within a product. Sidhu and others (1996) showed that two of three resin-modified products were more radiopaque than enamel and dentin. While it is important that each product has sufficient radiopacity, this study was initiated to evaluate if there were any differences among shades within each of three resin-modified glass-ionomer restorative materials as well as among products.

METHODS AND MATERIALS

The restorative resin-modified glass-ionomer materials evaluated in this study are listed in Table 1. Five standardized specimens of each material were made according to the individual manufacturer's instructions. The mixed materials were packed into stainless steel ring molds, each with an internal diameter of 10 mm and a height of 1 mm. The specimen preparation method followed previous studies (Shah & others, 1996; Sidhu & others, 1996). The materials were light cured for 40 seconds each and coated with the appropriate gloss provided by the individual manufacturer. The specimens were stored in moist conditions until the radiographic part of the experiment was conducted.

Radiographs were taken with a target-film distance of approximately 300 mm using a cardboard extension to the cone of the x-ray machine. Prior to taking radiographs of the specimens, a series of known exposures was given to dental x-ray occlusal films (Kodak Ultraspeed DF 50, size 4, Eastman Kodak Company, Rochester, NY 14650). A characteristic curve was obtained by plotting the photometric density of the film at each step against the logarithm of the exposure. This ensured that the exposure to be used (i e, steepest portion) was such that there was optimum radiographic contrast between the specimens used.

The dental x-ray unit (Heliodent-MD, Siemens, Bensheim, Germany) was set at 70 kV, a current of 7 mA, with an exposure time of 0.25 seconds. This was to give a radiographic density reading of approximately 2 (including base and fog) for the exposed and processed film under the 1 mm-thick section of the aluminum stepwedge used (Protex Ten-Step Aluminium Stepwedge, Everything X-ray Ltd, Watford, England). The use of an aluminum stepwedge in radiopacity studies is fairly standard and is described in relevant ISO documents (1994). A pilot study was carried out to ascertain the angulation of the anode and thus ensure that the film and aluminum stepwedge were placed in the appropriate alignment. The specimens were placed directly on the film packets. A 10 mm lead block was used to ensure

Table 1. Resin-modified Glass-Ionomer Restorative Materials Tested and Their Respective Shades

Proprietary Name	Manufacturer	Presentation	Shades Tested
Fuji II LC	GC Dental Corp, Tokyo, Japan	capsulated	A1, A2, A3.5, A4, B2, B3, B4, C2, D2
Vitremer	3M Dental Products, St Paul, MN 55144	hand-mixed	A3, A4, C2, C4
Photac-Fil	ESPE GmbH, Seefeld/Oberbay, Germany	capsulated	A1, A2, A3, A3.5, B2, B3, C4, DBO

Table 2. Relation of Thickness of Aluminum to Relative Radiographic Density (n = 5)

Aluminum Thickness	Mean Radiographic Density	
	Gross	Net
1	1.69	1.48
2	1.40	1.19
3	1.19	0.98
4	1.01	0.80
5	0.88	0.67
6	0.76	0.55
7	0.67	0.46
10 mm lead	0.21	

Table 3. Mean Radiopacity of Materials Expressed in Equivalent Thickness of Aluminum (n = 15)

Material	Shade	Mean Radiopacity Value in Equivalent Thickness of Aluminum (mm)	SD
Fuji II LC	A1	2.61	0.23
	A2	2.75	0.34
	A3.5	2.66	0.40
	A4	2.89	0.14
	B2	2.81	0.16
	B3	2.52	0.41
	B4	2.77	0.38
	C2	2.59	0.07
	D2	2.59	0.43
Vitremer	A3	1.61	0.20
	A4	1.52	0.18
	C2	1.53	0.09
	C4	1.59	0.25
Photac-Fil	A1	0.50	0.12
	A2	0.43	0.09
	A3	0.44	0.83
	A3.5	0.21	0.15
	B2	0.17	0.12
	B3	0.36	0.12
	C4	0.54	0.12
	DBO	0.38	0.18

that a small section of the occlusal films had no exposure, and the photometric reading from this area was used to work out the base and fog of the processed film.

An occlusal dental film was used each time. Due to space limitations, a maximum of five specimens were placed adjacent to the step-wedge in the middle of the film beneath the center of the x-ray beam. The materials were radiographed by laying them out in five groups. The first group consisted of Fuji II LC shades A1, A2, A3.5, and A4; the second group consisted of Fuji II LC shades B2, B3, B4, C2, and D2. The third group comprised Vitremer shades A3, A4, C2, and C4; the fourth group of Photac-Fil shades A1, A2, A3, and A3.5, while the last group consisted of Photac-Fil B2, B3, C4, and DBO. A total of five radiographic films were taken of each group. The films were processed in an automatic developer (P10, Hope Industries, Letchworth, England). For consistency in processing the films, all the specimens were exposed and processed on the same day in the same machine.

A photographic densitometer (Melico/Photolog, B/W Transmission Densitometer, Model TDX, Medical and Electrical Instrumentation Ltd, London, England) was used to take readings of the radiographic image of the specimens, each step of the stepwedge, and the unexposed part of the film. Three readings were taken for each film of each material, and the mean subsequently calculated. The net radiographic density values were derived from the following equation:

Net radiographic density = (Gross radiographic density) - (base + fog).

Graphs were plotted for log net radiographic density of the aluminum steps versus thickness of aluminum (mm) for each group. These gave straight line plots from which the mean net radiographic density values of the materials and their equivalents related to thickness of aluminum were derived (Table 2). The results of gross radiographic density of the materials were statistically analyzed by analysis of variance followed

by Bonferroni tests to compare the shades within each material, with the level of significance set at the $P < 0.05$ level.

RESULTS

The mean radiographic density of the aluminum steps is given in Table 2. Table 3 lists the mean radiographic densities of the shades of the materials investigated in terms of equivalent thicknesses of aluminum. Of all of the materials tested, Fuji II LC was the most radiopaque material and Photac-Fil was the least radiopaque (Table 3). In general, Fuji II LC showed radiopacity values equivalent to >2.5 mm aluminum while the values for Vitremer were >1.5 mm aluminum; Photac-Fil demonstrated very low radiopacity values, equivalent to <0.6 mm aluminum.

Statistical analysis (analysis of variance) indicated that all the materials had significantly different radiographic densities from each other ($P < 0.05$). However, further analysis (Bonferroni test) revealed that there were no significant differences in radiopacity values among the shades within each material.

DISCUSSION

It is very important that restorative materials possess radiodensities that permit the clear radiographic detection of early caries. This also helps distinguish them from tooth structure, to detect faulty contours, voids, and marginal gaps (Curtis, von Fraunhofer & Farman, 1990; Akerboom & others, 1993). The radiopacity values ought to be higher than enamel and dentin to display the material with a greater degree of distinction. The image contrast between the restorative material and the adjacent tooth structure is also an important factor in the detection of recurrent caries (Matteson & others, 1989). Although a material may be advertised as being radiopaque, it does not mean that it is easily visible and distinguishable on a radiograph. The radiopacity of dental restorative materials has been reported to be highly variable (Williams & Billington, 1990), as was also seen from the results of our study. It would seem to benefit the clinician if there is consistency within a product in terms of its radiopacity. The purpose of this study was not only to compare the radiopacity among various resin-modified cements, but also to investigate if differences existed among shades in any of the three commercial products tested.

Glass-ionomer materials have inherently low radiopacity values when compared to metallic restorative materials. The powder portion of the glass-ionomer cement contains a large amount of aluminum and silicon compounds, both of which have low radiopacity values, rendering the material generally radiolucent (Matsumura & others, 1993). The incorporation of elements like strontium, barium, and zirconium helps achieve a measure of radiopacity (Smith, 1990). Obviously, differences in formulation and manufacture give rise to variations in the radiopacity of products available. It was not previously known if the modification of colorants or pigments within a product affected its radiopacity. The results of this study suggest that the pigments do not significantly alter a product's radiopacity.

Control group specimens were thought to be unnecessary, since the purpose of the investigation was to examine the variations within each product, rather than to establish the relative radiopacity or the radiopacity compared to tooth structure, which has been previously reported (Sidhu & others, 1996).

The use of a cone for making repetitive radiographs in the same position each time and from the same distance allowed comparisons to be made among densities of equal volumes of restorative materials within the same study. Unfortunately, not only differences in test methodology but also variability in terms of samples and testing conditions may preclude a comparison of radiopacity values among different studies, which may explain slight differences in mean radiopacity values compared to the same materials in a previous study (Sidhu & others, 1996).

In clinical practice other factors besides material radiopacity must be taken into account. For example, variations in thickness of materials may influence radiopacity. These variations in thickness of a material may still significantly influence the radiodensity (Prevost & others, 1990), particularly materials with low radiopacity (De Abreu, Tavares & Vierira, 1977). Nevertheless, it is important that the same materials do not vary in terms of properties. Our study indicated that this is the case with the radiopacity of different shades for the three materials tested.

CONCLUSIONS

The following conclusions may be made regarding the materials in this study:

1) There were statistically significant variations in radiopacity values among the materials tested;

2) Fuji II LC was the most radiopaque and Photac-Fil the least radiopaque material tested;

3) Within each of the three materials there was no significant difference among the shades ($P < 0.05$).

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Effects of Surface Treatments on Amalgam Repair

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Clinical Relevance
When repairing an existing amalgam restoration, roughening the surface with a #557 carbide bur yields higher repair strength than treating the surface with air abrasion of 50 µm aluminum oxide, Amalgambond Plus, or retentive undercuts.

SUMMARY

Dentists are faced with clinical situations that require the decision to replace or repair an amalgam restoration. The purpose of this study was to compare five amalgam repair techniques. Six groups of 15 amalgam beams each were fabricated by mechanical condensation of Tytin into an anodized aluminum split mold. Specimens were aged for 7 days prior to repair. Repaired specimens were stored for 7 days and thermocycled 500 times. Repair strength was measured by transverse strength testing in an Instron testing machine. Data were analyzed by a one-way ANOVA and a Student-Newman-Keuls test at the $P \leq 0.05$ level. The surface treatments were: Group A) intact beams, B) roughened with a #557 bur, C) air abraded with 50 µm aluminum oxide, D) retentive undercuts with a #33½ bur, E) Amalgambond Plus, and F) no treatment. The repair strength of the various experimental groups ranged from 7-18% of the intact specimens. The #557 bur-roughened group yielded statistically higher repair strengths than all other surface treatments, which were statistically equivalent to each other.

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INTRODUCTION

Dental amalgam continues to be one of the most widely used restorative materials in dentistry. Due to its ease of manipulation, adequate physical properties, proven longevity, and low cost, it remains the restorative material of choice in many clinical situations (Anderson & McCoy, 1993). Dentists are frequently faced with a clinical decision to replace or repair an amalgam restoration. These situations involve amalgam or cuspal fracture, inadequate marginal integrity, and inadequate interproximal contact (Terkla, Mahler & Mitchem, 1961; Hadavi & others, 1992), and most frequently occur soon after condensation, in which a marginal ridge of amalgam or interproximal contact is lost due to fracture (Bagheri & Chan, 1993; Brown & others, 1986). Repair of multisurface pin-retained amalgam restorations may be preferred when small cuspal or restoration fractures occur. The complete replacement of these large restorations is time consuming, technically difficult, and may be potentially damaging to the pulp (Gordon & others, 1987; Hibler & others, 1988).

An important factor in the quality of the amalgam repair is the strength of the joined amalgam surfaces. Many researchers have studied the repair strength of amalgam with conflicting results. Repair strengths ranged between 11% to 97% of intact samples, with most studies reporting repair strengths of approximately 50%. Berge (1982), Leelawat and others (1992), and Lacy, Rupprecht, and Watanabe (1992) recorded repair strengths as low as 11.5%, 13%, and 12% respectively for surface-roughened samples. Conversely, Jorgenson (1968) reported repair strengths of 97% for specimens ground on carborundum paper in the presence of a drop of mercury. Brown and others (1986) and Hadavi and others (1992) reported repair strengths as high as 84% and 79% respectively on carved or bur-roughened samples. Diefenderfer, Brown, and Reinhardt (1996) reported repair strengths of bur-roughened specimens equal to intact controls.

The wide range in results can be attributed to various factors affecting repair strength such as time of repair, use of a mercury-rich interface between the repair surfaces, effects of roughening the fractured segment, type of alloy used, and the use of adhesive resins. Each of these factors has been evaluated by researchers with little agreement among studies. Early repair (5-15 minutes) yielded the highest repair strengths in some studies (Terkla & others, 1961; Bagheri & Chan, 1993; Brown & others, 1986), but was not significantly better than late repairs (7-120 days) in others (Hibler & others, 1988; Jorgenson, 1968; Walker & Reese, 1983). The use of a mercury-rich amalgam mixture at the repair interface is a common repair technique (Cowan, 1983). This technique was evaluated, and significantly higher repair strength was found in some studies (Terkla & others, 1961; Jorgenson, 1968; Hornbeck, Duke & Norling, 1986), while others reported no significant increase over control samples without the use of mercury (Hibler & others, 1988; Erkes, Burgess & Hornbeck, 1990). Some investigators found spherical alloys to have higher repair strengths than lathe-cut and dispersed-phase alloys (Hadavi & others, 1991; Roeder, DeSchepper & Powers, 1991). Others failed to find a correlation between alloy type and increased repair strength (Hibler & others, 1988; Lacy & others, 1992). Research concerning the use of adhesive resins to facilitate amalgam repair has consistently found either no improvement in repair strength (Hadavi & others, 1991; Lacy & others, 1992) or a decrease in repair strength (Carr-Hosie & others, 1992; Roeder & others, 1991; Lacy & others, 1989). Leelawat and others (1992) were the only investigators to find a significant increase in repair strength utilizing resin adhesives.

The effect of roughening the surface of the existing amalgam is another factor that has been studied. Walker and Reese (1983) reported improved bond strengths after roughening the surface of the samples with a carbide bur prior to repair. Hadavi and others (1992) reported similar results after sample preparation with diamond and carbide burs. Roeder and others (1991) were the first to evaluate the effect of sandblasting on the bond strength of amalgam repairs utilizing an adhesive system. While no control samples were tested, sample groups air abraded with 50 μm aluminum oxide and treated with All-Bond (Bisco, Itasco, IL 60143) yielded consistently higher tensile bond strengths than those groups roughened with 120-grit silicon carbide paper and treated with All-Bond.

The singular effect of surface treatment with air abrasion on amalgam repairs has not been reported. The purpose of this study was to compare five different amalgam repair techniques.

