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Aim and Scope

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

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EDITORIAL

The Declining Applicant Pool: Can This Trend Be Stopped?

The number of applicants applying for admission to predoctoral programs has been decreasing steadily for more than 10 years. For the class entering the first year in 1988 the number of applications was down to 5,018 for an enrollment of 4,196. The ratio of applicants for each of those entry positions was 1.2:1.

In 1979 there were 58,715 applications from 10,000 applicants for a class entry number of 6,132. A total of 1.63 applicants existed for each available position. This equates to a 32 percent reduction in the number of applicants for each available position.

Considering that there were only 1.2 applicants available for each position, then surely many schools had difficulty filling their classes, and if they did, it is likely that they had to accept marginal candidates. There are only a few schools which still have a number of applicants with outstanding GPAs from which to make their selections.

All this is in spite of decreasing dental school enrollments which have resulted from school closures and reduction in class size. We now are facing difficult days ahead for our profession, particularly if we cannot attract excellent students. One cannot help but ask the question: Why do we have so few applicants? Could it be that we have ceased to promote the profession to our young patients and students? And what about all of the negative input from members of the profession who would like to see even more schools closed to increase the number of patients for each dentist? We all know dentists who tell their young patients that dentistry is not a viable profession today. Perhaps it is a result of prospective students having heard that dental decay is declining and therefore coming to their own conclusion that dentistry is a dying profession. Whatever the cause, the time is here for us to help recruit excellent candidates for our dental schools.

We can say with all sincerity that dentistry as a profession has never been so exciting and offered so many challenges for the years ahead. While it is true that the dental decay rates for a large segment of the population have decreased, we know that there still remains so much to do. The reduction in the caries rate makes it possible to spend our time and talents addressing other aspects of dental disease neglected in the past. Operative dentistry and fixed prosthodontics are significantly impacted by the reduction in caries, because we can now devote more time to increasing the quality of care. This type of dentistry is much more rewarding than merely trying to restore cavities to stamp out dental disease, which we were unable to do.

It is incumbent upon us all that we promote dentistry for what it really is, a dynamic, fascinating, and rewarding profession. We must point out that the unmet needs of our population as well as the projected needs for those already seeking care will generate a shortage of dentists in this country within the decade. We must encourage our youth to enter the profession if we are to keep the profession alive and well. To do anything less will foster mediocrity, as our schools will never receive enough qualified students to fill their classes, and are forced to accept those less qualified. Who knows what type of dentists they will become if this trend continues? Let's all pitch in and do our part! This trend can be reversed, but only with your help.

DAVID J BALES
Editor

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ORIGINAL ARTICLES

Fracture Resistance of Teeth with Class 2 Silver Amalgam, Posterior Composite, and Glass Cermet Restorations

S JAGADISH • B G YOGESH

Summary

This article reports the fracture resistance of maxillary premolars in which ideal class 2 mesio-occlusal or disto-occlusal cavities were prepared and restored with silver amalgam, posterior composite, and glass cermet. Sound teeth and teeth with prepared but unrestored cavities were also studied for comparison. Dentin-bonded posterior composite resin produced the best tooth fracture resistance, followed by glass cermet, intact teeth, silver amalgam, and unrestored-prepared teeth, in that order.

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Introduction

The effect of masticatory stresses on teeth either restored or unrestored is variable. The anatomic forms of posterior teeth with cusps and fossae present a design with a tendency to deflect the cusps under stress. While sound teeth rarely fracture from mastication stress, cusp fracture may occur in teeth which have been weakened by caries and the cavity preparation required for restoration. While a fracture may not occur, deflection of a weakened cusp may open the tooth-restoration interface and lead to subsequent marginal leakage and secondary caries (Bassett, Ingraham & Koser, 1964;

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Mondelli & others, 1980).

Previous fracture studies have shown that teeth with cavity preparations become weaker as the occlusal isthmus is widened and they fracture more easily than do intact teeth (Vale, 1959; Mondelli & others, 1980; Larson, Douglas & Geistfeld, 1981; Blaser & others, 1983; El-Sherif & others, 1988). Amalgam, a widely used restorative material, does not bind the walls of the cusps together and may not strengthen the remaining tooth (Markley, 1951, 1958, 1966; Share, Mishell & Nathanson, 1982; Joynt & others, 1985, 1987; Gelb, Barouch & Simonsen, 1986). Bell, Smith, and de Pont (1982), in their study of cuspal failures in teeth restored with MOD amalgams, concluded that cusp fracture occurs as a result of brittle tooth structure fatigue caused by propagation of microcracks under repeated loading. Studies by Re, Draheim, and Norling (1981) and Eakle and Braly (1985), have dealt with the effect of sharp versus round line angles for cavity preparations on fracture resistance of teeth and have found no significant difference.

The use of adhesive materials to reinforce weakened teeth and support-undermined enamel was first proposed by Denehy and Torney in 1976. Etched and bonded composite resin restorations have been shown to increase the fracture resistance of teeth (Share & others, 1982; Landy & Simonsen, 1984; Morin, Delong & Douglas, 1984; Eakle, 1986; Gelb & others, 1986; McCullock & Smith, 1986b; Mackenzie, 1986). Combined enamel- and dentin-bonded composite resin restorations (Eakle, 1986), combined glass-ionomer and composite resin restorations (McCullock & Smith, 1986b) and glass-ionomer bases (Halverson & Hamilton, 1987) have been shown to increase the fracture resistance of teeth. But composites do have certain disadvantages in the form of polymerization shrinkage and cuspal movement (Causton, Miller & Sefton, 1985; McCullock & Smith, 1986a).

Recently glass cermets, introduced by McLean and Gasser in 1984, have been tried as a posterior restorative material. Glass cermets have been claimed to have certain advantages, such as adhesive chemical bonding, fluoride release, improved strength, and abrasion resistance (McLean & Gasser, 1985; Simmons, 1983).

The purpose of the present study was to compare the fracture resistance of teeth with class 2 preparations restored using glass cermet, posterior composite resin, and silver amalgam under compression load in a Universal Instron Testing Machine (Instron Corporation, Canton, MA 02021).

Materials and Methods

Unrestored, noncarious maxillary premolars that had been extracted as part of orthodontic treatment and had been kept moist in 10% formalin were examined with Translux-Kulzer visible light (Kulzer & Co GmbH, Friedrichsdorf, West Germany). Teeth found to have pre-existing cracks were discarded. The teeth used had been extracted from one week to two months prior to the study. The crowns of the teeth were measured faciolingually and mesiodistally to establish a medium size range (faciolingually 8.3 - 9.3 mm and mesiodistally 6.5 - 7.5 mm). Forty teeth in this size range were selected and then randomly divided into five groups: Group 1: five intact teeth, Group 2: five teeth with class 2 cavities prepared and unrestored, Group 3: 10 teeth with class 2 cavities prepared and restored with silver amalgam, Group 4: 10 teeth with class 2 cavities prepared and restored with dentin-bonded posterior composite resin, and Group 5: 10 teeth with class 2 cavities prepared and restored with glass cermet.

Ideal class 2 mesio-occlusal or disto-occlusal cavities were prepared in the specimens of Groups 2 through 5. The preparation was cut under air-water spray in a high-speed handpiece. Access was gained by using a #2 round bur on the occlusal surface at the center of the mesiodistal groove by preparing a well with slight pulpal pressure until a depth of 1.5 mm was attained. Mesial or distal extension was prepared using a #56 straight fissure bur. The width of the occlusal portion was kept to between 1.5 mm to 1.75 mm faciolingually. The approximal step was prepared to a width of 2 mm faciolingually and 1.5 mm mesiodistally. The gingival floor was kept to 1.5 mm from the cementoenamel junction. A metal gauge 2 mm x 1.5 mm was used as a guide in preparation. A pear-shaped bur #245 was used to prepare facial and lingual walls of the cavity to be perpendicular to the occlusal inclines. The occlusal dovetail included a mesial pit for disto-occlusal cavities and a distal pit for mesio-occlusal cavities. All the line angles were rounded except for the axiogingival line angle, which was kept sharp. Bevels and retentive grooves were not utilized. Preparation was finished by using suitable hand instruments such

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as hatchets, hoes, and gingival marginal trimmers.

The teeth in Group 3 were restored with high-copper silver amalgam (Solila Nova, Dentsply/DeTray, Weybridge, Surrey, England) and the teeth in Group 4 were restored with visible-light-cured dentin-bonded posterior composite resin (Estilux Posterior, Kulzer & Co GmbH) and the teeth in Group 5 were restored with glass cermet (Chelon Silver, ESPE & Co GmbH, Seefeld/Oberbay, West Germany). All materials were used in accordance with the manufacturers' recommendations. All 40 of the teeth were then mounted in a base of dental stone within a metal ring of 2 cm diameter, exposing only the crown portion. After the dental stone had set, the specimens were wrapped in damp gauze and stored for 24 to 48 hours before testing.

All 40 of the teeth were then subjected to a compressive load in a Universal Instron Testing Machine. Two metal rods were used, each 2 mm in diameter, contacting the specimens parallel to the occlusal surface. They were fixed to a magnet 4.5 mm x 15 mm, which was added to the crosshead of the testing machine. The points of contact were flattened with a fine diamond to prevent the metal rods from slipping. The use of a magnet and two metal rods allows for appropriate adjustment to the various occlusal surfaces. The use of two metal rods, each 2 cm in diameter, instead of one metal rod 4.81 mm in diameter, assured contact with tooth structure alone without loading the restorative material during the testing procedure (Fig 1). A crosshead speed of 0.1 mm/second (0.23 inch/minute) was used to apply a load to the point of fracture for each specimen (Fig 2). The loads required to fracture the teeth were recorded in kilograms (kgs), and the data obtained were subjected to statistical analysis.

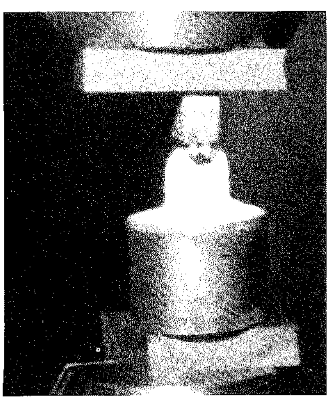

FIG 1. *Close-up view of tooth under load in Universal Instron Testing Machine*

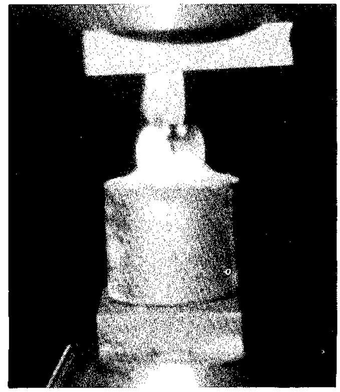

FIG 2. *Tooth being fractured after maximum load*

Results

Table 1 depicts the mean and standard deviations of the loads required to fracture the samples of the five groups. It may be observed that the values of Group 2 are the lowest and that of Group 4 the highest, while the values of the other groups are between these two. Group 5 had higher fracture resistance values than Group 1, and Group 3 had lower values than Group 1.

Table 1. Mean and Standard Deviations of Five Groups (Kgs)

Group	# of Samples	Mean	Standard
1. intact	5	187.24	38.07
2. prepared-unrestored	5	81.42	20.37
3. silver amalgam	10	169.41	61.34
4. posterior composite	10	256.33	78.64
5. glass cermet	10	217.64	76.06

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Table 2 demonstrates the significant difference between the five groups using analysis of variance (ANOVA), $P < 0.005$.

Table 2. Analysis of Variance between the Groups

Source	df	SS	MS	F	P
Between groups	4	114081.51	28520.3775	6.6976	< 0.005
Error	35	149039.93	4258.28		
Total	39	263121.44			

Discussion

The purpose of a restorative material is not only to restore the decayed or defective tooth, but also to strengthen the tooth and provide an effective seal between the restoration and the tooth.

The present study varies from several other studies in which either MO or DO cavity preparation was used instead of MOD cavity preparation, because the clinician is more often confronted with MO or DO restorations than MOD restorations in routine practice.

In the present study, the strength of the teeth was reduced significantly after cavity preparation, as shown in most of the other studies (Mondelli & others, 1980; Joynt & others, 1985, 1987; Gelb & others, 1986; El-Sherif & others, 1988). It is interesting to note that in the studies of Blaser and others (1983) and Re and others (1981), there was no significant difference between fracture resistance of teeth which were intact and that of teeth which were prepared and unrestored.

In this study teeth restored with silver amalgam (Group 3) fractured to a lesser load than that applied to intact teeth (Group 1). Group 3 (silver amalgam) had significantly better fracture-resistance values than that of Group 2 (prepared-unrestored teeth). But according to Bell and others (1982), the widely used restorative material, amalgam, does not bind the walls of the cusps together and thus does not strengthen the remaining tooth. The clinician who uses silver amalgam should always be aware of the fact that whenever the cavity is cut and restored with silver amalgam, the tooth is no stronger than the intact tooth, rather it will be weaker; hence the more conservative the cavity design for amalgam, the less damage or lowering of tooth strength. Bell and others (1982), in their study of cuspal failure in teeth restored with MOD amalgam, concluded that cusp fracture occurs as a result of brittle tooth structure fatigue caused by propagation of microcracks under repeated loadings. For these reasons, the use of adhesive restorative materials was considered to strengthen the teeth.

The results of Group 4 (posterior composite resin) indicate that posterior composite resin has great potential as a cusp-reinforcing material. In this study, the dentin-bonded posterior composite resin has proved to be the most effective in offering fracture-resistance of teeth. Studies of Eakle (1986), Eakle and Braly (1985), McCullock and Smith (1986b), and Gelb and others (1986), also have shown improved fracture resistance of teeth after using composite resins for MOD restorations.

The results of Group 5 (glass cermet) indicate that glass cermets are also good in reinforcing the teeth. Donly, Wild, and Jensen (1988) in their study have found glass cermet to be better than amalgam and inferior to posterior composite in reinforcing primary teeth.

It is interesting to note in the present study that Group 4 (posterior composite resin) and Group 5 (glass cermet) produced better fracture-resistance values than that of Group 1 (intact teeth). The retained marginal ridge may by itself add strength to a tooth in which a MOD cavity has been prepared. The additional area for adhesion in Group 4 and Group 5 may also contribute some additional strength.

Individual variations in morphology among the teeth, including angulation of cuspal inclines, thickness of enamel, inherent weaknesses, slight variation among the size of teeth, and slight variations in the level of contact of the metal rods with the cuspal inclines during fracture were among many factors that likely contributed to the large standard deviations. Had a standardized tooth model been available, the standard deviations may have been reduced.

Fractures of the teeth in Groups 1, 2, and 3 either separated one cusp at its base near the cementoenamel junction or split the tooth through the pulpal floor extending into the root. In Group

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4, fractures occurred through the preparation, with failure occurring at the interfacial area of the facial or lingual wall and the restoration. Fractures in Group 5 always occurred through the bulk of the glass cermet. The samples show glass cermet adhering to the cavity walls after fracture, which proves superior bonding of glass cermet to tooth structure when compared to posterior composite. Based on the nature of fractures seen in the present study, it is apparent that the strengthening effect on the teeth of the restorative materials is influenced by various factors responsible for achieving superior bond between restoration and tooth structure.

Many differences exist between fractures occurring clinically and those induced by a testing machine. Forces generated intraorally during function vary in magnitude, speed of application, and direction, whereas the forces applied to the teeth in this study were at a constant direction and speed, and they increased continually until fracture occurred.

Cuspal movement produced by polymerization shrinkage of posterior composites is undesirable, since it may lead to enamel fracture, gap formation between dentin and restoration, cracked cusps, postoperative pain, or microleakage (McCullock & Smith, 1986a; Causton & others, 1985). McCullock & Smith (1986a), have shown significantly reduced cuspal movements produced by glass cermet when compared to posterior composite.

McLean and Gasser (1985) describe glass cermets as glass-metal powders sintered to high density which can be made to react with acids to form a cement. A commonly used metal is silver powder. Like other glass-ionomer cements, glass cermets chemically bond to tooth structure and are considered to be cariostatic through fluoride release. McLean and Gasser (1985), have concluded that glass cermet's strength is still insufficient to replace amalgam alloys and their use should be restricted to low-stress-bearing cavity preparations.

Even though amalgam is widely used for class 2 restorations because of its superior mechanical properties, especially wear resistance, it does not reinforce teeth against fracture. The results of the present study indicate that posterior composite resin and glass cermet can increase the fracture resistance of teeth with MO or DO cavity preparations in the controlled laboratory environment; however, many factors influence the longevity and suitability for clinical use of these materials. Further improvements are needed in the posterior composite resins and glass cermets, and additional laboratory studies and studies in vivo are needed before these materials can be recommended for routine use as posterior restorative materials in clinical practice.