METHODS AND MATERIALS

Specimen Preparation

To examine the effects of amalgam surface treatments on repair strength, six groups of 15 amalgam beams each were fabricated in an anodized aluminum split mold (Figure 1). Control specimens consisted of intact beams of amalgam fabricated in a mold measuring approximately 5 mm x 5 mm x 20 mm, while experimental specimens were fabricated in a mold

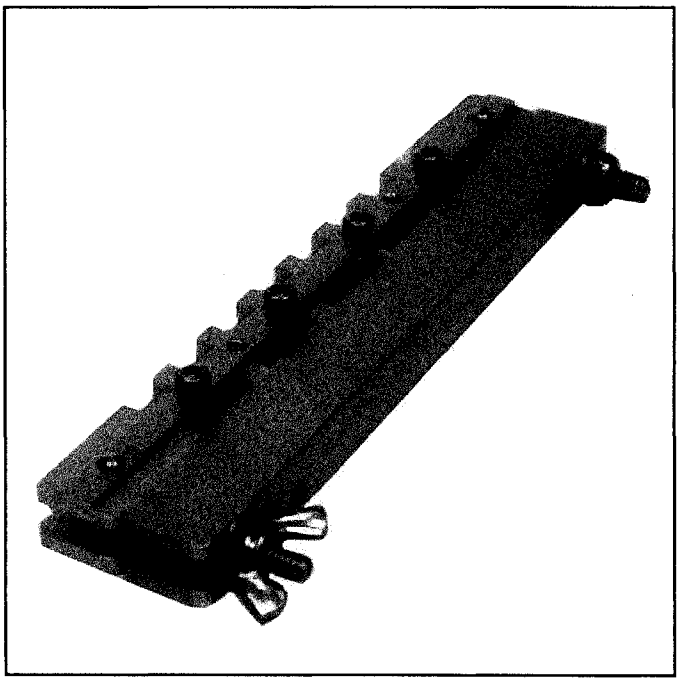

Figure 1. *Anodized aluminum mold for sample fabrication*

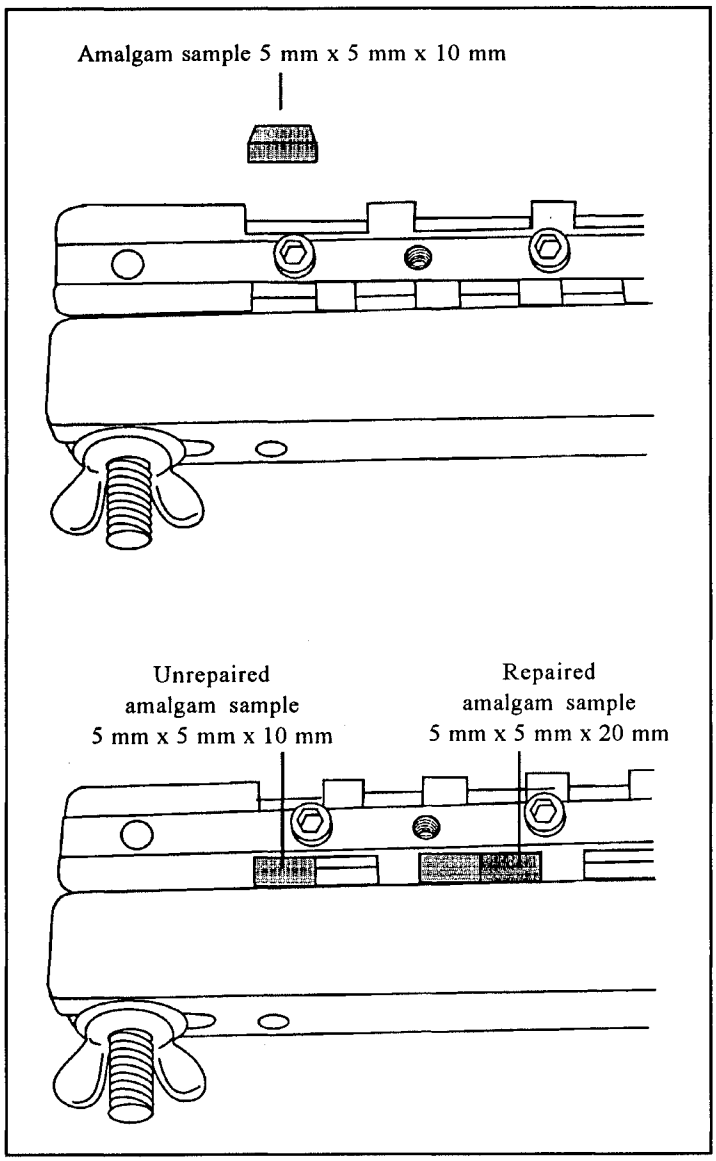

Figure 2. Fabrication of repaired specimens

measuring 5 mm x 5 mm x 10 mm. Intact and repaired specimens measured approximately 5 mm x 5 mm x 20 mm. Specimens were made of high-copper spherical alloy (Tytin, Kerr Mfg Co, Romulus, MI 48174) triturated according to the manufacturer's instructions in a Kerr Automix triturator for 6.8 seconds at 3570 cpm. Condensation was accomplished with a Condensaire mechanical condenser (Teledyne Water Pik, Fort Collins, CO 80553) with a circular flat tip of 2.0 mm in diameter. The split mold was overfilled and excess amalgam carved away with a Walls carver. Specimens were removed from the mold after 15 minutes and stored at 100% relative humidity for 7 days at 37°C. The experimental specimens were divided into six experimental groups and designated Groups A to F.

Repair Procedures and Fracture Strength Testing

The stored experimental specimens received the following surface treatments:

Group A specimens consisted of the intact beams of amalgam. **Group B** specimens were roughened with a #557 crosscut fissure bur (Brasseler USA Inc, Savannah, GA 31419) in a high-speed handpiece with air-water spray. The load on the bur was standardized by one operator performing the procedure with very light hand pressure to achieve a visually roughened surface. **Group C** specimens were microetched for 10 seconds with 50 µm aluminum oxide (Danville Microetcher, Danville Engineering, San Ramon, CA 94583), rinsed for 5 seconds with tap water, and air dried. **Group D** specimens received macromechanical retentive undercuts, placed with a 33½ inverted cone bur (Brasseler) with air-water spray. Two retentive channels were placed in the end of each specimen by sinking the bur to its depth and undercutting to the extent of the shaft. **Group E** specimens were treated with a resin bonding system (Amalgambond Plus, Parkell, Farmingdale, NY 11735). The specimens were first air abraded with 50 µm aluminum oxide for 5 seconds and rinsed with an air-water spray for 5 seconds. The AA adhesive agent of the Amalgambond Plus system was brushed on the amalgam surface to be repaired, thinned with the air syringe, and left for 30 seconds. Three drops of the base, one drop of the catalyst, and one scoop of the HPA powder of the Amalgambond Plus system were mixed and brushed on the amalgam surface to be repaired. Immediately following application, freshly triturated amalgam was condensed against the surface to be repaired. **Group F** received no treatment prior to repair.

Within 5 minutes of surface treatment, the stored experimental specimens in groups B through F were placed back into one-half of the larger split mold and repaired with fresh amalgam condensed into the unfilled half of the mold (Figure 2). Repaired specimens were removed from the mold after 15 minutes and stored in water for 7 days at 37°C and thermocycled at 5 - 55°C for 500 cycles with a 30-second dwell time. A pilot study revealed that the Amalgambond Plus-treated specimens could only be successfully demolded by waiting 30 minutes after repair. This was in contrast with the 15-minute demolding time for the other groups.

The repair strength was measured by transverse strength testing (three-point bend) in an Instron Universal Testing Machine (Instron Corp, Canton, MA 02021). The samples were loaded to fracture along a line midway between the beam supports at a crosshead speed of 0.20 mm/minute. The load was placed directly above the repair site as illustrated in Figure 3. Upon fracture of the samples, the fracture loads were recorded and converted to

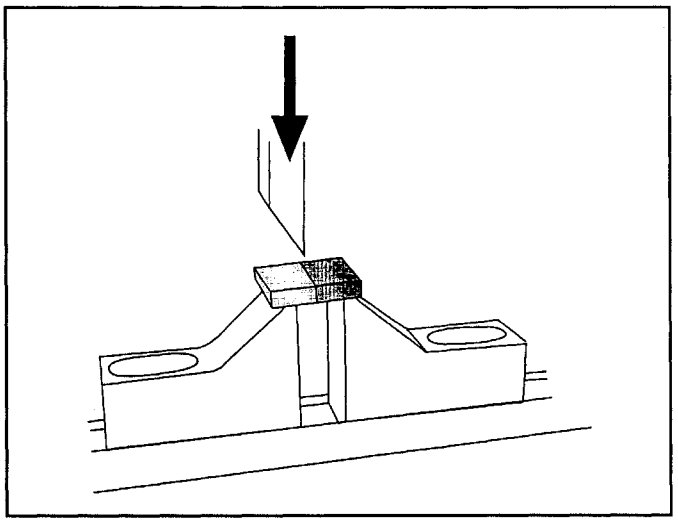

Figure 3. *Sample orientation for transverse strength testing*

transverse strength (MPa) using the following formula:

$$S_T = \frac{3WL}{2bh^2} \quad \text{where}$$

S_T = transverse strength (MPa)
W = fracture load (Newtons)
L = sample length between supports
b = sample width
h = sample thickness

Transverse Fracture Strength of Intact and Repaired Specimens

Experimental Group		MPa	±1 SD
A	Intact beams	170	[20]
B	Roughened with a #557 bur	30	[8.4]
C	Air abraded with 50 μm aluminum oxide*	18.2	[8.4]
D	Two retentive undercuts with a #33½ bur	15.6	[2.6]
E	Amalgambond Plus †	12.5	[6.5]
F	No treatment	12.5	[3.4]

*Danville Microetcher, Danville Engineering;
†Amalgambond Plus, Parkell

Means connected by vertical bars are not significantly different at $P \leq 0.05$.

Statistical Analysis

The data were analyzed by a one-way analysis of variance at $P \leq 0.05$. Significant differences between groups were determined by the Student-Newman-Kuels test at the $P \leq 0.05$ level. A power analysis of data from previous studies indicated that a sample size of 15 per group should provide a 0.8 power to detect a 50 % difference at the 0.05 level of significance.

RESULTS

The repair strength of the various experimental groups ranged from 7-18% of the intact specimens (table and Figure 4). The #557 bur-roughened group yielded statistically higher repair strengths than all other surface treatments ($P \leq 0.05$). Air abrading the amalgam surface did not improve the fracture strength significantly over control samples.

DISCUSSION

The repair strength of the bur-roughened group was similar to that found in studies by Terkla and others (1961), Lacy and others (1992), and Leelawat and others (1992) but were much lower than those of Walker and Reese (1983), Brown and others (1986), Erkes and others (1990), Hadavi and others

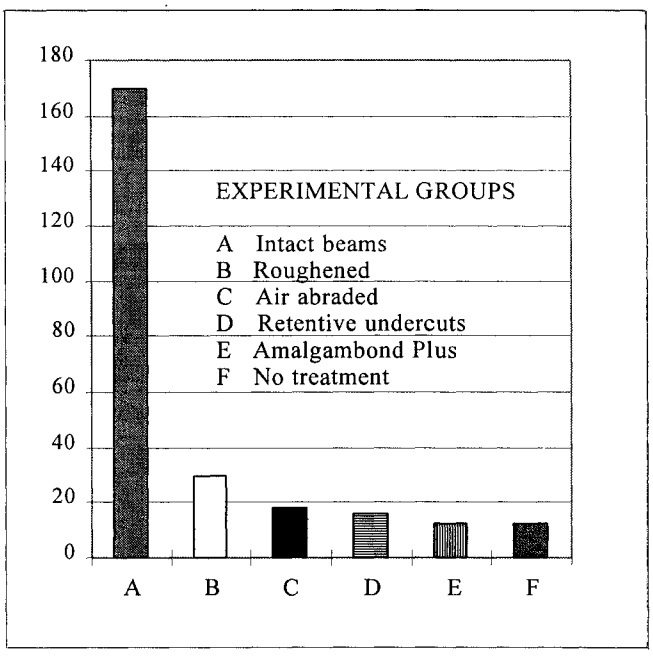

Figure 4. *Mean repair strengths of control and experimental groups (MPa)*

(1991), and Diefenderfer and others (1996). The study by Brown and others (1986) simulated early repair, and this may have accounted for the differences in results. Hadavi and others (1991) reported tensile strength values, while Diefenderfer and others (1996) reported shear strength, making comparison between studies difficult. The present study simulated the effects of surface treatments in a late amalgam repair (7 days). Some studies indicate that repairs performed within 15 minutes will have higher repair strengths than repairs made after 7 days (Terkla & others, 1961; Bagheri & Chan, 1993; Brown & others, 1986). The specimens roughened with a #557 bur appeared visually to have a rougher surface texture than the other groups. Presumably, the increased surface area associated with a roughened surface resulted in some degree of micromechanical retention.

The specimens repaired with a resin adhesive had mean repair strengths not significantly different from untreated specimens. These results correlate with those of Hadavi and others (1991), Lacy and others (1992), and Carr-Hosie and others (1992). Amalgambond Plus is capable of forming a macromechanical bond with unset amalgam due to incorporation of the resin within the amalgam during condensation. However, there appears to be no significant adhesion between the aged amalgam and the resin adhesive. This was supported by observations in the present study that the Amalgambond Plus-treated group failed adhesively between the resin and the repaired specimen.

Air abrasion is a useful technique for improving the bonding characteristics of some dental restorative materials. Studies by Swift and others (1992a,b) showed improved repair bond strength of composite resin and improved bonding of resin cements to indirect composite resin restorations following air abrasion with 50 µm aluminum oxide powder. McConnell (1993) described the improved bonding of resin cements to metals following air abrasion. It was theorized that the use of air abrasion would potentially increase the repair strength of amalgam repairs. The results of the present study show that air abrading the specimens did not significantly improve the repair strength over the untreated specimens.

Repairing amalgam restorations remains a viable clinical alternative to amalgam replacement in some situations. A clinical evaluation by Cipriano and Santos (1995) of early and late repair of amalgams using retentive preparations found that 44 of 45 repaired amalgam restorations were clinically acceptable after 2 years. However, the results of the present study indicate that the repair strength of amalgam is significantly less than the intact restoration and should not be solely relied upon for retention. The continued use of traditional retentive features within the adjacent fractured amalgam and tooth structure can be relied upon to contribute to the overall repair strength of the repaired restoration. The use of resin adhesives can also be justified if sufficient dentin and enamel remain adjacent to the fractured segment to serve as a bonding substrate. When amalgam repairs are considered, it remains prudent to consider the time of repair. The best indications may be for immediate repair of amalgams fractured during carving or due to inadequate interproximal contacts.