Conclusions

1. Dentin-bonded posterior composite resin produced the best fracture-resistance of teeth, followed by glass cermet, intact teeth, silver amalgam, and unrestored-prepared teeth, in that order.

2. Dentin-bonded posterior composite resin and glass cermet appear to increase the inherent strength of teeth when used as restorative materials.

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Effect of Retention Grooves on Fracture Strength of Class 2 Composite Resin and Amalgam Restorations

D J CAPLAN • G E DENEHY • J W REINHARDT

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Summary

The effect of approximal retention grooves on fracture strengths of class 2 composite resin and amalgam restorations was tested in vitro. Results indicated that retention grooves significantly improved ($P < 0.05$) the compressive strength of amalgam restorations (38.6% stronger). For posterior composite resin restorations, there was no significant difference in mean compressive strength of restorations in preparations with and without retention grooves.

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Introduction

The design of a cavity preparation is influenced by the chemical and physical properties of the restorative material. Since the traditional class 2 cavity preparation was designed with respect to amalgam, the use of posterior composite resin may dictate that modifications be made on the preparation.

One component of the class 2 cavity preparation is retention grooves in the approximal box (in the facial and lingual walls at the axial wall). These grooves improve the fracture strength of an amalgam restoration by protecting against approximal dislodgement resulting in fracture at the isthmus. Amalgam does not bond to tooth structure, while posterior composite resin may form a strong bond to enamel and a weaker bond to dentin (Leinfelder, McCartha & Wisniewski, 1985). This bonding may lessen or eliminate the need for approximal retention grooves in the posterior composite resin preparation.

Lloyd (1983) reported that some posterior composite resins have a "fracture toughness" comparable to high-copper (> 6% copper) amalgams, but lower than most low-copper amalgams. He defined "fracture toughness" as a property of the restorative material itself, and "fracture strength" as a measure of the resistance to fracture in an individual restoration as influenced by the external contour of the restoration, the fracture strength of the unrestored tooth, and the specific features and dimensions of the cavity preparation.

Amorim and others (1978) demonstrated that approximal retention grooves improved the compressive strength of class 2 amalgam restorations by 55% and decreased the standard deviation of results by 46%. Mondelli and others (1981), in a similar experiment, reported that approximal retention grooves improved compressive strength by 41%. These studies employed simulated cavity preparations in re-usable, flat-topped metal dies to minimize experimental variability. Due to the necessity of the posterior composite resin bond at the enamel bevel, extracted human molars were used in this study despite inherent differences in both occlusal morphology and fracture resistance of the teeth themselves.

The primary purpose of this investigation was to determine the effect of approximal retention grooves on compressive strength of class 2 posterior composite resin restorations. A secondary goal was to compare the relative compressive strengths of equivalent class 2 posterior composite resin and amalgam restorations.

Materials and Methods

Fifty freshly extracted permanent molars were utilized in this study. Each tooth was mounted in a phenolic ring with self-curing acrylic up to the CEJ. The mounted teeth were randomly distributed into five groups of 10 samples.

The five groups were assigned the following treatments: Group 1: Amalgam preparation with approximal retention grooves, Group 2: Amalgam preparation with no approximal retention grooves, Group 3: Composite preparation with approximal retention grooves, Group 4: Composite preparation with no approximal retention grooves, and Group 5: Control (no cavity preparation).

Class 2 MO cavity preparations were cut to the following dimensions and criteria (Fig 1): 1) Pulpal floor 1.5 mm deep, perpendicular to the direction of compressive load, 2) Axial wall 1.5 mm deep at the gingival floor, parallel to the direction of compressive load, 3) Gingival floor 2.0 mm gingival to the pulpal floor, perpendicular to the direction of compressive load,

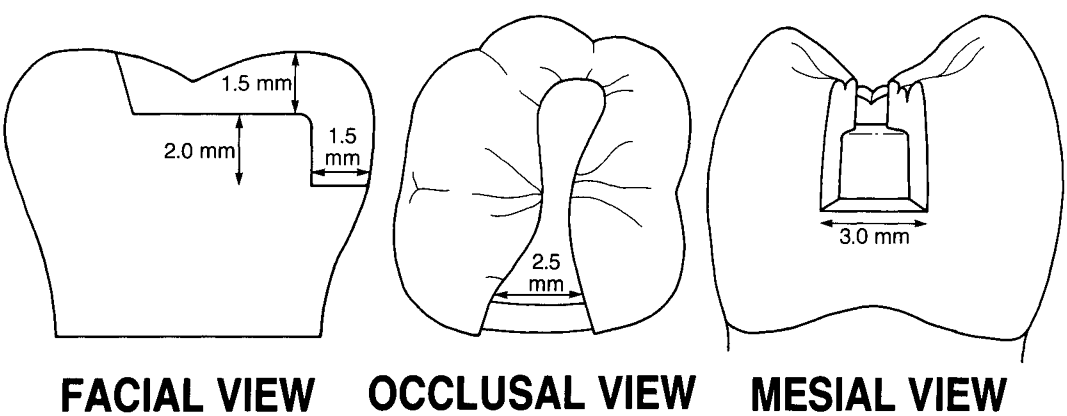

FIG 1. *Internal and external dimensions of initial class 2 MO cavity preparations*

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4) Faciolingual width at the isthmus: 2.5 mm, 5) Faciolingual width at the gingival floor: 3.0 mm, 6) Slight convergence of all facial and lingual walls toward the occlusal, 7) Slight divergence of the distal wall toward the occlusal, and 8) Slightly rounded axiopulpal line angle.

Groups 1 and 2 were cut with a #55 straight fissure bur and Groups 3 and 4 were cut with a #1157 bur. Groups 1 and 3 had retention grooves placed in the facial and lingual walls of the approximal box at the axioproximal line angles. Groove depth was that of a #1/2 round bur (0.60 mm) at the gingival floor, tapering to zero at the level of the pulpal floor (Fig 2). A 45°, 0.5 mm bevel was placed at the cavosurface margins of Groups 3 and 4. Group 5 served as the control and was not prepared.

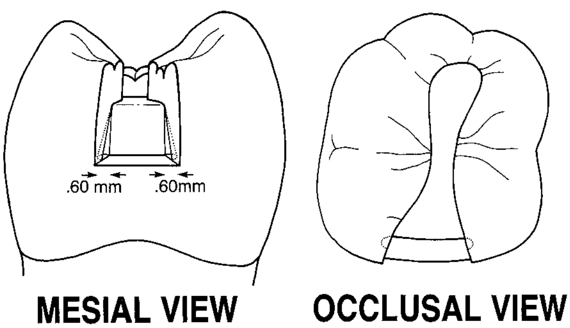

FIG 2. *Placement of retention grooves in Groups 1 and 3*

Relevant dimensions of each preparation were recorded after measurement to the nearest 0.25 mm with a periodontal probe.

Groups 1 and 2 were restored with amalgam. Each sample was rinsed and air-dried, and SnF_2 (Stable Stannous Fluoride, L D Caulk, Milford, DE 19963) was applied to the preparation for 15 seconds. Following air-drying, Copalite cavity varnish (Teledyne Getz, Elk Grove Village, IL 60007) was applied in two layers. A matrix band was affixed to the tooth, and Tytin amalgam (Kerr Dental Manufacturing Co, Romulus, MI 48174) was condensed into the preparation. Carving was completed according to the external contour of the tooth, and the restoration was thoroughly burnished. After 24 hours in a humidor at 37 °C, the restoration was polished and tested.

Groups 3 and 4 were restored with composite resin. Each sample was rinsed and air-dried. All beveled enamel surfaces were etched for 60 seconds with Kulzer Estic-Gel, a 37% phosphoric acid gel etchant (Kulzer Inc, Irvine, CA 92718), rinsed for 15 seconds, and air-dried. Two coats of a universal bonding resin, Caulk Prisma Universal Bond (L D Caulk, Milford, DE 19963), were placed on the dentin and enamel surfaces, lightly air-dried, and light-polymerized for 10 seconds. A posterior composite resin, Ful-Fil (L D Caulk) was placed into the preparation in 1.0 mm increments. Initial placement was at the gingival floor, and subsequent increments were placed occlusally. Each increment was light-cured for 40 seconds to ensure adequate polymerization. The restoration was finished and polished according to the external contour of the tooth. The sample was stored in a 37 °C humidor for 24 hours and then tested.

An Instron Universal Testing Machine (Instron Corporation, Canton, MA 02021) with a 5000 kg compression load cell was used for the fracture test. The instrument was calibrated electronically and the center of a probe with a 5 x 1 mm rectangular testing surface was placed above the center of the restored marginal ridge. A double thickness of lead foil was placed between the probe and the restoration in order to minimize chipping of the restoration. The probe moved apically (i e, perpendicular to the gingival floor) at a constant rate of 0.5 mm/min, and the value of the compressive load (in kg) at the time of restoration failure was recorded. Mean compressive strengths were statistically compared using analysis of variance (ANOVA).

Results

Before statistical analysis was done, each sample was visually examined to determine whether irregularities in the testing technique had led to any invalid data. Several values were discarded for the follow reasons: 1) On several specimens, the probe created a niche in the restorative material as it moved apically. This led to an inaccurate measurement, since the compressive load was borne not only by the gingival floor under the marginal ridge, but also by the mesial-most portion of the pulpal floor, and 2) In several trials, tooth fracture occurred prior to restoration fracture. Since the restoration was no longer completely supported by sound tooth structure, the data were discarded.

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The table presents the mean compressive strength and standard deviation of each group. ANOVA indicated significant differences between groups. The Duncan's Multiple Range Test shows the mean for Group 1 (amalgam with retention grooves) to be significantly higher than the other three restoration groups at the 95% confidence level, with no significant difference among the other groups.

Fracture Strengths of Restorations and Control Teeth

Treatment Group	Number of Samples	Mean Fracture Strength (kg)	Standard Deviation
Amalgam with retention grooves	7	92.0	13.2
Amalgam without retention grooves	7	66.4	28.0
Composite with retention grooves	8	71.8	5.7
Composite without retention grooves	8	65.1	11.9
Control (no preparation)	8	86.4	23.0

Discussion

The fact that posterior composite resin restorations exhibit only a minor increase in compressive strength when approximal retention grooves were added (10.3%, not significant, $P < .05$, compared to a significant 38.6% increase for amalgam restorations) is a reflection of the retention provided at the acid-etched enamel bevel. The decrease in standard deviation, seen in both amalgam and posterior composite resin restorations with approximal retention grooves, is consistent with Amorim and others (1978).

Only one dimension of the cavity preparation showed a relationship with compressive strength at the 95% confidence level: the greater the axial wall depth, the higher the compressive strength (only for amalgam restorations with no approximal retention grooves). This is understandable, as cavity preparations in only this group contained no mechanical retention (approximal retention grooves or acid-etched enamel bevel).

The clinical ramifications of this study are twofold. First, if posterior composite resin is to be used as the restorative material in a class 2 cavity preparation, approximal retention grooves will provide only minimal, if any, improvement in compressive strength. Second, the class 2 restoration will have the greatest compressive strength if approximal retention grooves are placed and amalgam is used as the restorative material.

Conclusions

1. Compressive strength of amalgam restorations was increased almost 40% by the incorporation of approximal retention grooves into the class 2 cavity preparation. The effect of retention grooves on posterior composite resin restorations was not significant at the 95% level.
2. Amalgam restorations with approximal retention grooves had significantly higher compressive strengths than amalgam restorations with no grooves, posterior composite resin restorations with no grooves, and posterior composite resin restorations with grooves. In addition, amalgam restorations with retention grooves had compressive strengths which were statistically no different than unprepared teeth. There was no significant difference in compressive strength among the latter three groups.
3. Approximal retention grooves decreased compressive strength variability for both amalgam and posterior composite resin restorations; variability was less for posterior composite resin restorations than for equivalent amalgam restorations.
4. If no approximal retention grooves are placed in class 2 amalgam preparations, the compressive strength of the restoration is proportional to the depth of the axial wall at the gingival floor.

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A Comparative Study: Bond Strength and Microleakage with Dentin Bond Systems

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Summary

Four commercial bond agent-composite systems were tested with respect to the strength of the bond to bovine dentin and their ability to seal class 5 erosion lesions without cavity preparation. At seven days there was no significant difference in the bond strengths of the four bonding agents, Scotchbond, Gluma, Tenure, and Scotchbond 2. Restorations placed with Gluma had significantly less leakage than those placed with other bond agents. At 90 days the bond strength of Tenure was reduced and was significantly less than that of the other systems, while Gluma and Scotchbond 2 restorations exhibited significantly less leakage than Scotchbond and Tenure. There was an inverse correlation (r^2 = .5460) between bond strength and marginal leakage of class 5 restorations.

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INTRODUCTION

Research continues in an effort to develop more effective dentin bond agents for bonding composite resins to dentin in order to retain restorations and to seal margins located in dentin and/or cementum. The common methods of evaluating these adhesives are by measuring the strength of the bond to dentin (Stanford, 1985a; Stanford 1985b; Retief & others, 1986; Reinhardt, Chan & Boyer, 1987; Hinoura, Moore &

Phillips, 1986; Pashley & others, 1988), either in a shear or tensile mode, and by testing the marginal seal of restorations placed in extracted teeth (Gordon, Plasschaert & Stark, 1986; Montiero & others, 1986; Leclaire & others, 1988; Darbyshire, Messer & Douglas, 1988; Crim, Esposito & Chapman, 1985). However, there is little data correlating the two test procedures (Hammesfahr, Huang & Shaffer, 1987). Thus, in this study the bond to dentin of four popular bond agents was tested in tension and the values compared to the marginal leakage of these same systems when used to restore class 5 simulated erosion lesions without cavity preparation.

METHODS AND MATERIALS

The dentin bond agent-composite systems tested are shown in Table 1.

Table 1. Dentin Bond Agents

Dentin Bond Agent	Composite	Manufacturer
Scotchbond	Silux (microfill)	3M Dental Products St Paul, MN 55144
Scotchbond 2	Silux (microfill)	3M Dental Products
Gluma	Lumifor (hybrid)	Columbus Dental St Louis, MO 63188
Tenure Simplified + Visar Seal	Perfection (microfill)	Den-Mat Corp Santa Maria, CA 93456
No Bond Agent	Silux (microfill)	

Adhesion Tests

The substrate employed in the adhesion tests was bovine dentin. The facial surfaces of bovine incisors, stored wet following extraction, were ground under water so as to expose a flat area of dentin 7 or 8 mm in diameter. The teeth were mounted in cylinders of cold-cure acrylic so as to expose the dentin surface. Immediately before preparation of each adhesion specimen, the exposed dentin surface was freshened by hand grinding on wet 600-grit silicone carbide paper. The surface was then rinsed in a stream of water for 30 seconds, dried for 20 seconds with compressed air and the dentin bond agent applied in accordance with the respective manufacturer's instructions, with the exception of one material. The manufacturer of Gluma did not recommend curing the bond agent prior to the placement of the first increment of the composite filling resin; however, preliminary tests indicated a higher bond strength to dentin was attained by curing the sealant. Thus in this study the Gluma bond agent was exposed to the light source for 20 seconds. All curing was done via a Coe light (Coe Laboratories, Inc, Chicago, IL 60658); the output was monitored before and after fabrication of each group of specimens to ensure a minimum intensity at 1000W/m^2.

After placement of the bond agent, a Delrin mold (Du Pont Pharmaceuticals, Wilmington, DE 19898), 6 mm high with a 4-mm bore chamfered at the top, was placed on the surface (Fig 1). The appropriate composite resin was introduced into the mold in 2-mm increments with each increment being subjected to a one-minute exposure to the curing light. The specimens were placed in a humidor at 37 °C for one hour, then immersed in water and stored at 37 °C until tested at seven and 90 days. All specimens were thermal-stressed during the storage periods by

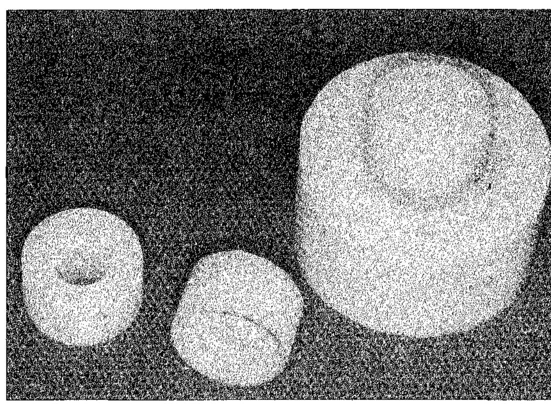

FIG 1. *Adhesion specimens: Left--Delrin molds; Right--completed adhesion specimen*

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subjecting them to 2500 cycles between two water baths having a 40 °C temperature differential. The dwell-time in each bath was 30 seconds.