CONCLUSIONS

The repair strength of amalgam as measured by transverse strength testing ranged from 7-18% of the strength of an intact amalgam beam. The highest repair strength was obtained by surface roughening the amalgam with a carbide bur. The placement of retentive undercuts and the use of Amalgambond Plus yielded repair strengths similar to untreated controls. Air abrasion of the amalgam with 50 µm aluminum oxide did not significantly improve the repair strength.

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Monkey Pulpal Responses to Conventional and Adhesive Luting Cements

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Clinical Relevance
The pulpal response to a combination of an adhesive resin and luting composite used for cementation of metal inlays was comparable to those of conventional dental luting cements.

SUMMARY

Monkey pulpal responses to metal inlays luted with a combination of an adhesive resin and luting composite and conventional dental cements were histopathologically evaluated. Initial pulpal responses caused by re-exposure of the cut dentin surfaces and luting procedure under hydraulic pressure subsided at 90 days after final cementation. There was no significant difference among pulpal reactions to conventional dental cements and a combination of an adhesive resin and luting composite. The adhesive resin coating of freshly cut dentinal walls/floors immediately after cavity preparation seems to provide protection for the dentin and pulp in indirect restorations requiring temporary sealing.

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INTRODUCTION

Cast gold restorations have been an important component of operative dentistry for almost a century, and they are commonly believed to represent one of the most durable types of restorations (Knudsen, Finger & Glantz, 1988). Zinc phosphate cement has been the dental cement most widely used for cementation of cast restorations. However, due to the lack of adhesion to tooth substance and risk of pulp damage by the initial acidity, it has been gradually replaced by other luting cements. Glass-ionomer cements have been gaining popularity due to their adhesion to tooth structure, improved mechanical properties, cariostatic activity, and easy mixing characteristics (Klausner, Brandau & Charbeneau,

1989; Reinhardt, Swift & Bolden, 1993). Adhesive resin cements are also increasing significantly in use because of recent advances in the technology of dentin adhesion.

However, initial postoperative sensitivity has been reported to occur occasionally after cementation with dental cements (Christensen, 1990; Johnson, Powell & DeRouen, 1993). Zinc phosphate cements were reported to cause moderate to severe initial pulpal responses after cementation of inlays and crowns (Eames & others, 1979; Stanley, 1990). Occasional prolonged hypersensitivity and, in some cases, pulp death have been reported after cementation of crowns with some glass-ionomer materials (Council on Dental Materials, Instruments, and Equipment, 1984). Resin-bonded indirect resin composite inlays were reported to induce initial moderate responses, which subsided after 90 days (Inokoshi & others, 1995).

The aim of the present study was to compare pulpal responses between a combination of an adhesive resin and luting composite to zinc phosphate and glass-ionomer luting cements used in indirect metal inlay restorations made with a precision casting technique (Fusayama, 1959).

METHODS AND MATERIALS

The restorative materials employed are listed in Table 1. Four monkeys were placed under general anesthesia by intramuscular injection of 20 mg/kg ketamine (Ketaral, Sankyo Co, Tokyo, Japan) and intravenous injection of 10 mg/kg pentobarbital sodium (Nembutal Sodium Solution, Abbott Laboratories, North Chicago, IL 60064). Two animals were assigned to the short-term group, and the other two to the long-term group. Class 5 cavities were prepared on the facial surfaces of 100 teeth using a high-speed tapered diamond bur (ISO #170, GC Corp, Tokyo, Japan) under water-spray coolant. These were divided into five groups: a group for zinc phosphate cement (group ZP) (n=10 x 2), a group for glass-ionomer cement (group GI) (n=10 x 2), a group for an adhesive resin and luting composite (group AR) (n=10 x 2), a group for an adhesive resin lining (group AL) (n=10 x 2), and a group for a temporary sealing material (group TP) (n=10 x 2) as a control (Figure 1). The five groups were randomly assigned to each animal. The time between cavity preparation and temporary sealing varied from 10 to 20 minutes. Rubber dam and local anesthesia were not used during the experiment.

Table 1. Restorative Materials Employed

Material	Brand Name	Content	Batch #	Manufacturer
Zinc phosphate cement	Elite 100	P: zinc oxide, magnesium oxide L: phosphoric acid, water P/L ratio = 1.45 (g/ml)	280641 240641	GC Corp, Hasunuma, Tokyo, Japan
Glass-ionomer cement	Fuji I	P: fluoroaluminosilicate glass L: acrylic-maleic acid copolymer Polybasic carboxylic acid, water P/L ratio = 2.0 (g/g)	220841 220841	GC Corp
Adhesive resin	Bondwell LC	Etching gel (10% citric acid + 2% $FeCl_3$) Primer (HEMA, organic carboxylic acid, CQ) Bonding resin (UDMA, HEMA, CQ)	260741 061042 250741	GC Corp
Metal adhesive primer	Metal Primer II	Thiophosphoric methacrylate, MMA		GC Corp
Dual-cured luting composite	Experimental (GC RC-101)	Paste A (BIS-GMA, TEGDMA, Ba-glass) Paste B (BIS-GMA, TEGDMA, Ba-glass)	227H0602B 2380603A	GC Corp
Temporary sealing material	Cavit-G	Zinc sulfate, zinc oxide Polyvinyl acetate, etc		ESPE, Seefeld/Oberbay, Germany

BIS-GMA: Bisphenol glycidyl dimethacrylate
CQ: Camphoroquinone
HEMA: Hydroxyethyl methacrylate
MMA: Methylmethacrylate
TEGDMA: Triethylene glycol dimethacrylate
UDMA: Urethane dimethacrylate

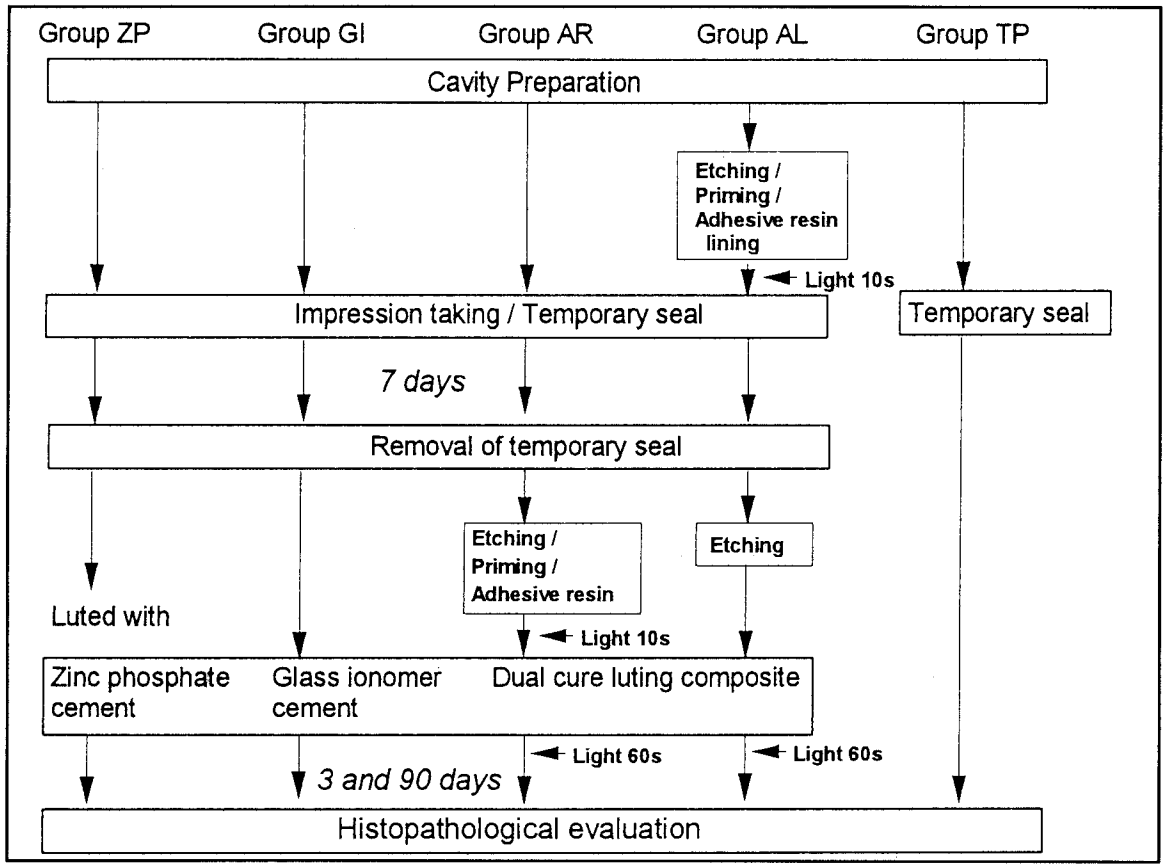

Figure 1. *Experimental procedure of the five groups*

For group AL, the cavity walls were covered with an adhesive resin (Bondwell LC, GC Corp) as described below. The cavity, including the dentin walls/floor, was etched with the accessory 10% citric acid gel containing 2% $FeCl_3$ for 20 seconds, spray washed for 10 seconds, and air dried with oil-free compressed air. The primer was applied for 10 seconds, and gently air dried, and then a one-liquid-type light-cured dentin adhesive resin was applied, air thinned, and light cured for 10 seconds. Since the adhesive resin was relatively thin, a second coat was applied to all the dentinal walls/floor and light cured to obtain a rigid protective film. This group was prepared prior to cavity preparation for the other groups to avoid inadvertent etching of open cavities of the other groups.

Impressions were then taken of the cavity preparations using a combination of injection and putty-type, addition-cured silicone impression material (Hydrophilic Exaflex, GC Corp). Then all preparations of all groups were washed, air dried, and temporarily sealed with Cavit-G (ESPE, Seefeld/Oberbay, Germany). Stone (New Plastone, GC Corp) was poured into the impressions to make working models. Metal inlays were made using gold-silver-palladium alloy (Castwell, GC Corp) according to a precision casting technique (Fusayama, 1959). For ease of handling during the try-in and luting procedure, a small projection 2 mm long was prepared as a spur to the facial surface of each inlay.

At 7 days after cavity preparation, the monkeys were again anesthetized. The temporary sealing material was thoroughly removed with a sharp explorer and water-spray washing, except group TP, which served as a control for the other experimental groups. The cast inlays were checked for fit in the prepared teeth.

For groups ZP and GI, cement was mixed according to the manufacturer's instructions, and the cavities were loaded with the mixed cement. Then the inlays were inserted into the cavities with a rocking motion to allow entrapped cement to escape, and were held until initial setting of the cement was confirmed. Excess cement and the small projection of the inlay were removed after the final set of each cement.

The fitting surfaces of the metal inlays for groups AR and AL were coated with a metal primer just prior to cementation for improved bonding to the luting cement. For group AR, all the cavity walls were

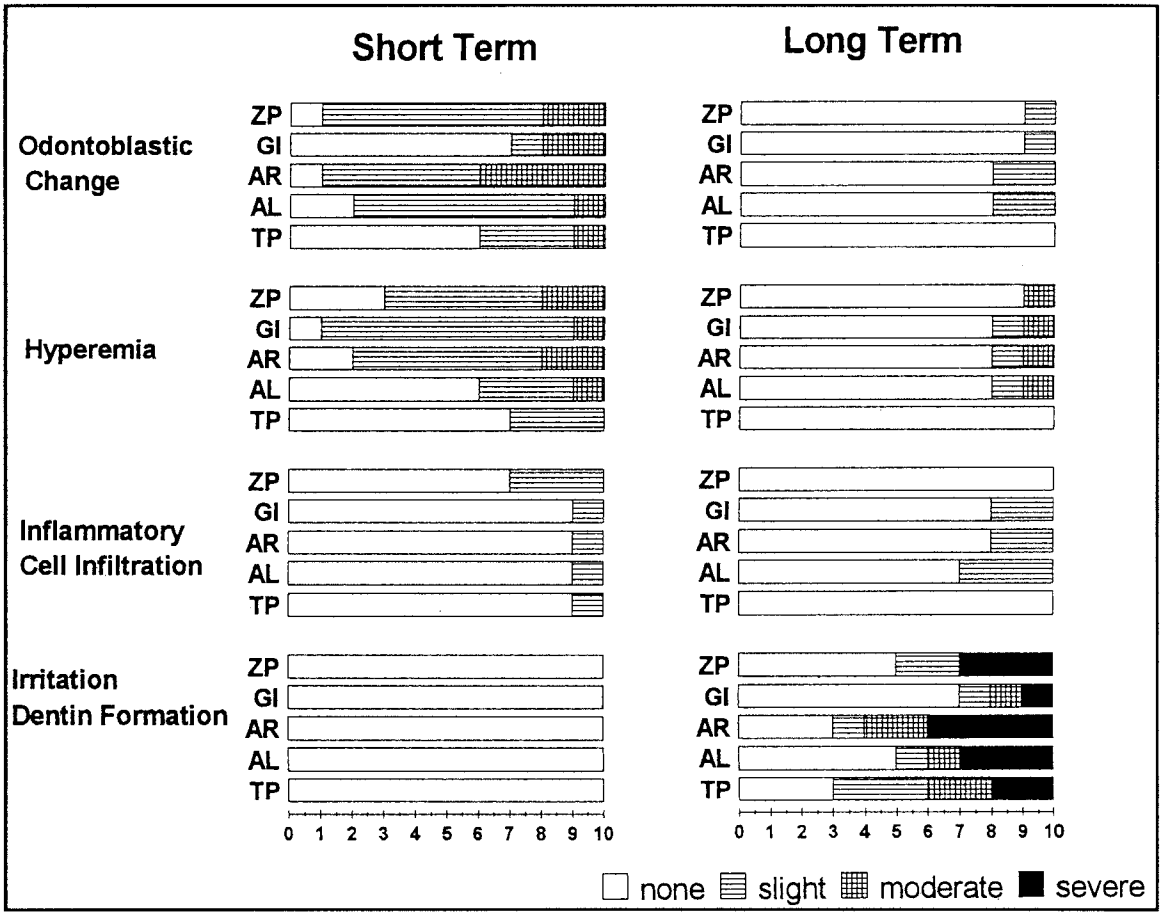

Figure 2. *Pulpal responses of the five experimental groups*

etched with the etchant for 20 seconds, spray washed, and air dried. The primer was then applied for 10 seconds and dried with a gentle stream of air. A single coat of the adhesive resin was applied, air thinned, and light cured for 10 seconds. Equal amounts of universal and catalyst pastes of the luting composite were mixed for 10 seconds, loaded in the preparations, and light cured for 20 seconds after insertion of the inlays. For group AL, the preparations were etched with the etchant for 20 seconds for cleaning, and the inlays were luted with the luting composite without priming and bonding of the preparations. The cement flash and small projections from the inlays were removed with a high-speed diamond bur (#A2, GC Corp) under water-spray coolant. For group TP, the temporary fillings remained in the preparations up to the time of sacrifice.