At the end of the storage period the specimens were supported in a Universal Testing Machine (Instron Corporation, Canton, MA 02021) by means of a device designed to minimize stresses other than tensile (Fig 2). They were loaded in tension to failure at a crosshead speed of 0.5 mm per minute. Failed specimens were examined by light microscopy to identify and record the failure modes.

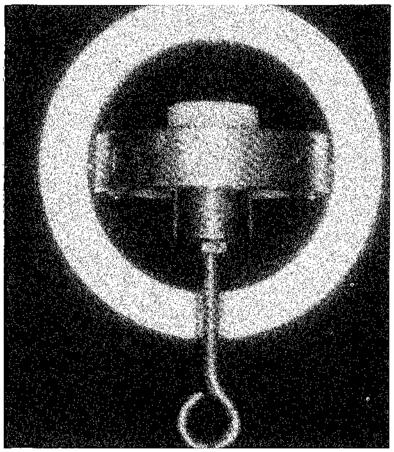

FIG 2. *Adhesion specimen supported on alignment device for testing in tension*

Each test group consisted of 20 specimens. Since the data were not normally distributed nor the variances uniformly distributed, the Kruskal-Wallis H test was employed to determine significant differences. When significant differences existed the Mann-Whitney U statistic was used for multiple comparison of test groups.

Microleakage Tests

Simulated class 5 erosion lesions were prepared in extracted human cuspid and premolar teeth that had been stored wet since extraction. The V-shaped cavities of uniform size were prepared by an inverted cone greenstone with water spray. All gingival margins were located in dentin and/or cementum.

In order to produce a dentin surface that more closely resembled that of a natural lesion the cavities were brushed for eight minutes in a mechanical brushing machine in a 1:1-by-weight water slurry of dentifrice. The surfaces of a natural and simulated cavity are compared in Figure 3.

Twenty teeth were restored with each of the four bond agent-composite systems. In addition a group of 20 teeth was restored with a microfilled composite without use of a dentin bond agent. Immediately before restoration of each tooth, the enamel margin was beveled and the

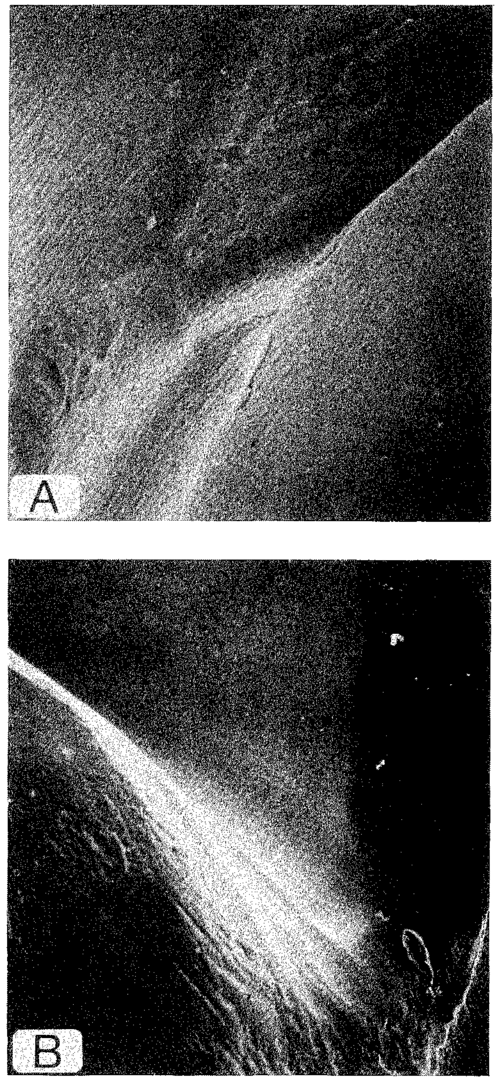

FIG 3. *Comparison of surfaces of (A) a natural erosion lesion, and (B) simulated erosion lesion (X50)*

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cavity was freshened by means of a pumice slurry applied with rubber cup. The cavity then was wiped with a cotton pledget moistened with H_20_2, rinsed, and dried. The respective dentin bond agents were applied to the cavity in the same manner as employed in preparation of the adhesion specimens. Two increments of composite resin were used to fill the cavities as shown in Figure 4. Each increment was cured for 60 seconds, the last one through the mylar matrix strip. At 15 minutes the flash was removed and the restorations finished with aluminum oxide disks. The restored teeth were then immersed in water at 37 °C until tested, 10 specimens at seven days and 10 at 90 days for each material. The specimens were thermal-stressed in the same manner as the adhesion specimens.

After storage the teeth were sealed, except for a 1-mm-wide area surrounding the restorations, and immersed in a pH 5.5 solution of $^{45}CaCl_2$, 0.1 mci/ml for two hours. Leakage was revealed by autoradiographs generated from longitudinal sections through the restorations.

Marginal leakage was scored by comparing coded test autoradiographs with the series of standards shown in Figure 5. Three individuals evaluated the films and each person conducted three separate evaluations. The Pearson correlation test indicated no significant difference in either intra- or inter-evaluator scores, hence the data were combined. Ridit analysis was done on the combined data and the ridit population values calculated. Since Bartlett's chi-square test indicated variances to be homogeneous, a one-way analysis of variance was performed on the seven-day and the 90-day data. The Newman-Kuels test was used for multiple comparisons. Student's *t*-test was employed to compare seven-day and 90-day data.

In order to compare the bond-strength data with that of the leakage data, the correlation coefficient was calculated.

FIG 4. *Erosion lesions were restored by insertion of composite resin in two increments. Increment #1 was cured for 60 seconds prior to insertion of increment #2, which then was cured for 60 seconds.*

RESULTS

Tensile Bond

The mean tensile bond strengths for the four

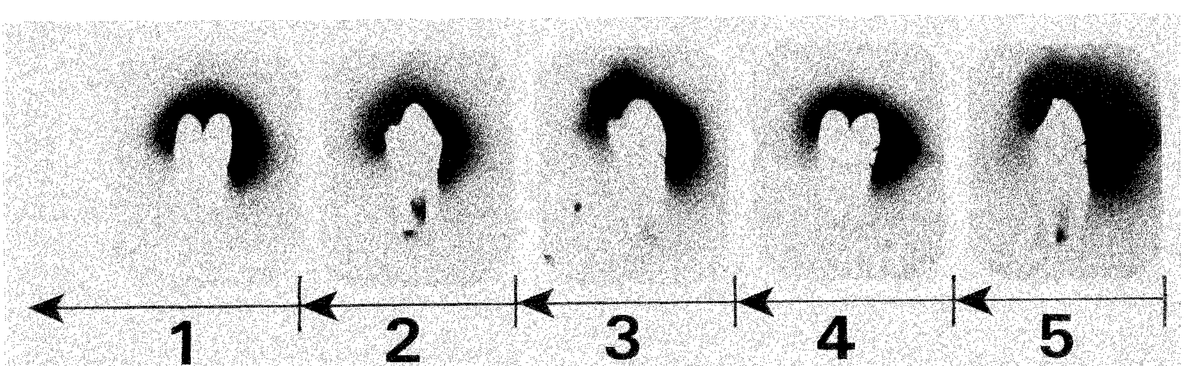

FIG 5. *Series of standard films for evaluating leakage. Scoring: penetration >Film 2 but ≤Film 3 = Leakage Value 3.*

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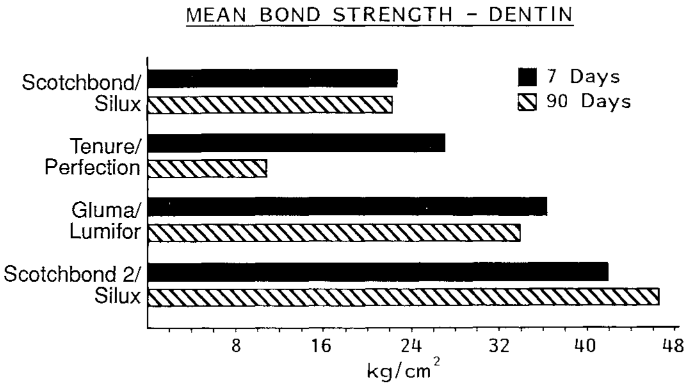

FIG 6. *Mean tensile bond strength to dentin of various bond agent-composite systems at seven and 90 days*

systems are compared in Figure 6. At seven days mean bond strengths ranged from 22.8 kg/cm² for Scotchbond to 42.0 kg/cm² for Scotchbond 2, and at 90 days from 11.1 kg/cm² for Tenure up to 46.5 kg/cm² for Scotchbond 2. Statistical analysis of the data (Table 2) does not indicate a significant difference between materials at seven days, but at 90 days the Tenure system was significantly different ($P \leq .05$) from the other three systems. Comparison of the seven- and 90-day data for each system shows no significant change in bond with time for materials other than Tenure. Examination of failed specimens revealed the predominant mode of failure of Gluma, Scotchbond, and Tenure specimens to be adhesive at the dentin-bond agent interface while approximately three-fourths of the Scotchbond 2 specimens failed partially or entirely in cohesion, generally through the composite but occasionally through dentin (Table 3).

Table 2. Summary--Statistical Analysis

Material	Bond Strength--Kg/cm² 7 days	Bond Strength--Kg/cm² 90 days
Scotchbond 2	42.0 ± 24.6	46.5 ± 20.6
Gluma	36.5 ± 36.4	34.3 ± 31.0
Scotchbond	22.8 ± 13.2	22.6 ± 10.2
Tenure Simplified + Visar Seal	27.1 ± 20.4	11.1 ± 8.5

(Values connected by lines not significantly different; $P \leq 0.05$)

Table 3. Failure Mode--Bond Strength

	# of specimens					
	7 days			90 days		
	A*	C**	A-C+	A*	C**	A-C+
Scotchbond 2	6	3	11	4	2	14
Gluma	16	0	4	16	2	2
Scotchbond	19	0	1	20	0	0
Tenure Simplified + Visar Seal	18	0	2	20	0	0

*A = Adhesive failure at dentin-bond agent interface
**C = Cohesive failure of composite or dentin
+A-C = Combination adhesive-cohesive failure

Microleakage

The mean leakage data for restorations placed with the various bond agent-composite systems appear in Figure 7. Ridit values for restorations at seven days ranged from 0.21 for Gluma-Lumifor up to 0.54 for Scotchbond-Silux. The ridit value for Silux restorations placed without a bond agent was 0.85. At 90 days ridit values ranged from 0.23 for Gluma-Lumifor to 0.75 for Tenure-Perfection.

The summary of the statistical analysis of the

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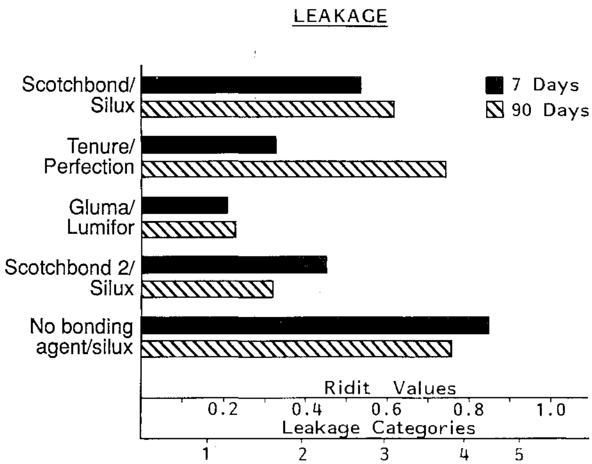

FIG 7. *Mean leakage of erosion lesions restored with various composite-bond agent systems and composite without a bond agent at seven and 90 days*

data is shown in Table 4. At seven days Gluma-Lumifor restorations had significantly lower leakage than the other three bond agent-composite systems tested while restorations placed without a bond agent had significantly more leakage than did those placed with bond agents. At 90 days Gluma-Lumifor and Scotchbond 2-Silux had significantly less leakage than Tenure-Perfection, Scotchbond-Silux, and the "no bond agent" restorations. Tenure-Perfection restorations exhibited a significant increase in leakage with time. Of those specimens that leaked, the most prevalent site of leakage was the gingival margin (Table 5).

The bond-strength values and the corresponding leakage values are compared in Figure 8. There was an inverse correlation, $r^2 = .5640$, between bond-strength and leakage data.

Table 4. Summary–Statistical Analysis

Material	Leakage--Ridit Values 7 days	90 days
Gluma	0.21 ± 0.09	0.23 ± 0.15
Scotchbond 2	0.45 ± 0.23	0.32 ± 0.18
Tenure Simplified + Visar Seal	0.33 ± 0.21	0.75 ± 0.18
Scotchbond	0.54 ± 0.20	0.62 ± 0.23
No Bond Agent	0.85 ± 0.14	0.76 ± 0.17

(Values connected by lines not significantly different; $P \leq 0.05$)

DISCUSSION

As with most dental adhesion tests, particularly those conducted on dentin, there was considerable scatter of data within test groups. A number of contributing factors associated with the test procedure have been cited as causes for difference in bond-strength values. These include the distance of the test surface from the dentino-enamel junction and alignment of specimens in the test apparatus. In this study a technical problem associated with the bond agents themselves was encountered. If the thickness of the bonding agent was too thin, the material failed to polymerize or the cure was inadequate, which resulted in no or low bond strengths. Although every effort was made to apply the resin in an appropriate thickness, this was difficult to judge. Therefore some of the extremely low bond strengths within test groups may have been the result of too thin a layer and hence inadequate polymerization. This same factor could have been responsible for some of the variation in the seal of the restoration within test groups since the same problem of determining an adequate thickness of bond agent existed. If this is a problem on the laboratory bench, it undoubtedly is a greater one in the clinical situation.

The inverse correlation between leakage and bond strength, although not a high one, might suggest that it may not be necessary to run both bond strength and leakage tests in the evaluation of a bond agent. However, the minimum bond strength required to counteract stresses induced by polymerization shrinkage and thermal stress is not known. Furthermore this minimum value could well be influenced by a variety of factors that include the polymerization shrinkage and coefficient of thermal expansion of the filling resin, the cavity size and geometry, as well

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Table 5. Site of Leakage

	# of specimens							
	7 days				90 days			
	No Leak	G*	O**	G+O+	No Leak	G*	O**	G+O+
Gluma	8	0	2	0	8	1	1	0
Scotchbond 2	3	5	0	1	5	5	0	0
Tenure Simplified + Visar Seal	5	0	4	0	0	1	2	5
Scotchbond	1	8	1	0	1	5	1	2
No Bond Agent	0	6	0	3	0	4	0	4

*G = Gingival only
**O = Occlusal only
+G+O = Both gingival and occlusal

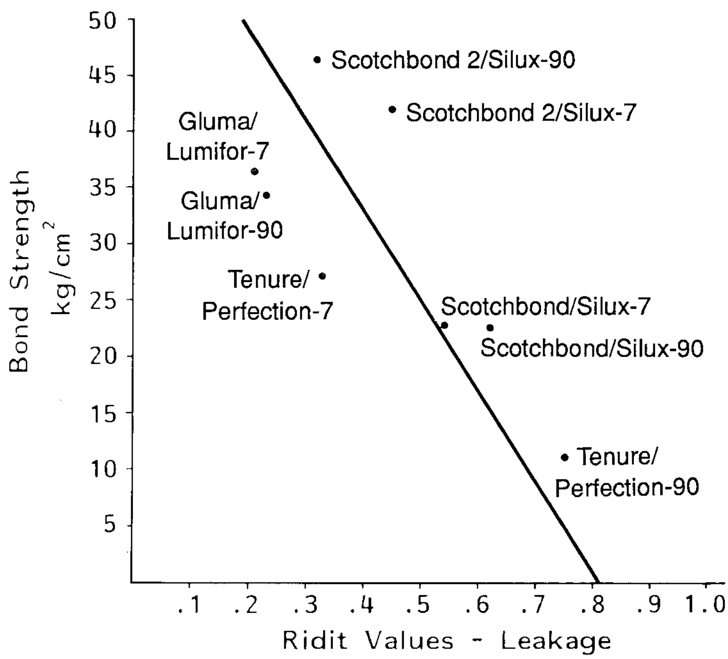

FIG 8. *Bond strength to dentin as related to leakage, regression curve,* $r^2 = .5460$.

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as technical problems in application of the bonding material. These factors would suggest that it would be prudent to employ both tests in screening materials.