At 3 and 90 days after placement of the inlays, the monkeys were sacrificed by intravenous injection of 250 mg/kg thiopental sodium (Ravonal, Tanabe Pharmaceutical Co, Osaka, Japan). The teeth were extracted and immersed in a 10% neutral buffered formalin solution for 1 week. Before immersion, the approximal surfaces of the teeth were reduced with a high-speed diamond bur under spray coolant until the pulp became almost visible through the remaining dentin to facilitate the penetration of the fixing solution. The teeth were demineralized with Plank-Rychlo's decalcifying solution at 4 °C for 5 days, neutralized with 5% sodium sulfate for 6 hours, and washed with running water for 6 hours. After removing the inlays, the teeth were dehydrated and embedded in paraffin. Histopathological serial sections 5 μm thick through the cavities and pulp were prepared, obtaining approximately 50 to 60 sections per cavity. These were stained with hematoxylin and eosin for routine histological evaluation and with Taylor's modification of Gram's staining technique for microorganisms (Taylor, 1966).

The remaining dentin thickness was measured parallel to the dentinal tubules and was represented by the shortest floor-to-pulp distance of each section. Among the 50 to 60 serial sections per cavity, one section of the thinnest remaining dentin thickness was selected for assessment as a representative section of the tooth. The intensities of the histological response, disarrangement and reduction of odontoblasts, hyperemia, inflammatory cell infiltration, and

irritation dentin formation were classified into four grades: none, slight, moderate, and severe (Mjör & Tronstad, 1972). The presence of bacteria along the cavity walls and floor was also evaluated.

The results of pulpal responses were statistically analyzed by the Kruskal-Wallis one-way analysis of variance (Siegel & Castellan, 1988) for difference among the three experimental groups for each time interval and the Mann-Whitney U test (Siegel & Castellan, 1988) for differences between the two time intervals. Parametric one-way analysis of variance (ANOVA) and Fisher's protected least significant difference (PLSD) test were used to determine a significant difference among remaining dentin thickness of the 10 experimental groups.

RESULTS

Findings on the histological sections and mean values and ranges of the remaining dentin thickness (RDT) are summarized in Figure 2 and Table 2. All 100 specimens showed no severe damage of the pulp, and all reactions were restricted to directly beneath the prepared cavities. The RDT of the long-term group AL was statistically significantly thicker than the rest of the groups ($F = 2.4$; $df = 9, 90$; $P < 0.02$).

Short-Term Pulpal Responses

Slight to moderate disarrangement and reduction of odontoblasts were present in all cases in groups ZP, AR, and AL, and three to four out of 10 cases in groups GI and TP (Figure 3). However, these changes were not statistically significant ($KW = 8.0$; $P = 0.06$). No aspiration of odontoblasts was observed.

Hyperemia was statistically significantly different among groups ($KW = 9.5$; $P < 0.05$). Group TP showed minimal reaction. Slight to moderate hyperemia was observed in seven to nine out of the 10 cases in groups ZP, GI, and AR (Figure 4). Groups GI and AR showed significantly higher incidence of hyperemia than group TP ($U_{GI} = 16.5$; $P < 0.05$; $U_{AR} = 22$; $P < 0.05$). Group AL showed less reaction than ZP, GI, and AR, but greater than that of TP. However, the change was not statistically significant. Inflammatory cell infiltration was negligible in all groups.

Long-Term Pulpal Responses

The disarrangement and reduction of odontoblasts were negligible in all groups. Hyperemia was observed in a few cases in all groups. Inflammatory cell infiltration was none to slight in all groups, and

Table 2. Summary of Results

		Short-Term					Long-Term				
Time Intervals											
Experimental Groups		**ZP**	**GI**	**AR**	**AL**	**TP**	**ZP**	**GI**	**AR**	**AL**	**TP**
# of Specimens		**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Odontoblastic	none	1	7	1	2	6	9	9	8	8	10
Changes	slight	7	1	5	7	3	1	1	2	2	0
	moderate	2	2	4	1	1	0	0	0	0	0
	severe	0	0	0	0	0	0	0	0	0	0
Hyperemia	none	3	1	2	6	7	9	8	8	8	10
	slight	5	8	6	3	3	1	1	1	1	0
	moderate	2	1	2	1	0	0	1	1	1	0
	severe	0	0	0	0	0	0	0	0	0	0
Inflammatory	none	7	9	9	9	9	10	8	8	7	10
Cell	slight	3	1	1	1	1	0	2	2	3	0
Infiltration	moderate	0	0	0	0	0	0	0	0	0	0
	severe	0	0	0	0	0	0	0	0	0	0
Irritation	none	10	10	10	10	10	5	7	3	5	3
Dentin	slight	0	0	0	0	0	2	1	1	1	3
Formation	moderate	0	0	0	0	0	0	1	2	1	2
	severe	0	0	0	0	0	3	1	4	3	2
Remaining	mean	1.35	1.18	1.13	1.00	1.20	1.27	1.34	1.16	1.68	1.29
Dentin	minimum	1.00	0.37	0.85	0.63	0.67	0.45	0.65	0.48	0.98	0.86
Thickness (mm)	maximum	1.60	1.63	1.45	1.50	1.58	1.88	1.75	1.95	2.50	1.83

Figure 3. *The short-term group TP: no inflammatory reaction except for moderate disarrangement of the odontoblastic layer directly beneath the cavity; RDT = 0.67 mm (magnification X11.368)*

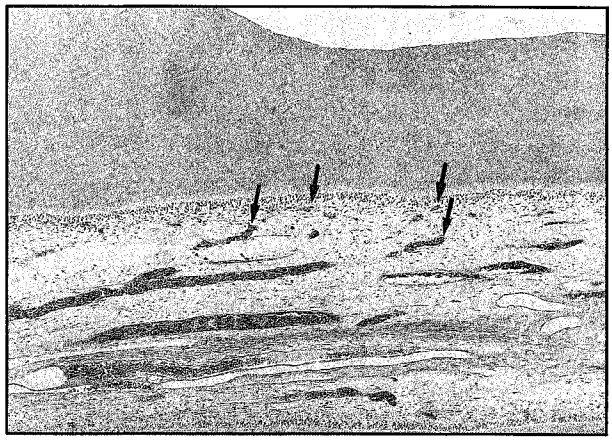

Figure 4. *The short-term group AR: capillaries packed with red blood cells (arrows) are apparent in the odontoblastic layer and subodontoblastic area (moderate hyperemia); RDT = 0.85 mm (magnification X11.368)*

comparable to those of the short-term group. Comparing the results of the short- and long-term groups, groups ZP, AR, and AL and groups ZP, GI, and AR showed a significant decrease of odontoblastic change (U = 11-19; $P < 0.05$) and hyperemia (U = 18.5-22.5; $P < 0.05$) respectively. Irritation dentin formation was observed in all groups, which was not statistically significant among the five groups (Figure 5).

Bacterial Penetration

Bacterial penetration along the cavity walls/floors could not be detected in any cases of the short- or long-term groups. However, the presence of cement remnants disturbed detection in groups ZP, GI, and TP.

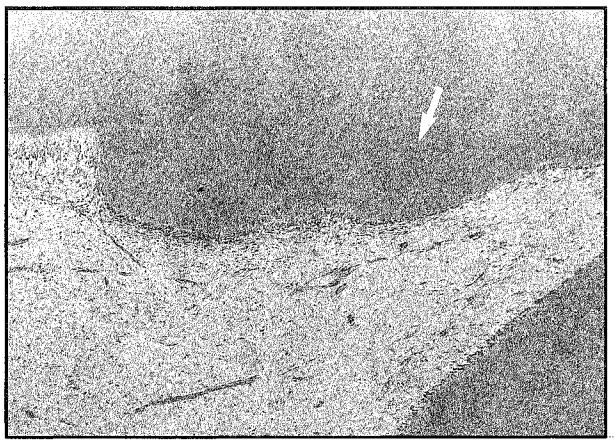

Figure 5. *The long-term group AR: moderate irritation dentin formation without inflammatory reaction (arrow); RDT = 0.65 mm (magnification X11.368)*

DISCUSSION

Since statistically significant differences of pulpal reactions among the five groups were found only in the short-term groups, and the reactions subsided by the long-term observations, discussion is focused on the short-term response of the dental pulp.

In comparison with pulp studies using direct restorative materials, indirect inlay restorations have additional sources of pulp irritation. On reading the histopathological findings, it should be kept in mind that the five experimental groups received different levels of irritation at different times (Figure 6). Group TP served as a control for this experiment. The cavities were filled with Cavit-G immediately after preparation, and received no further treatment. The short-term group TP received irritation only from cavity preparation and temporary restoration for 10 days. Groups ZP, GI, and AR received additional irritation at 7 days after preparation, namely re-exposure of the cut dentin surface and luting of inlays, causing hydraulic pressure to be exerted on the dentin and pulp. Group AL received a different irritation immediately after preparation, acid etching of dentin, priming, and resin bonding. This group exhibited little effect from temporary sealing and cementation procedures.

Group TP showed the least short-term pulpal reaction of all, and reactions were none to slight at the long-term except irritation dentin formation. The present study confirmed the excellent sealing and biological properties of Cavit-G and Cavit as reported previously (Widerman, Eames & Serene 1971; Provant & Adrian, 1978; Turner & others, 1990).

A higher incidence of initial vascular changes in groups ZP, GI, and AR was considered to be caused

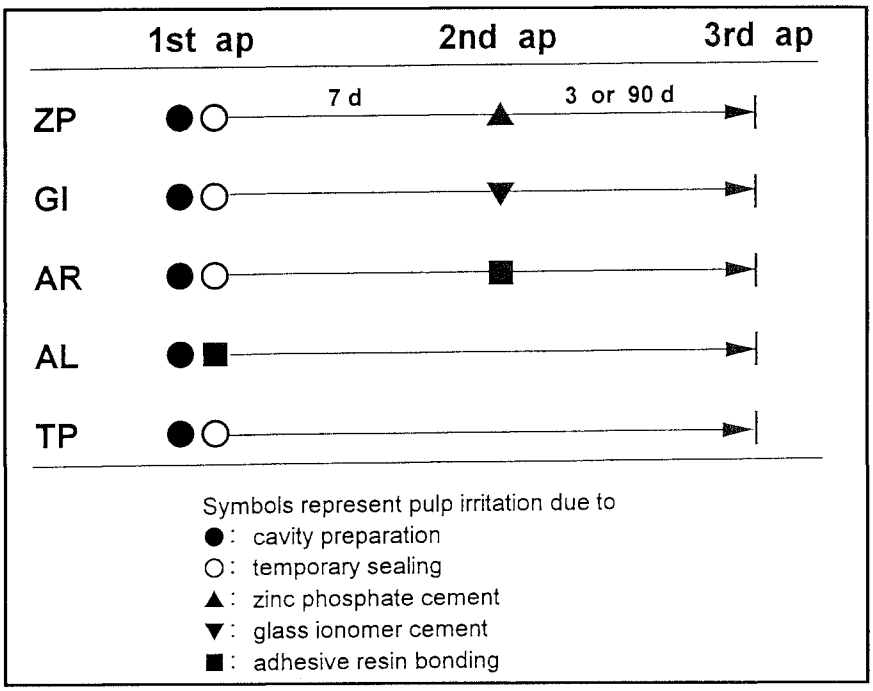

Figure 6. *Possible sources of irritation: five groups received different irritations at different times*

mainly by the mechanical and chemical irritation caused during temporary filling removal and the resin bonding and luting procedures causing increased hydraulic forces on the pulp. This finding of initial increased vascular changes coincided well with the results of a previous study where indirect resin composite inlays were adhesively luted (Inokoshi & others, 1995). Considering the findings of group TP, marginal leakage during the first 7 days of temporary sealing might be excluded as a possible initial irritant to the pulp.

The resin bonding material used in this study was a three-step system. It comprised an enamel and dentin conditioner of 10% citric acid containing 2% $FeCl_3$, a dentin primer (35% HEMA with some carbonic acid), and a one-liquid-type light-cured bonding resin (UDMA + HEMA). Bond strengths to enamel and dentin were reported to be 20 and 15 MPa respectively (Harada & others, 1995).

We could not find any difference in initial pulpal reactions among groups ZP, GI, and AR. Initial irritation from the phosphoric acid of zinc phosphate cement, polyacrylic acid of glass-ionomer cement, and acid etching and priming of the resin bonding material seemed to cause a similar magnitude of insult to the dental pulp under the hydraulic pressure created during inlay insertion in this study. Johnson and others (1993) reported postoperative sensitivity of crown restorations. The incidence of sensitivity was much higher with zinc phosphate cement than glass-ionomer cement at cementation and 2 weeks after cementation (32% vs 19% at cementation, and 34% vs 19% at 2 weeks after cementation). There were no differences between the two cements after 3 months. Compared with the results of the current study, postoperative sensitivity might be observed with the adhesive resin bonding of metal inlays at a similar frequency to those observed with zinc phosphate and glass-ionomer cements.

In a previous study (Inokoshi & others, 1995), pulpal responses to indirect resin composite inlays were investigated using a similar adhesive luting material, which comprised 10% citric acid containing 3% $FeCl_3$ for total etching of the cavity, a HEMA-based dentin primer, and an adhesive low-viscosity luting cement. The incidence of initial hyperemia observed in the current study was comparable to that of the previous study (KW = 0.58; P = 0.87), although the remaining dentin thickness of groups ZP, GI, and AR was statistically significantly thicker than that of the previous study (one-way ANOVA and Fisher's PLSD test, $F = 4.6$; $df = 3, 36$; $P < 0.002$). Since adaptation of resin composite inlays in the previous study was inferior to those of metal inlays obtained by a precision casting technique, the hydraulic pressure directly placed on the cut dentin surface seems to be one of the greatest insults to the dental pulp when doing cast metal restorative procedures.