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LITERATURE REVIEW

The Porcelain Inlay: A Historical View

A J E QUALTROUGH • N H F WILSON • G A SMITH

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INTRODUCTION

The search for the ideal restorative material continues. Amalgam alloy still remains the most widely used restorative for posterior teeth, but this pattern of practice is changing as a result of the materials and techniques developed in recent years, changing patterns of disease, and new approaches toward cavity design. There has been an increased demand for aesthetic restorations and also growing concern about biocompatibility, raising questions regarding the safety of mercury in amalgam, both to surgery staff and to the patient (Eley & Cox, 1988). Despite the promising results which have been achieved with posterior composite resins (e g, Wilson, Wilson & Smith, 1988), polymerization shrinkage, surface wear, and questions about biocompatibility have been highlighted as disadvantages. A practical solution may lie in the form of the porcelain inlay; porcelain has many excellent properties, particularly in terms of biocompatibility, chemical durability, and optical and aesthetic properties.

As long ago as 1913, N S Jenkins, writing in *The Dental Cosmos*, highlighted advantages of the porcelain inlay which includes conservation of tooth structure and thermal insulation. He concluded that, "... to add restoration of the original beauty of the teeth is a supreme triumph ... ." In fact the porcelain inlay technique was advocated as early as 1862 (McGehee, True & Inskipp, 1956), yet interest shown by the dental profession has fluctuated over the years and has to a large extent been influenced by other developments, including those in porcelain furnaces and frits, the introduction of silicate cements (Fletcher, 1871), acrylic resins (Blumenthal, 1947), and the acid-etch technique (Buonocore, 1955). Diamond cutting instruments, increased handpiece speeds, elastomeric impression materials, and glass-ionomer cements have all in some way influenced the role of the porcelain inlay.

Porcelain inlays, however, have never been

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adopted for routine, widespread use because of the exacting techniques, time-consuming methods, and consequential expense in fabrication. Since the introduction of porcelain inlays, numerous techniques have been devised both to increase the accuracy of fit of these restorations and to improve the simplicity and ease of fabrication. Firing shrinkage, soluble cements, and susceptibility to failure under occlusal loading have been cited as disadvantages in the past, and more recently concern has been directed towards the considerable effects of wear of porcelain on opposing teeth. Gradual wear of opposing teeth is a normal phenomenon, although the rate may vary. This natural process may be disturbed by the introduction of restorations, with wear resistance differing from that of enamel. Porcelain is of particular concern in this regard because of repeated clinical observations of excessive wear of opposing teeth or of restorative materials, and it is generally concluded that the rate of wear varies depending on the surface finish of the porcelain (Monasky & Taylor, 1971).

Recent advances in dental materials have resulted in the development of shrink-free porcelains which may be etched and bonded to composite resins via intermediate silane coupling agents, theoretically providing restorations exhibiting insignificant volumetric shrinkage and good marginal seal. Deines concluded that this advancement in restorative dentistry has resulted from the search for a more biocompatible substitution for natural tooth structure (Deines, 1986).

To date porcelain would appear to have a poor track record when used as restorative material for posterior teeth. With recent developments as outlined above, there would now appear to be new incentives to investigate different porcelain systems and to reassess the role of the porcelain inlay in operative dentistry.

The aims of this article are to outline the development of porcelain and the porcelain inlay, and to then consider more closely developments and attitudes pertinent to this restorative procedure over the past century.

HISTORY OF PORCELAIN: USE IN DENTISTRY

Definitions

The word ceramic is derived from the Greek 'keramos' (pottery) meaning "of or pertaining to pottery, especially as an art."

Porcelain is defined as a "fine kind of earthenware, having a translucent body and a transparent glaze, or as an article or vessel made of porcelain" (*The Shorter Oxford English Dictionary*, 1977).

Early History

Ceramics are thought to be the first materials ever made by human beings. Historically, three basic types of ceramic material were developed: earthenware was fired at low temperatures and was relatively porous; stoneware, which appeared in China 100 years BC, was fired at a higher temperature than earthenware, resulting in a stronger and more impervious material; fired porcelain was developed in China circa 1000 AD by potters/ceramists who were famous for their colored glazes, and it was produced at high temperatures. In 1375 porcelain was copied in Florence and rapidly became popular throughout Europe.

The history of porcelain used as a dental material goes back nearly 200 years, when it was found possible, using this material, to reproduce the color and translucency of natural teeth, and the first porcelain teeth were manufactured. In 1774 a French pharmacist and chemist, Alexis Duchâteau, became unhappy with the odor, taste, and discoloration of his hippopotamus-ivory denture, which had become impregnated with various medicinal compounds tasted in their preparation, but he could find nothing that would bleach the stains away. He noticed that the porcelain materials in daily use for grinding chemicals appeared to resist staining and abrasion, so he attempted to make a set of porcelain dentures for himself following an application to the porcelain manufactory of M Guerhard in Paris (Guerini, 1909). Following several unsuccessful attempts, Duchâteau enlisted the help of Nicholas Dubois de Chemont, a surgeon in Paris before the French Revolution. Together they made new attempts by modifying the composition of their high-fusing porcelain paste by adding pipe clay and coloring earths to appreciably lower the firing temperature, and were successful in producing satisfactory dentures. Dubois continued to develop techniques to control contraction, shading, and also retention by fixing the dentures with interarch springs.

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The first single porcelain teeth were introduced in 1808 in Italy by Fonzi (Guerini, 1909). Small metal hooks or loops were embedded in the porcelain teeth for mounting on denture bases. These teeth soon became known as 'bean teeth' because they were rounded and enamelled on the buccal and fitting surfaces. Porcelain teeth were subsequently manufactured around long, straight platinum pins that were intended to be soldered with gold to a metal base plate. With the introduction of vulcanite, these pins had to be bent by the dentist in order to provide mechanical retention in the vulcanite base.

THE PORCELAIN INLAY

John Murphy of London in 1839 introduced a platinum-foil technique which made the present-day development of porcelain-inlay construction possible (Huff, 1928).

1880-1890

Inlays of "pulverized" glass were advocated by Herbst of Germany in 1882 (Ernsmere, 1900). The method described was to take an impression in wax and cast two models in a mixture of plaster and asbestos. A quantity of ground glass made from Venetian glass beads of several colors was placed in one model and fused by means of a Bunsen burner and mouth-blow pipe. Firing shrinkage was accommodated by placing the inlay in the second model, adding more glass and fusing again. It was said of this technique that "The filling is made in a very few moments and can be prepared by an assistant ... can with practice be made a very good match to the colour of the natural tooth and a perfect fit" (Bruce, 1891).

In order to secure an impression which would give clearly defined edges, Land devised the metal-foil technique (Ernsmere, 1900). He initially tried gold, but found that it would not stand the heat required to fuse high-grade porcelain and that low-fusing porcelain did not then have the texture, strength, color, and permanency of the high-grade porcelain bodies. He then went on to use platinum foil, which was burnished directly into the inlay cavity, withdrawn, and used as a replica of the prepared cavity. Into this model or die could be placed high-grade porcelain, which was fused twice, additional porcelain being added after the first firing to accommodate for shrinkage.

Land took out a patent covering the platinum-foil technique and in 1884 pioneered the development of the first gas furnace for fusing porcelain. By 1886 he was said to be making successful inlays and crowns.

1890-1900

Following the development of the first electric furnace by Custer in 1894 and the introduction of low-fusing porcelain for inlays by Jenkins in 1898, Le Gro is reported to have said, "About 1899 or 1900 there crept over the dental profession a wonderful enthusiasm for porcelain-inlay work, and for a period of two to three years, more attention was given this material than any other operative work" (Le Gro, 1921). This, he noted, was without full appreciation of the poor edge-strength of porcelain inlays and the limitations of the cement (silicophosphate) lute.

1900-1910

Porcelain-inlay work was at its most popular at around the turn of the century, following the introduction of mineral stains in 1904.

Enthusiasts of this decade (Nyman, 1905) recommended porcelain for class 3, 4, and 5 cavities in incisors and for buccal and occlusal cavities in vital premolars and permanent molar teeth. The inlays were produced either by a direct or more usually by an indirect technique, using an impression of composition into which an amalgam die was formed and boxed-in with cement.

High-fusing electric furnaces (fusion at 2200 °F) were recommended at this time, resulting in minimum shrinkage of the fused porcelain, and hydrofluoric acid was applied to the fitting surface until a 'honeycombed' appearance was produced. This procedure was considered to enhance retention by creating interlocks into which the cement would flow. The literature is unclear as to whether this is one of the first references to acid-etching in operative dentistry.