Heys and others (1987) reported that histological pulpal responses after crown cementation showed no statistically significant difference among zinc phosphate, polycarboxylate, and glass-ionomer luting cements. However, Eames and others (1979) reported moderate to severe pulpal responses at 2 days after cementation of precision amalgam inlays with zinc phosphate cement, which were less severe with a polycarboxylate cement. Stanley (1990) reported a severe initial reaction of the dental pulp after luting crowns with zinc phosphate cement. The permeability of the floor dentin was directly related to remaining dentin thickness (Pashley, 1990), which was relatively thick in the current study. Because metal inlay restorations normally require adequate thermal insulation under the restoration, we did not prepare deep cavities. We might have been able to detect a difference among luting cements if remaining dentin thicknesses were much thinner.

Short-term pulpal responses of group AL were slightly greater than that for group TP, but less than groups ZP, GI, and AR. Since total etching of the whole cavity wall with a 10% citric acid containing 2% $FeCl_3$ was performed for 20 seconds, priming

with HEMA and resin bonding must cause an apparent initial reaction, as shown in group AR. The adhesive resin coating of the prepared dentin surfaces appeared to protect the dental pulp from irritation caused by temporary sealing removal and the luting procedure (Otsuki & others, 1993; Inokoshi & others, 1995).

In the long-term groups, all specimens showed none to slight inflammatory reactions, which is consistent with other studies that have shown the absence of bacterial leakage (Brännström & Nyborg, 1973, 1977; Fujitani, Inokoshi & Hosoda, 1992).

CONCLUSIONS

The present study showed that indirect restorations requiring temporization and re-exposure of the cut dentinal walls/floors caused slight initial pulpal responses, which seemed to be due to mechanical irritation during temporary sealing removal and mechanical and chemical irritation during the resin bonding/luting procedures. However, the initial pulpal responses subsided by 90 days after cementation of the inlays. No differences in pulp irritation among zinc phosphate cement, glass-ionomer cement, and a combination of an adhesive resin and luting composite were identified.

Application of adhesive resins to coat freshly cut dentinal walls seems to provide a new technique for minimizing pulpal irritation for indirect restorations.

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Microleakage of Dentin/Amalgam Alloy Bonding Agents: Results after 1 Year

J C MEIERS • E W TURNER

Clinical Relevance
In vitro data indicate that dentin bond/resin liners may clinically reduce microleakage with high-copper amalgams after 1 year.

SUMMARY

The purpose of this study was to evaluate the 1-year results of the dentin bond (DBS)/viscous resin liner combinations Amalgambond Plus, Tenure/Panavia, Syntac/Dual Cem, and All-Bond 2/Liner F in reducing microleakage in class 5 cavity preparations restored with an admixed or a spherical amalgam alloy and to compare these results to the previously reported short-term (4-day) data from this same study. Class 5 cavity preparations with occlusal margins in enamel and gingival margins in cementum were prepared on extracted human molar teeth. Prepared teeth were distributed randomly into 12 treatment groups (n=10) consisting of the various DBS/liners, Copalite, and no liner for each alloy. Samples were stored in saline for 12 months, thermocycled, and stained with dye. Restorations were sectioned and microleakage scored. The DBS/liner combinations, with the exception of Syntac/Dual Cem, had significantly less microleakage with both alloys than Copalite or no liner. Comparing short-term to long-term results within the DBS/liners, only Tenure/Panavia with Tytin had a significant increase in microleakage scores. These data indicate DBS/liner combinations can provide significant protection against microleakage under high-copper amalgam alloys for up to 1 year.

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INTRODUCTION

Amalgam has been used for over 150 years as the primary posterior restorative material in dentistry (Craig, 1993). Numerous studies have identified microleakage as a significant problem with this material because of interfacial gap formation (Going, Massler & Dute, 1960; Kidd, 1976; Mertz-Fairhurst & Newcomer, 1988; Ben-Amar, 1989). This gap is thought to be the result of several variables, which include lack of chemical adhesion, differing thermal coefficient of expansion between tooth and amalgam, dimensional changes on setting of the amalgam, inadequate condensation and adaptation to cavity walls, and improper trituration (Mertz-Fairhurst & Newcomer, 1988; Craig, 1993; Mahler & Lyle, 1994). Microleakage as a result of this gap can result in pulpal irritation, tooth discoloration, and

secondary caries (Kidd, 1976; Ben-Amar & others, 1986).

Corrosion of conventional, low-copper amalgam alloys over several months has been proven to reduce microleakage (Wei & Ingram, 1969; Craig, 1993). High-copper amalgam alloys have eliminated the highly corrosive gamma-two phase in the setting reaction and consequently have delayed the development of this corrosion-related seal (Andrews & Hembree, 1980; Craig, 1993; Ben-Amar, Cardash & Judes, 1995; Westerhoff, Darwish & Holze, 1995).

Various types of liners have been used to provide a dentin seal prior to corrosion product formation within the interfacial gap. Copal varnish has been the traditional liner used with amalgam alloys to prevent initial microleakage (Ben-Amar & others, 1986). However, copal varnish has been shown to dissolve over time, resulting in loss of its initial seal (Liberman & others, 1989).

Most recently, dentin bonding agents have been evaluated as liners for amalgam alloys and have usually produced significant improvement in the reduction of microleakage versus copal varnish (Staninec & Holt, 1988; Cooley, Tseng & Barkmeier, 1991; Charlton, Moore & Swartz, 1992; Edgren & Denehy, 1992; Saiku, St Germain & Meiers, 1993; Berry & Tjan, 1994; Turner, St Germain & Meiers, 1995). Most of these studies were of short duration, and the ability of these dentin bonding systems to reduce microleakage over time has not been fully explored. A recent long-term microleakage study using a 4-META dentin bonding system showed reduced effectiveness in preventing microleakage when 1-year data were compared to the initial data (Moore, Johnson & Kaplan, 1995).

The purpose of this investigation was to evaluate the 1-year effectiveness of four dentin bond/viscous liner systems—Amalgambond Plus (Parkell Products, Farmingdale, NY 11735), Tenure (DenMat Corp, Santa Maria, CA 93456)/Panavia EX (J Morita, Tustin, CA 92680), Syntac/Dual Cem (Ivoclar Vivadent, Amherst, NY 14228) and All-Bond 2/Liner F (Bisco Dental Products, Itasca, IL 60143)—in reducing microleakage when used with a spherical and admixed high-copper amalgam alloy and to compare these data to our previously published short-term (4 days) data from this same study (Turner & others, 1995).

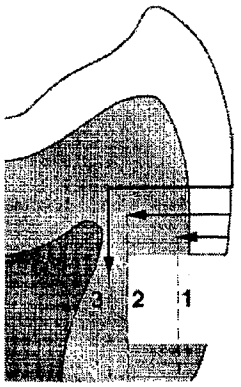
METHODS AND MATERIALS

The experimental design was described previously in the analysis of the short-term data (Turner & others, 1995). Sixty noncarious extracted human teeth were stored in deionized water with a bactericidal agent, 0.2% sodium azide, until ready for use. Residual tissue tags were scraped and the teeth thoroughly rinsed under running tap water for 15 minutes to remove the sodium azide solution. Class 5 cavity preparations were placed on the mesial and distal surfaces of each tooth using a high-speed handpiece with air and water spray and a #35 bur. The preparations were 1.5 mm deep, oblong in shape, measuring 2 x 6 mm, parallel to the cementoenamel junction (CEJ), and the gingival half of the preparations extended 0.5 mm below the CEJ. Cavosurface walls were finished to a butt joint with a #55 slow-speed bur. Cavity preparations were rinsed for 20 seconds with an air/water spray and gently air dried for 30 seconds. The 12 test groups used in this study (n=10) are shown in Table 1.

Table 1. Test Groups: Liner and Amalgam Alloy Combinations (n=10)

Group	Liner	Alloy
1	None	Tytin
2	Copalite	Tytin
3	Amalgambond Plus	Tytin
4	Tenure/Panavia EX	Tytin
5	Syntac/Dual Cem	Tytin
6	All-Bond 2/Liner F	Tytin
7	None	Dispersalloy
8	Copalite	Dispersalloy
9	Amalgambond Plus	Dispersalloy
10	Tenure/Panavia EX	Dispersalloy
11	Syntac/Dual Cem	Dispersalloy
12	All-Bond 2/Liner F	Dispersalloy

The mesial and distal surfaces of each tooth were numbered from 1 to 120, and the treatment sequence/scheme for each surface was determined using a random number table. The dentin bond systems/viscous liners were applied according to the manufacturer's directions. The unlined control preparations were rinsed and air dried as previously described. Copalite (HJ Bosworth Co, Skokie, IL 60076) was applied in two thin layers, allowing the first layer to air dry for 30 seconds prior to applying the second layer. Tytin (Sybron/Kerr, Romulus, MI 48174) or Dispersalloy (Johnson & Johnson, Skillman, NJ 08558) alloy was hand condensed into each



Microleakage Scores

1 = Leakage ≤ ½ gingival/occlusal walls

2 = Leakage > ½ gingival/occlusal walls and up to axial wall

3 = Leakage along axial wall

Diagram of scale used to quantitate microleakage

preparation. Restorations were overfilled, burnished, and carved back to proper contour. Specimens were then placed in normal saline at 37 °C for 1 year. After this time period, teeth were thermally stressed for 3000 cycles in deionized H2O between 5 and 55 °C using a dwell time of 30 seconds. Teeth had their root apices sealed with Vitrabond glass ionomer (3M Dental Products, St Paul, MN 55144) and dental compound. The entire tooth surface was painted with two coats of fingernail polish to within 1 mm of the restoration margins and then placed in 0.5% basic fuchsin dye in a 37 °C bath for 24 hours. Teeth were then mounted in orthodontic acrylic, cut serially into four sections on an Isomat slow-speed diamond saw (Buehler, Lake Bluff, IL 60044) with both mesial and distal sections included in each cut. Sections were treated with 0.5% citric acid to remove the smear layer created during sectioning and rinsed with distilled water. Each section was viewed under an Olympus SC 35 stereoscopic microscope (Olympus Corp, Lake Success, NY 11042) at X10 magnification and blindly scored for microleakage by a second investigator. Microleakage scores were based on the degree of dye penetration according to the following scale (see figure) (Turner & others, 1995): 0 = No leakage; 1 = Dye penetration less than half way to the axial wall; 2 = Dye penetration greater than half way to the axial wall; and 3 = Dye penetration along the axial wall.

Microleakage scores were recorded for both enamel and cementum margins, and the four section scores were averaged to provide one score for each margin of the restoration.

Statistical analysis was performed initially on the ordinal data utilizing Kruskal-Wallis analysis of variance. If a significant difference was found in the ANOVA analysis, the data were then subjected to Dunn multiple comparison tests to determine where those differences occurred. Wilcoxon Signed Rank tests were used to test occlusal/enamel versus gingival/dentin microleakage differences. All statistical tests were run at a significance level of $P < 0.05$ using the Stat Primer program (Glantz, 1992). Comparison of the microleakage data from the various groups of liner/amalgam combinations from the 1-year study to their corresponding groups in the short-term study was done with a Mann-Whitney Rank Sum test again at a significance level of $P < 0.05$.

RESULTS

Tables 2-5 display the 1-year total microleakage data (all viewed sections) and are organized the same way as for the short-term data analysis (Turner & others, 1995). The type of amalgam alloy--spherical

Table 2. Occlusal/Enamel Microleakage of Dispersalloy/ Liner Specimens (n = 40 sections/group)

Liner	Microleakage				Median
	0	1	2	3	
No Liner	4	11	16	9	2
Copalite	2	26	9	3	1
Amalgambond Plus	27	10	0	3	0
Tenure/Panavia	14	23	4	0	1
Syntac/Dual Cem	0	10	18	12	2
All-Bond 2/Liner F	10	21	6	3	1

Table 3. Gingival/Dentin Microleakage of Dispersalloy/Liner Specimens (n=40 sections/group)

Liner	Microleakage				Median
	0	1	2	3	
No Liner	0	6	24	10	2
Copalite	1	11	21	7	2
Amalgambond Plus	7	19	11	3	1
Tenure/Panavia	2	19	18	1	1
Syntac/Dual Cem	0	10	11	19	2
All-Bond 2/Liner F	4	20	14	2	1

Table 4. Occlusal/Enamel Microleakage of Tytin/Liner Specimens (n=40 sections/group)

Liner	Microleakage				Median
	0	1	2	3	
No Liner	1	9	22	8	2
Copalite	1	8	22	9	2
Amalgambond Plus	14	22	4	0	1
Tenure/Panavia	19	18	3	0	1
Syntac/Dual Cem	6	8	10	16	2
All-Bond 2/Liner F	8	25	5	2	1

Table 5. Gingival/Dentin Microleakage of Tytin/Liner Specimens (n = 40 sections/group)

Liner	Microleakage				Median
	0	1	2	3	
No Liner	0	3	19	18	2
Copalite	1	5	19	15	2
Amalgambond Plus	4	23	11	2	1
Tenure/Panavia	2	18	17	3	1.5
Syntac/Dual Cem	5	3	9	23	3
All-Bond 2/Liner F	4	20	14	2	1

or admixed--did not play a factor in microleakage for the 1-year data except with Copalite, where Tytin had significantly greater microleakage than Dispersalloy.

Tables 2 and 3 show the occlusal and gingival microleakage data for Dispersalloy. All groups showed significantly greater gingival microleakage when compared to the occlusal except for Syntac/ Dual Cem, where there was no difference. Within the dentin bond/viscous resin liner systems, Syntac/ Dual Cem had significantly greater microleakage than Amalgambond Plus, Tenure/Panavia EX, or All-Bond 2/Liner F. Except for Syntac/Dual Cem, the dentin bond/viscous liner systems had significantly less microleakage than Copalite or no liner. When comparing the Dispersalloy/liner 1-year data to our short-term data (Turner & others, 1995), there was no difference in microleakage within the dentin bond/ viscous liner groups. However, both the Copalite and no liner groups had significantly greater microleakage in the short term versus 1 year.

Tables 4 and 5 show the microleakage data for the Tytin alloy groups. Essentially the same pattern was followed as was previously discussed for Dispersalloy, where within the dentin bond/viscous liner groups, Syntac/Dual Cem had significantly greater microleakage than the other three dentin bond/ viscous liners. Again, the dentin bond/viscous liner groups, with the exception of Syntac/Dual Cem, had significantly less microleakage than Copalite or no liner.

Comparing the Tytin/liner 1-year data to our short-term data (Turner & others, 1995), there were no significant differences within the dentin bond/ viscous liner groups except for Tenure/Panavia EX, where there was an increase in microleakage over time. There was no difference in microleakage for Copalite or no liner between short-term and 1-year data, which was in contrast to the Dispersalloy results for these two groups.

DISCUSSION

The results of this study indicate that three of the four dentin bond/viscous resin liner systems significantly reduced microleakage after 1 year when used with high-copper amalgams. When compared to our previous short-term data (Turner & others, 1995), there was no significant increase in microleakage within the dentin bond/viscous liner groups after 1 year. We did see in the comparison of the short-term and 1-year data that the Copalite and no liner groups did attain the same degree of microleakage protection as Syntac/Dual Cem. There was also a difference between the two amalgam alloys in the two groups that would have allowed us to see the sealing process contribution of corrosion products with time. There was a significant decrease in microleakage over time within the Disperalloy no liner and Copalite groups but not within these same groups with Tytin.

Our results contrast the results reported in a recent study (Moore & others, 1995). These investigators showed that Amalgambond when used with Dispersalloy had a significant increase in microleakage after 1 year when compared to 1 week and 6 months. Additionally, they noted that after a year the copal varnish group produced the same degree of protection against microleakage as the Amalgambond group. Moore's explanation of these results focused around the breakdown of the 4-META bond to dentin for the increase in microleakage seen with the Amalgambond-lined

Dispersalloy groups. The formation of corrosion products within the tooth/alloy interface from Dispersalloy was considered the reason for the decrease in microleakage with the copal varnish groups. Various investigators have reported that high-copper amalgam alloys may take up to 2 years to achieve the type of corrosive seal found after a relatively short period of time with low-copper products (Andrews & Hembree, 1980; Liberman & others, 1989; Fitchie & others, 1990). Delayed formation of corrosion products could cause a longer duration of sensitivity for patients after receiving a restoration using a high-copper alloy. In this study, Dispersalloy displayed a better seal after 1 year than initially, but still not enough to equal the seal of three of the four dentin bond/viscous liner systems. Tytin did not show any improvement in sealing from initial placement to 1 year. This could be explained by the fact that Tytin is a single-phase alloy and forms the corrosion products CuO_2 and CuC_{l2} more slowly than the dispersion-type 2 alloys such as Dispersalloy (Lin, Marshall & Marshall, 1983).

Few studies have been published on the effect of long-term storage on microleakage of dentin bonding systems. Crim (1993) found that after 6 months three of five dentin bond systems he tested showed increased microleakage at the gingival margin in class 5 preparations restored with composite resin when compared to initial microleakage data. Amalgambond in the Moore and others (1995) study also showed deterioration as evidenced by the increase in microleakage. The long-term stability of the hybrid layer that is formed by the present generation of dentin bond systems has come under question by several investigators and may explain these results (Sano & others, 1994, 1995).

This study used a dentin bonding agent in combination with a viscous resin to simulate a "bonded" versus a "lined" amalgam restoration. Most of the previous studies done by other investigators in this area have used resin-lined amalgams. In the "bonded" amalgam technique, the viscous liner is used to specifically mix with the amalgam during condensation to form a mechanical lock with the amalgam. This mechanical attachment, through this hybrid layer of amalgam and resin, theoretically aids in the retention of the amalgam to the tooth. A potential reason why three of our four tested dentin bond/viscous resin systems did not degrade significantly over time may be from the stabilizing influence of this viscous liner on the dentin/resin hybrid layer. An example of this was demonstrated with Amalgambond and Amalgambond Plus. Amalgambond Plus, which uses a powder to provide a viscous mix, performed well in our 1-year study. Amalgambond, which is a thin liner, deteriorated in the study by Moore and others (1995).

There is, however, a potential problem with a viscous liner used with amalgams. If the viscous liner mixes with and remains attached to the amalgam alloy at the interface, corrosion products may not form over time. This could result in the inability of the saliva to contact the alloy at the tooth/alloy interface. If the hybrid layer is not stable and degrades over time, microleakage may ensue, potentially causing the patient to experience tooth sensitivity over time. Three out of four of the dentin bond/viscous liner combinations in the 1-year data showed no signficant increase in microleakage when compared to the short-term data. However, there was a trend for more sections to be located in the higher microleakage scores with the 1-year versus the short-term data. Whether this trend would continue and translate into significant increases in microleakage over 2 or more years is unknown at this time.

More long-term studies are needed to provide insight into the stability of new materials and techniques that are being developed and marketed to the profession. The true test of the quality of any dental material is its durability over time. Only more long-term studies will determine whether the present generation of dentin bonding agents is the right approach to prevent long-term microleakage when used with high-copper amalgam alloys.

CONCLUSION

The dentin bond/viscous resin liner systems Amalgambond Plus, Tenure/Panavia EX, and All-Bond 2/Liner F had significantly less microleakage after 1 year than Syntac/Dual Cem, Copalite, or no liner when used with both Dispersalloy and Tytin. The corrosion products developed from these high-copper amalgam alloys at the tooth/alloy interface did not provide a seal over time equal to that formed from three of the four dentin bond/liner systems. When compared to short-term microleakage data, there was no significant increase in microleakage for the dentin bond/viscous liner systems, indicating at least 1 year of stability for these materials' hybrid layer.

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The Effect of Three Finishing Systems on Four Esthetic Restorative Materials

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Clinical Relevance
Abrasive impregnated disks and aluminum oxide disks provided smoother finished surfaces on glass-ionomer and microfilled composite resin materials than did diamond and carbide finishing burs.

SUMMARY

Previous studies have investigated the finishing and smoothness of composite and traditional glass-ionomer restorations, but few have included resin-modified glass-ionomer cements or more recent finishing systems. The results of using three different finishing systems (Sof-Lex, Enhance, finishing burs) on two composites (Silux, Prisma TPH), a traditional glass ionomer (Ketac-Fil), and a resin-modified glass ionomer (Fuji II LC) were studied. Sixty samples were condensed into sectioned acrylic tubes, covered with a Mylar matrix plus a glass slide at each surface, then cured as per the manufacturers' instructions. Samples were randomized to three groups of five for each material and testing with a Surfanalyzer 4000 of unfinished samples (cured with Mylar matrix) was done to obtain baseline average surface roughness (R_a). Samples were then finished as per the manufacturers' instructions using polishing disks, abrasive impregnated disks, and finishing burs before further surface testing. Samples finished with burs and with abrasive impregnated disks were further polished using polishing paste (Prisma Gloss) and again tested. Data were analyzed with ANOVA testing and Tukey's HSD pairwise comparison. Initial testing after randomization to groups showed no significant difference in surface roughness ($P = 0.24$). Two-factor analysis revealed no significant difference between materials ($P = 0.34$), a significant difference in method of finish ($P \leq 0.00$), with no significant interaction between type of material and method of finish ($P = 0.11$). Aluminum oxide disk and impregnated disk systems provided the best finish for microfilled composite and both glass-ionomer materials ($P \leq 0.00$). No significant difference in method of finish existed with the hybrid composite ($P = 0.07$). Overall, esthetic restorative material finishing is best accomplished using abrasive impregnated disks or aluminum oxide disks. Finishing burs gave a significantly rougher surface than the former methods.

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INTRODUCTION

The restoration of cervical lesions can be very challenging to the dental practitioner from both a materials and technique standpoint. Many factors must be considered when making decisions regarding the treatment of these lesions. Dentin bonding is often compromised in the cervical area due to a variety of factors, and placement and finishing procedures can be complicated by lesion location and size (Heymann & Bayne, 1993). In addition, achieving a favorable esthetic result is critical, especially in anterior regions of the mouth. Smoother, better polished restorations are shown to be more esthetic and more easily maintained (Strassler & Bauman, 1993; Weitman & Eames, 1975), leading to increased patient satisfaction and longer lasting restorations.

Microfilled and hybrid composites as well as traditional and light-activated glass-ionomer cements have been used to restore cervical lesions. Most current materials provide enamel and dentin adhesion and relative ease of placement and finishing. Glass-ionomer cements provide the added advantage of sustained fluoride release after placement (Cranfield, Kuhn & Winter, 1982; Forsten, 1977; Kidd, 1978). However, traditional glass-ionomer cements (autocure) lack color depth and translucency, pose minor problems in clinical placement (Mount, 1993), and possess poor polishability (Liberman & Geiger, 1994). Light activated, dual-cure (also termed resin-modified) glass-ionomer cements have been developed in an attempt to address some of the limitations of traditional glass-ionomer cements (Mount, 1993).

Proper finishing and polishing of tooth-colored restorations enhances the esthetics and the longevity of restored teeth. Plaque retention, surface discoloration, and esthetics of the restoration have been related to the smoothness of the restoration surface (Herrgott, Ziemiecki & Dennison, 1989; Weitman & Eames, 1975; Waerhaug, 1975). Many studies have demonstrated that the smoothest surface on composite resin restorations is achieved using a clear matrix in contact with the composite surface during curing (Dennison, Fan & Powers, 1981; Wilson, Heath & Watts, 1990; Woolford, 1988). However, further contouring and finishing are usually required, so it is important to determine the finishing technique that will result in the smoothest restorative material surface under these clinical circumstances.

Various techniques for polishing and finishing esthetic materials have been investigated. These methods include the use of aluminum oxide finishing disks, carbide finishing burs, fine diamond finishing burs, polishing pastes, and abrasives embedded in resin polishing points (Herrgott & others, 1989; Jefferies, Barkmeier & Gwinnett, 1992; Chung, 1994). Several studies have suggested that certain polishing techniques may be best suited to specific materials (Strassler & Bauman, 1993; Kelsey & others, 1984; Boghosian, Randolph & Jekkals, 1987). Differences in surface smoothness have been demonstrated using identical finishing systems on different composite resins (Stoddard & Johnson, 1991).

Sof-Lex finishing disks, carbide and diamond finishing burs, and the Enhance system are popular among clinicians and have been used for the finishing of composite resin and glass-ionomer restorations. The specific aim of the current study was to compare the surface smoothness achieved using these three finishing techniques on two composites, one traditional glass-ionomer cement, and one resin-modified glass-ionomer cement.

METHODS AND MATERIALS

Three finishing techniques, Enhance (abrasive impregnated disks), Sof-Lex (aluminum oxide disks),

Table 1. Restorative and Finishing Materials Tested

MATERIAL	MANUFACTURER
Hybrid composite	
Prisma TPH	L D Caulk/Dentsply, Milford, DE 19963
Microfilled composite	
Silux	3M Dental Products, St Paul, MN 55144
Traditional glass ionomer	
Ketac-Fil	ESPE-Premier Corp, Norristown, PA 19404
Resin-modified glass ionomer	
Fuji II LC	GC America Inc, Chicago, IL 60658
Finishing burs	
#7901 carbide finishing bur	Midwest, Des Plaines, IL 60018
#265:MF diamond finishing bur	ESPE-Premier
Finishing and polishing systems	
Enhance Finishing/Polishing System	L D Caulk/Dentsply
Sof-Lex Finishing/Polishing System	3M Dental Products

and #7901 carbide finishing bur plus #265:MF diamond finishing bur were applied to the Mylar-created surface of four different restorative materials: Silux, Prisma TPH, Ketac-Fil , and Fuji II LC (Table 1).

The sample size for this research protocol was calculated using approximate range and standard deviations, in microns, from data presented in previous literature (Herrgott & others, 1989; Dennison & others, 1981). Based on those published values, a significance level of alpha = 0.05 with a power of 0.80, a sample size of three units per cell was calculated. To provide protection against Type II error, the final sample size was increased to five samples per group, with three groups for each of the four materials.

Sixty samples (the total sample set) were fabricated by placing the appropriate material into eight cylindrical cavities (one sample at each side) created by sectioning hollow acrylic rods for each of the four material groups. The cavity preparation measured 9 mm in diameter and 4 mm deep. The composite resin and resin-modified glass-ionomer materials were condensed using a plastic filling instrument lightly coated with bonding resin, specific for that particular material. The samples were then covered with a Mylar matrix strip (S S White Co, Philadelphia, PA 19177) and a glass slide on each side prior to curing with a visible light curing unit (Command, Sybron/Kerr, Romulus, MI 48174). Curing light intensity was monitored using a Dentek photometric tester (Dentek, Inc, Buffalo, NY 14207). Materials were cured on each side of the cylinder for 30 seconds through the matrix strip and glass slide, receiving an additional 60 seconds without those matrices in place. The traditional glass-ionomer material was covered by a matrix strip and glass slide on each side and allowed to cure for 7 minutes in 100% relative humidity. The cured samples were stored at 100% relative humidity and 37 °C for no less than 24 hours prior to randomization to finishing method and initial testing.

Following the storage period, the matrix-created surface was evaluated using a Surfanalyzer 4000 surface analyzer (Federal Products Corp, Providence, RI 02940) with a cut-off length of 0.80 mm and a crosshead speed of 0.25 mm per second to obtain average surface roughness values (R_a, μm) and surface profile tracings. Each sample was rotated 120°, relative to the center, for each of three readings and averaged to generate an average roughness value (R_a) per sample.

Five samples from each of the four restorative materials were finished using one of three polishing systems. A permuted-block randomization scheme was employed for this assignment to guarantee a balanced study design and equal probability sample. One investigator finished all samples in order to control variability.

Finishing using the abrasive impregnated disks and aluminum oxide disks was accomplished according to the manufacturers' directions. Disks were applied with light pressure in a circular pattern and were discarded after use. Carbide finishing

Table 2. Results of Overall Factor Analysis

Factor	Factor Level	μ Roughness	Statistical Test	*P* Value
surface	Mylar	0.17 ± 0.17	one-way ANOVA	≤ 0.00
	finished	0.54 ± 0.37		
material (Mylar surface)	Fuji II LC	0.20 ± 0.12	one-way ANOVA	0.24
	Ketac-Fil	0.23 ± 0.30		
	Silux	0.12 ± 0.08		
	Prisma TPH	0.13 ± 0.09		
material (finished surface)	Fuji II LC	0.55 ± 0.35	one-way ANOVA	0.34
	Ketac-Fil	0.64 ± 0.40		
	Silux	0.45 ± 0.38		
	Prisma TPH	0.52 ± 0.33		
finish (combined materials)	carbide & diamond burs	0.96 ± 0.32	one-way ANOVA, Tukey HSD	≤0.00
	Enhance	0.32 ± 0.25		
	Sof-Lex	0.50 ± 0.28		
	burs then paste	0.66 ± 0.30		
	Enhance then paste	0.26 ± 0.17		

Values connected by brackets are not significantly different.

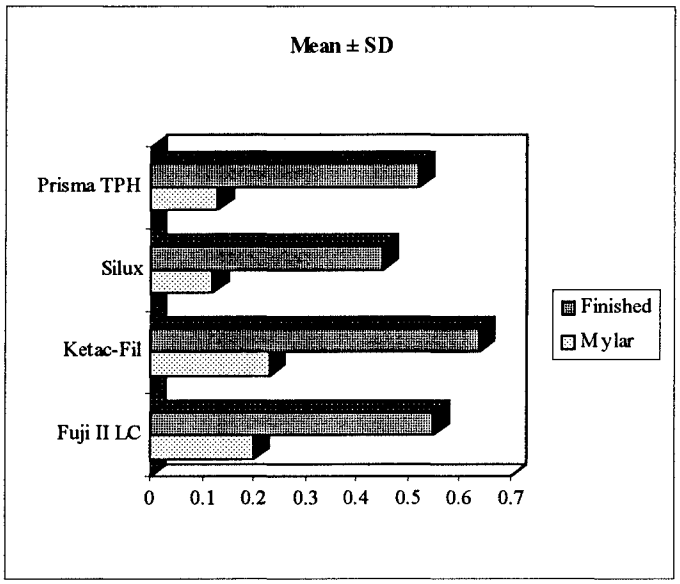

Figure 1. *Average surface roughness of all finishing methods by material in microns*

burs and diamond burs were used in sequence in a high-speed handpiece without water spray. Each bur was applied using light pressure in multiple directions to obtain a visually smooth surface and were discarded after use. Samples were again stored at 100% relative humidity prior to data collection using the surface analyzer as previously described.

Twenty samples finished with carbide finishing burs followed by diamond burs were further polished using Prisma Gloss polishing paste (LD Caulk/ Dentsply) following initial data collection on the surface analyzer. Polishing paste was also applied to the 20 samples finished with abrasive impregnated disks. Polishing paste was applied according to the manufacturer's directions. After paste polishing, samples were again tested for surface roughness with the surface analyzer as previously described.

In addition, representative samples were selected for each material and finishing procedure and imaged using a scanning electron microscope (SEM) for visualization of the surface roughness data.

RESULTS

Data were analyzed with ANOVA testing and Tukey's HSD pairwise comparison. Initial surface roughness after randomization to groups showed no significant difference ($P = 0.24$) within material groups (Table 2 and Figure 1). Furthermore, a probability plot of the average roughness data was prepared and verified a normal distribution of the data values. Two-factor ANOVA analysis revealed no significant difference between materials for comparing finishing method ($P = 0.34$), and significant difference in method of finish within each material group ($P \leq 0.00$), with no significant interaction between factors detected ($P = 0.11$) (Table 2). Aluminum oxide disk and impregnated disk system data showed significantly less surface roughness for microfilled composite and both glass-ionomer materials ($P \leq 0.00$). No significant difference in surface roughness between methods of finish existed with the hybrid composite material ($P = 0.07$) (Table 3). Overall, a Mylar matrix-created surface was smoother than any finished surface obtained ($P = 0.00$), regardless of restorative material (Figure 2).

Two-factor ANOVA analysis showed significant surface roughness difference between the finished materials and significant surface roughness difference between finishing methods ($P \leq 0.0$ and $P \leq 0.0$ respectively). Impregnated disks and impregnated disks plus polishing paste produced the least surface roughness in this sample. Furthermore, Table 3 presents data to show the following:

1. Impregnated disks, impregnated disks plus paste, and aluminum oxide disks provided significantly less roughness on resin-modified glass-ionomer cement. Resin-modified glass-ionomer

Table 3. Results of Finishing Method by Material

FINISH METHOD	MATERIAL			
	Fuji II LC	Ketac-Fil	Silux	Prisma TPH
carbide & diamond burs	0.99 ± 0.14	1.07 ± 0.31	1.12 ± 0.19	0.66 ± 0.42
Enhance	0.24 ± 0.11	0.22 ± 0.04	0.16 ± 0.07	0.65 ± 0.30
Sof-Lex	0.38 ± 0.23	0.64 ± 0.37	0.47 ± 0.19	0.50 ± 0.30
burs + paste	0.82 ± 0.07	0.86 ± 0.34	0.31 ± 0.05	0.62 ± 0.24
Enhance + paste	0.30 ± 0.23	0.40 ± 0.18	0.19 ± 0.10	0.16 ± 0.05

Values connected by brackets are not significantly different.

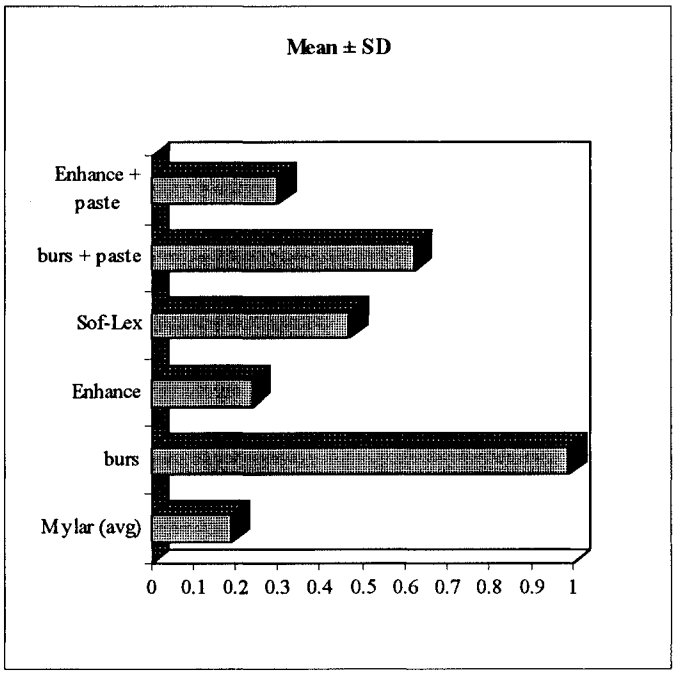

Figure 2. *Average surface roughness of all materials by finishing method in microns*

surfaces finished with impregnated disks exhibited less roughness than those finished with aluminum oxide disks, but the difference was not significant.

2. Impregnated disks and impregnated disks plus paste provided significantly less surface roughness on traditional glass-ionomer cement.

3. Testing of the microfilled composite revealed that impregnated disks provided significantly less surface roughness than aluminum oxide disks.

4. For the hybrid composite, no significant difference existed among any of the finishing methods (Table 3).

Representative SEM photographs of samples finished with the methods described above as well as the unfinished matrix surface are shown in Figures 3 through 6.

DISCUSSION

In this study, no significant difference in surface smoothness was shown between unfinished materials (matrix surface). However, a trend was evident that showed composite resin materials provided a smoother finished surface, compared to glass-ionomer materials, with any of the finishing methods chosen. Other studies have also reported no significant differences among composite materials (Herrgott & others, 1989; Pratten & Johnson, 1988).

The smoothest surfaces were produced using a Mylar matrix strip on all materials tested in this study. This is consistent with the findings of other investigators who tested composite (Lee, Orlowski & Kidd, 1975) and glass-ionomer materials (Eide & Tveit, 1990; Pearson & Knibbs, 1987; Woolford, 1988). However, it is usually necessary to further finish and polish composite and glass-ionomer restorations. In the current study, data revealed that abrasive impregnated disks (both with and without subsequent use of polishing paste) and aluminum oxide disks provided significantly smoother finished surfaces than finishing burs. In addition, there was a trend in this study favoring abrasive impregnated disks used alone for all materials except the hybrid composite. Previous studies have reported that aluminum oxide disks provided the smoothest surface on both composite (Tate, DeSchepper & Cody, 1992; Chen, Chan & Chan, 1988; Wilson & others, 1990) and glass-ionomer materials (Tate & Powers, 1996; Pearson & Knibbs, 1987; Woolford, 1988) while other studies reported similar

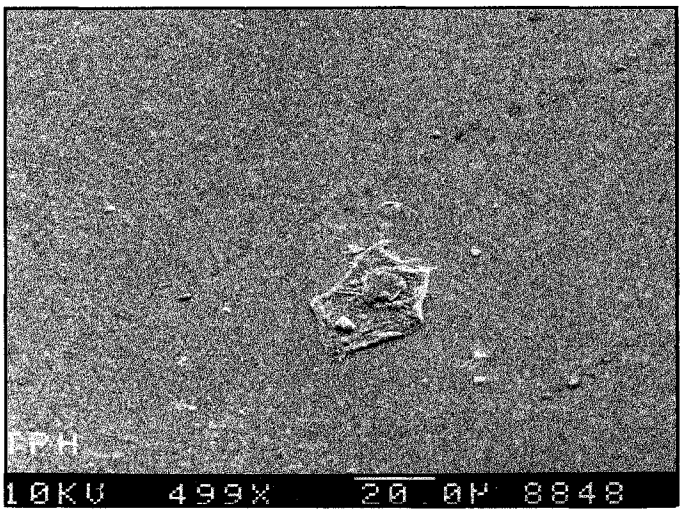

Figure 3. *Matrix-created surface on hybrid composite (Note areas of artifact on composite surface) (Magnification X440)*

Figure 4. *Microfilled composite finished with finishing burs (Magnification X440)*

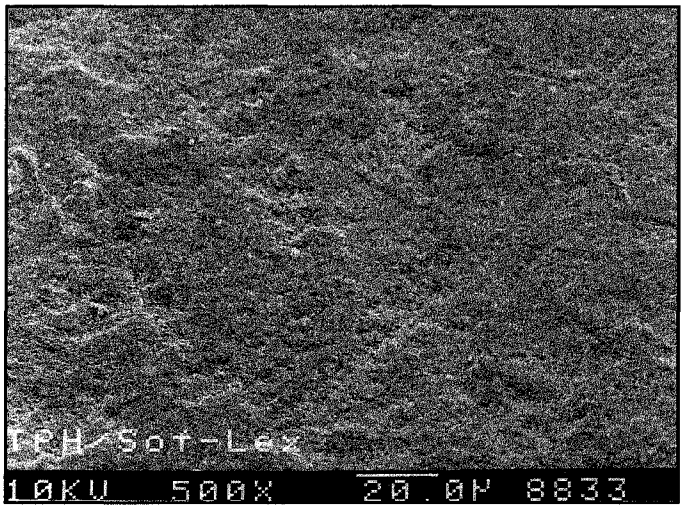

Figure 5. *Hybrid composite finished with aluminum oxide disks (Magnification X440)*

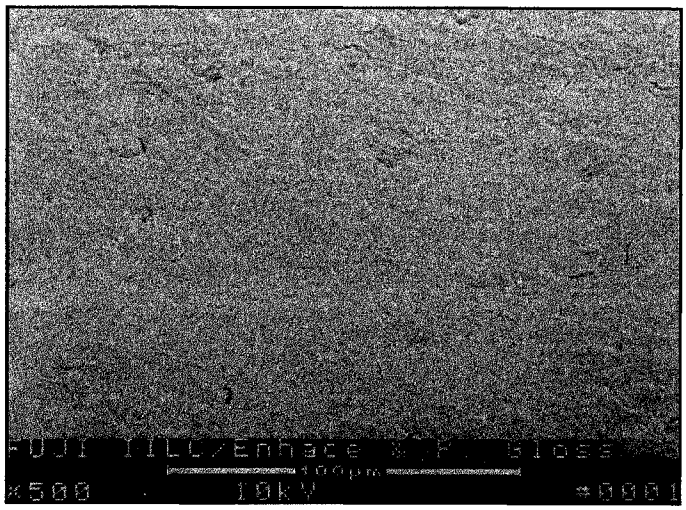

Figure 6. *Resin-modified glass ionomer finished with abrasive impregnated disks and polishing paste (Magnification X410)*

levels of finish obtained using either aluminum oxide disks or abrasive impregnated disks (Jefferies & others, 1992; Chung, 1994).

Tate and Powers (1996) reported rougher surfaces on glass-ionomer materials using abrasive impregnated cups, which they felt caught and dislodged filler particles in the materials they tested. However, they used cups (which they said "seemed to grind into the surfaces") instead of disks to finish flat samples. A correlation may exist between the shape of the abrasive instrument and the degree of smoothness obtained.

This study and others (Eide & Tveit, 1990; Quiroz & Lentz, 1985; Chen & others, 1988; Pratten & Johnson, 1988) reported that finishing burs provided a significantly rougher surface than the other finishing methods tested. However, in a study that compared the smoothness of light-activated glass-ionomer surfaces finished using a combination of techniques, it was shown that diamond burs produced a significantly smoother surface than carbide burs or carbide burs followed by either the Enhance system or silicone rubber finishers (St Germain & Meiers, 1996).

The use of finishing burs followed by polishing paste alone did not provide the same level of smoothness achieved using abrasive impregnated disks or aluminum oxide disks in this study. Other studies also showed that use of polishing paste following carbide burs, abrasive impregnated finishing cups, or aluminum oxide disks did not significantly improve the surface smoothness of composite and glass-ionomer materials (Chen & others, 1988; Tate & Powers, 1996; Tate & others, 1992).

Based on the results of this study, abrasive impregnated disks or aluminum oxide disks will provide a smooth finished surface on any of the composite and glass-ionomer materials tested. Due to the rough finish produced by finishing burs, their use should be limited to gross contouring and removal of excess restorative material. While the current study did not test surface roughness of samples finished using a combination of finishing burs and impregnated disks or aluminum oxide disks, other studies have recommended the use of aluminum oxide disks following carbide finishing burs to obtain a clinically smooth restoration surface (St Germain & Meiers, 1996; Tate & Powers, 1996).

It is important to exercise caution when interpreting the results of this in vitro study. As was discussed by St Germain and Meiers (1996), correlation to clinical practice may be limited to situations where accessible, relatively flat surfaces are finished. Further study is needed to determine which finishing techniques are best suited to clinical situations where access is limited and restoration surfaces are not flat.

CONCLUSION

No significant difference in surface smoothness was demonstrated between the materials for the matrix-created surface in this study. The smoothest finish for microfilled composite, traditional glass ionomer, and resin-modified glass-ionomer materials was achieved using either aluminum oxide disks or abrasive impregnated disks. Finishing burs provided the roughest finish. This difference was significant for microfill composite and both glass-ionomer materials. The use of polishing paste does not appear necessary to improve the finish obtained using abrasive impregnated disks if clinical significance is

considered. No significant difference in method of finish was shown with the hybrid composite in this study.

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DEPARTMENTS

BOOK REVIEWS

HANDBOOK OF LOCAL ANESTHESIA
Fourth Edition

Stanley F Malamed

Mosby-Year Book, Inc, St Louis, 1997. 310 pages, 346 illustrations. $44.95, softbound

The first three editions of this textbook have become the standard in local anesthesia instruction at the dental and dental hygiene student level. As a result, this new edition has been eagerly awaited by educators and clinicians in the field.

The book is organized into four parts with a total of 20 chapters. While there are many similarities between this and previous editions, the new format and layout are much easier to read. In addition, there are more tables and diagrams, which makes the material much easier to absorb, particularly for the new student. This version includes updated information relative to newly popularized techniques such as the intraosseous and intraseptal injections and specific data on local anesthetics currently unavailable in the US, such as articaine.

About 110 pages, or one-third of the text, is devoted to local anesthetic techniques, which demonstrates the clear clinical emphasis of the book. The real value of a textbook such as this is that it serves both as a step-by-step guide for the student just learning the maneuvers, as well as a good review for the experienced clinician desiring a "tune-up" for injection technique.

Overall, this remains an excellent text in the field of local anesthesia and continues to be the standard against which other textbooks are compared. While the illustrations are not as impressive as those in Evers and Haegerstam's text, the combination of solid scientific information and practical instruction in administering local anesthetics cannot be beaten. This is a textbook that should not only be an absolute requirement for all students in dental disciplines, but is also a valuable addition to the libraries of established clinicians.

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FUNDAMENTALS OF FIXED PROSTHODONTICS
Third Edition

HT Shillingburg, S Hobo, LD Whitsett, R Jacobi, and SE Brackett

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 582 pages, 1290 illustrations. $58.00

This is probably one of the most widely recognized textbooks in the field of fixed prosthodontics. The third edition includes many changes to the text and layout, as outlined in the preface.

With developments in fixed prosthodontics moving quickly, it is unrealistic to expect any textbook to be entirely up-to-date and to include informed opinion and guidance on the latest materials and techniques. As a consequence, the third edition of *Fundamentals of Fixed Prosthodontics* must be viewed as providing a well-balanced overview of current techniques. The layout of the chapters has been well conceived, with each section of the book able to stand on its own. This is important to many readers wishing to graze through selected sections or look for specific items of interest.

The style of the book, with its numerous hand-drawn illustrations instead of color plates, may not be to everyone's taste but has the advantage of clarity, particularly if the reader is unsure about a subject or preparation technique. For those who prefer an atlas-type approach, comprehensive supplemental reading lists are given.

This is a book that has something for everybody at all stages of their education or level of practice skills in fixed prosthodontics. The reader who wishes to review the more practical aspects can simply follow the drawings, which, by virtue of their clarity, need very little explanation. However, the reader who wishes to gain further insight into the situation may read the accompanying text, which is supported by appropriate references. Indeed, this book covers a wealth of clinical and laboratory techniques in astounding detail, which can sometimes overwhelm the reader. In particular there is probably too much detail on laboratory techniques for general clinical practice. For those in postgraduate studies, however, such information is pertinent. Some readers may also consider the authors to have been too didactic in their approach. This is not a criticism of the book but rather one of its strengths. The fundamentals of many aspects of dentistry must include some ground rules. These are well laid out in this book without straying too much into gray areas

that may ultimately confuse the reader. There is certainly no confusion in this book!

In a book like this, which contains a vast repository of information, there are bound to be details with which the reader may not entirely concur. For example, it is suggested that the preparation technique advocated for porcelain laminate veneers may introduce undercuts with respect to the path of insertion, but this and other small anomalies pale into insignificance with the rest of the presented information. Perhaps the only serious criticism lies within the history of the book itself. In the preface the authors reflect on the origin of the book as being derived from The *UCLA Fixed Prosthodontics Syllabus,* and it is probably because of this beginning that there are lists of armamentarium for each procedure and specific materials mentioned. Thus the book has yet to break away from the original teaching manual format; doing so would further enhance its appeal to a truly international readership.

Overall, *Fundamentals of Fixed Prosthodontics* probably remains the book by which others of the same genre must be judged. For students and clinicians who are involved in the practice of fixed prosthodontics, and also those who teach it to any level, this book must be considered as an authoritative reference and kept within easy reach.

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1997 PHYSICIANS' GENRX MOSBY'S COMPLETE DRUG REFERENCE Seventh Edition

L Suzanne BeDell, Editor-In-Chief

Published by Mosby-Year Book, Inc, St Louis, 1997. 2500 pages, $67.95.

The stated purpose of this reference book is to provide a unique indexing system to locate complete prescribing information along with price listings for both branded and generic pharmaceuticals. After identifying the availability of generic drugs, information is provided to determine their therapeutic equivalency and any cost benefit to the patient. In an attempt to provide unbiased information, the editorial review panel for this reference text was comprised of a cross section of healthcare professionals, RPhs, PharmDs, DDSs, DMDs, MDs, and PhDs, affiliated primarily with academic institutions.

One of the most useful features of this reference is the Keyword Index. Rather than looking through multiple indexes as in the *PDR* (*Physicians' Desk Reference*, Montvale, NJ: Medical Economics), the brand name, generic name, therapeutic category, pharmacologic category, and indication for use are all included in one effective index of keywords at the front of the text. The generic drug can be found by any of the preceding keyword categories, which are cross-referenced to the generic. Since most drugs would fall under several categories, the Keyword Index provides additional ways to locate drugs other than by therapeutic category as in other references. The Keyword Index is especially useful in identifying a specific drug by indication or therapeutic classification when the patient can identify the medical condition under treatment but cannot recall the medication that has been prescribed.

Once the drug is located in the Keyword Index, the specific page number for the drug in the Drug Information section is given. One can also refer to the therapeutic categories within the Keyword Index to identify alternative drugs used to treat a specific condition and compare costs of therapy for brand name and generic drugs. Unfortunately this reference does not include drugs available without a prescription (OTC) as does *Volume I: Drug Information for the Health Care Professional* (Rockville, MD: United States Pharmacopoeia).

The Drug Identification Guide provides full-size, color pictures of tablets and capsules arranged in alphabetic order by generic name rather than by manufacturer as in the *PDR*.

By knowing the generic drug name one can skip the index and go directly to the Drug Information section, which is organized alphabetically by generic name. This section provides the usual prescribing information based on FDA-approved labeling for each drug. Following the generic name is a list that includes therapeutic category, pharmacologic category, FDA indications for use, and indications not approved by the FDA. The drug listing includes brand names, alternative generic names, branded generics, and brand names no longer in use. Updated FDA therapeutic equivalency ratings are listed so that comparable generic drugs can be identified. A Cost of Therapy section gives the net cost for a dosage regimen as specified in the FDA-approved package insert. Comparative costs of therapy for many brand name and generic drugs are provided so that relative cost of therapy can be determined.

Prescribing information has as many as 14 sections, including description, clinical pharmacology, clinical studies, indications and usage, contraindications, adverse reactions, warnings, precautions, drug interactions, drug abuse and dependence, overdosage, dosage and administration, references, animal pharmacology, Centers for Disease Control dosage information, patient information, and some package inserts.

The How Supplied section lists therapeutic and pharmaceutical equivalency ratings, both positive and negative, or indicates that equivalent drugs are not available. When considering the substitution of generic drugs, the practitioner can assess the equivalency ratings and the potential cost differential.

Normal values of standard laboratory and function tests are provided on the inside of the cover and overleaf of the text.

While this reference lacks the within-drug-category comparisons, depth of coverage and monthly updates of *Drug Facts & Comparisons* (St Louis: JP Lippincott Co) and *Volume I: Drug Information for the Health Care Professional*, most dentists do not require such in-depth information on a day-to-day basis. In the opinion of this reviewer, the highly usable Keyword Index and coverage of all FDA-approved drugs, including generics, makes the *1997 Physicians' GenRx* similar to *PDR Generics* (Montvale, NJ: Medical Economics) and more usable than the *Physicians' Desk Reference*. This is a well-organized reference that would be useful for any dentist who wants quick access to well-indexed, unbiased, and detailed information about prescription drugs.

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BOUCHER'S PROSTHODONTIC TREATMENT FOR EDENTULOUS PATIENTS
Eleventh Edition

George A Zarb, Charles L Bolender, and Gunnar E Carlsson

Published by Mosby-Year Book, Inc, St Louis, 1997. 539 pages, 841 illustrations

It is always a challenge, and perhaps somewhat of a risk, to make significant changes in a publication when that publication is considered by many to be the standard for a particular subject. In the eleventh edition of *Boucher's Prosthodontic Treatment for Edentulous Patients*, the authors have managed to incorporate a substantial quantity of new material on implant prosthodontics into the text without compromising the traditionally excellent coverage of conventional complete denture prosthodontics. Doctors Zarb, Bolender, and Carlsson are again the principal authors, with 19 eminently qualified clinicians and scholars contributing to the text. The target audience remains primarily dental students, general dentists, and prosthodontists. However, operative dentists will find this text an outstanding resource for most issues regarding complete denture prosthodontics.

The text is divided into five sections: 1) "On Being Edentulous," 2) "Preparing the Patient for Complete Denture Treatment," 3) "Rehabilitation for the Edentulous Patient: Fabrication of Complete Dentures," 4) "Diverse Aspects of Complete Denture Prosthodontics," and 5) "Implant Prosthodontics." The first four sections contain many chapters that are relatively similar in appearance and content to those in past editions, but there has been some consolidation and restructuring of sections by the authors, which has resulted in a more streamlined composition that is efficient and easy to read. Sections 1 and 2 provide an in-depth review and diagnosis of the physiological and psychological aspects of the edentulous state. Section 3 focuses on preparing and treating the patient as well as the actual fabrication of denture prostheses. Section 4 identifies and describes the complex treatment associated with immediate dentures, overdentures, and single dentures opposing natural teeth. The last chapter in this section provides an introduction to maxillofacial prosthodontics.

The fifth section is composed of five new chapters devoted entirely to the subject of implants for completely edentulous patients. The authors do not present implants as a panacea for edentulous patients, but as part of a broader spectrum of treatment options for these patients. Although the subject of implants is covered in detail, it is not the focus of the text, and is insufficiently in-depth for the graduate student or restorative dentist who wishes a comprehensive reference.

The work seen in this book is well organized and quite readable. Although many of the pictures and diagrams in the text are repeated from previous editions, which may give one an initial impression that little has changed, the authors are to be commended for bringing one of the classic texts on complete dentures up to date.

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FUNDAMENTALS OF OPERATIVE DENTISTRY—A CONTEMPORARY APPROACH

Richard S Schwartz, James B Summit, and J William Robbins

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 424 pages, 992 illustrations including 78 color photographs, indexed. $68.00 softbound.

This new textbook, which was written by three principal authors in addition to 14 contributing authors, consists of 16 chapters. Many operative dentistry techniques and materials have gone through significant changes and developments over the past few years; however, for a number of reasons many dentists were unable to catch up with these new changes. The authors' objective in this new textbook is to "bring to students and practitioners current and practical concepts of preventive and restorative dentistry that will allow them to serve their patients well." Their statement on the back cover, "Traditional, time-proven methods combined with recent scientific developments for a contemporary approach to operative dentistry," is indeed a true description of what this textbook is all about. The three principal authors are university educators with current professorial appointments with the University of Texas Health Science Center at San Antonio. Most of the 14 contributing authors have higher degrees and hold relevant professorial appointments with universities in the United States, Belgium, and Portugal.

The first three chapters of this book are concerned with biologic considerations, patient evaluation, treatment planning, caries management, and pulpal considerations, including an up-to-date section on bases and liners. Chapters 4 and 5 deal with nomenclature and instrumentation as well as field isolation. Chapters 6 to 9 deal with adhesion and direct and indirect esthetic restorations of all classes, including posterior composite and bonded porcelain/ceramic restorations. Chapter 10 is about class 1 and 2 amalgam restorations, including pin-retained complex restorations and bonded amalgam. A separate chapter (11) was devoted to class 5 restorations made in either amalgam, resin composite, or glass ionomer. Chapter 12 deals with the treatment of endodontically treated teeth using postretained restorations. Chapter 13 deals with impressions and provisional restorations, while Chapter 14 deals with porcelain veneers. Chapter 15 is about anterior crowns, including metal ceramic crowns as well as all-ceramic crowns, while the final chapter deals with cast-gold restorations including inlays, onlays, and partial- and full-coverage crowns. Line drawings are of superior quality and black-and-white photographs as well as color ones, which are generally excellent, are used liberally and reproduced with a high degree of resolution.

Rightly omitted from the chapter on amalgam restorations is class 3 distal amalgam restoration on canines, which until recently remained a preferred material for restoring these cavities. With the increasing reliability of resin composite materials, such restorations can now be confidently made with resin composites. While the authors presented modern designs for moderate amalgam restorations, perhaps for complex amalgams, they tended to recommend the use of what appears to be in some situations an excessive number of pins for retention, particularly horizontally placed ones, ignoring the important role of the less-invasive retention grooves when used in combination with pins. In one situation, two approximal pins were recommended for retention of a large class 5 amalgam restoration (Chapter 11). This is a little too extreme, as properly designed and well-prepared retention grooves are capable of providing the same amount of retention in such situations without any pins. The section on adhesion and esthetic restorations (Chapters 6-9) is well written in a balanced and concise manner and provides the reader with updated information on this important aspect of the field. There is timely emphasis on posterior esthetic restorations, more than one would find in other textbooks of the same category. This is of particular importance for many older practitioners who missed learning about these new materials and techniques during their undergraduate education, as they were either nonexistent or not fully developed at the time. These restorations are currently in more demand by patients in preference to metallic ones. Porcelain veneers are well described and presented, and there is a good number of representative cases.

This interesting textbook, which is full of useful tips, is an excellent resource for students and practitioners alike who are keen on learning new concepts and providing their patients with state-of-the-art preventive/operative dentistry services. It ranks high among other available textbooks that ignored many of the new changes in our field and continued to promote outdated and obsolete philosophies and techniques. The authors are to be congratulated on producing such an impressive, modern, well-illustrated, and easy-to-read textbook on operative dentistry.

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Dr Stephen Campbell
UIC Restorative Dentistry, mc555
801 S Paulina Street
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Dr John Reinhardt
University of Iowa
College of Dentistry
229 Dental Science Building South
Iowa City, IA 52242

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30 April - 2 May 1998
Hotel du Lac et du Parc, Riva del Garda, Italy

This meeting is being held in association with the 1998 Annual Meeting of the Accademia Italiana di Conservativa. The speakers are Michael Degrange, Burkhard Hugo, Heinrich Kappert, Francesco Mangani, John McLean, Michael Noack, Massimo Nuvina, Cesare Robello, Richard Simonsen, and Nairn Wilson. Information may be obtained by contacting:

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Send manuscripts and correspondence regarding manuscripts to the Editor, Richard B McCoy, at the editorial office: University of Washington, OPERATIVE DENTISTRY, Box 357457, Seattle, WA 98195-7457; (206) 543-5913, FAX (206) 543-7783; URL: http://weber.u.washington.edu/~opdent/.

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