Nyman praised porcelain for many of its commendable properties, including those of good thermal insulation and excellent aesthetics, but described the poor edge-strength as being 'deplorable.' Noting that, as with any other filling material, the permanence of a porcelain inlay depends upon the integrity of its margins, he

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advised ardent inlay advocates that "... the sooner they recognise its metes and bounds and confine themselves to it, the better it will be for them and for their patients. One of the first problems that occurs to us is, 'Will the porcelain inlays preserve a tooth? Are they permanent?' ... in its proper field, it must be conceded that it is a most valuable filling material. Where are porcelain inlays advocated? Is there a sharp dividing line? Yes ... exposure of the margins to the stress of mastication."

1910-1920

Silicate cement appeared in 1912 and many dentists saw this material as a promising replacement for the more time-consuming porcelain. As it was eventually found that restorations of early silicates did not generally withstand the test of time, there was a gradual return to the porcelain inlay, but such inlays never regained the popularity they enjoyed at the turn of the century.

Jenkins was enthusiastic about the role of the porcelain inlay (when compared with the gold inlay), pointing out that such restorations necessitated less loss of tooth structure and were unaffected by thermal stimuli: "The well made porcelain inlay also renders the tooth practically exempt from secondary caries. It does not shrink in cooling. ... but it is in its aesthetic aspect that the porcelain inlay is most attractive" (Jenkins, 1913).

1920-1930

Le Gro spoke to the Michigan State Dental Society in 1921 regarding "The present status of porcelain in dentistry," saying that the porcelain art was no further advanced than it had been fifteen years ago and was falling from the crest of an operative wave of seven years' duration. He spoke of the tremendous enthusiasm for porcelain inlay work in 1899-1900, which had been followed by a very perceptible diminution in the number of porcelain enthusiasts. This reduced popularity could be attributed to failure to recognize the limitations of porcelain, underestimating edge strength, and that porcelain had been used for inlay work without thought for cavity design or for the mechanical properties of the material. He concluded that "Porcelain inlay work is gradually coming back in a more safe and sane way" (Le Gro, 1921).

Black's *Textbook of Operative Dentistry* highlighted problems encountered with the opaqueness of available cements. "Often a prepared inlay will appear as perfection itself when laid in the cavity without cement, but when cemented in place will look very badly because the opaque cement shows through the porcelain and completely changes its color and translucence" (Black, 1922).

1930-1940

The difficulties encountered with opaque cements persisted into this decade, although some special translucent inlay cements were introduced in an attempt to overcome problems of matching color and translucence.

Sir Norman Bennett cited three methods of fitting an inlay to a prepared cavity (Bennett, 1931):

1. Grinding ready-made porcelain to shape. There were various methods by which this could be achieved, e g:

   a. Cutting a piece of an artificial tooth to shape,

   b. Dall's method (Fig 1). This was confined to labial cavities which could be reduced to a circular form. The cavity would be cut to a circular shape and to its full depth and well undercut with burs which corresponded in size and shape to ready-made inlays. The inlay was tried in, cemented, and "polished" with Arkansas stones,

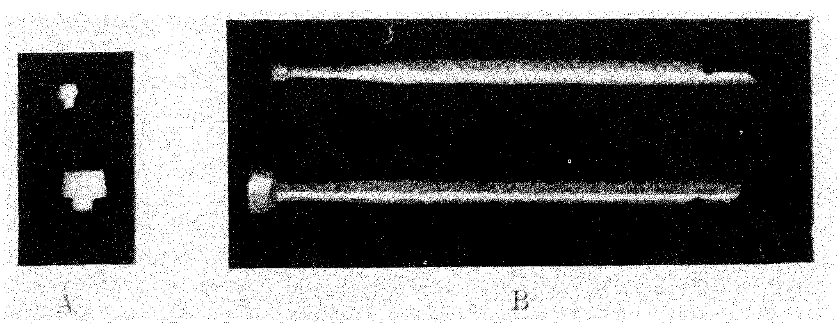

FIG 1A. *Large and small Dall's inlays*
FIG 1B. *Corresponding burs*

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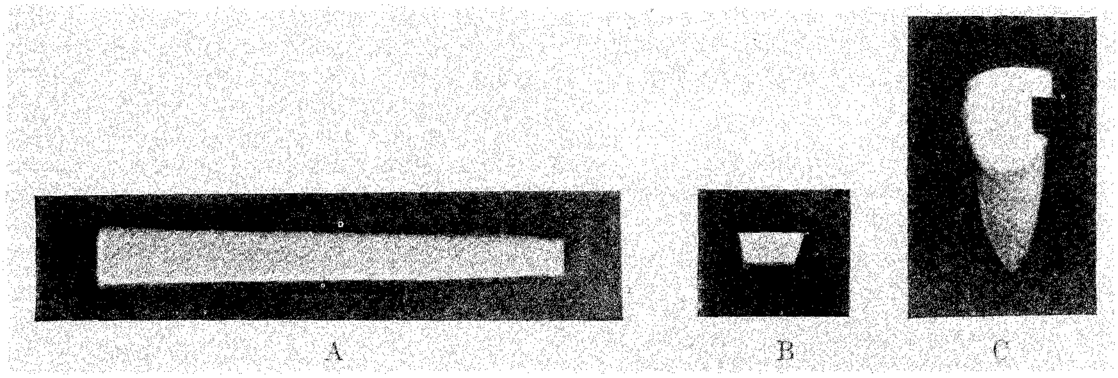

FIG 2A. *Howard inlay rod*

FIG 2B. *Howard inlay rod–cross section*

FIG 2C. *Cavity preparation for Howard inlay*

but further attention to surface finish was not detailed,

c. The Howard method (Fig 2). This included the fitting to the cavity of a ready-made porcelain rod which was dovetail-shaped in cross-section and tapered from the larger to the smaller end, so that an inlay of any size could be obtained by cutting the appropriate section.

2. Firing porcelain
3. Casting porcelain

Following a fall in popularity, the use of porcelain for inlays was revived in the 1930s by renewed interest in fusing porcelain directly into an investment model which eliminated the customary platinum matrix previously formed by burnishing and swaging into the prepared cavity or die.

A refractory model material coated with colloidal platinum was used with success by Brill and Wihmer in 1930 (McGehee, True & Inskipp, 1956), and other investigators in the 1930s introduced a variety of such refractory model materials.

1940-1950

Textbooks of this decade (e g, Parfitt & Herbert, 1943) advised against the application of the porcelain inlay in the class 2 situation due to its brittle nature. Mesial cavities in upper first premolars were considered to be exceptional to this rule for aesthetic reasons. Various techniques were described including:

1. Direct method using platinum foil,
2. Indirect method using platinum foil,
3. Indirect method without platinum, but using a refractory investment material,
4. Dall's method,
5. Peck 's method--a platinum matrix swaged to the impression (Fig 3), and
6. Cast method.

The casting temperature was 630 °C, but this technique was considered to be relatively inaccurate with a poor color match, and the long sprue accounted for considerable time in trimming and polishing the final restoration.

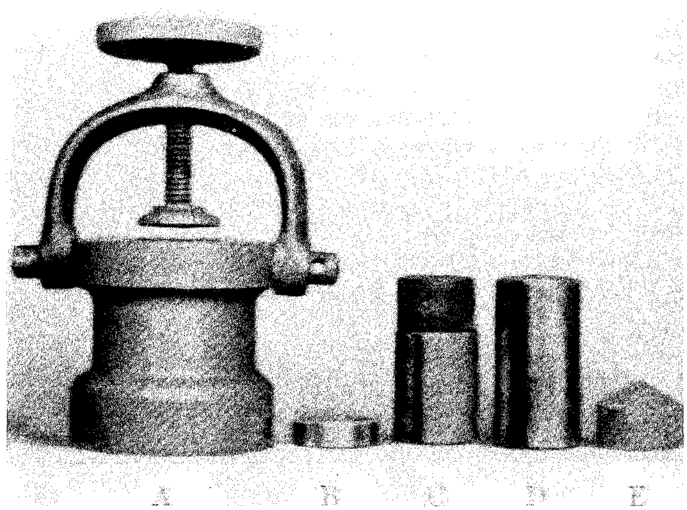

FIG 3A. *Ash's inlay press*

FIG 3B. *Bed plate*

FIG 3C. *Water bag plunger (thin foil swaging)*

FIG 3D. *Iron plunger (heavy swaging)*

FIG 3E. *Hard rubber block*

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Following the introduction of acrylic resin materials in 1945, the development and interest in porcelain underwent a considerable decline.

1950-1960

The 1955 edition of Black's *Operative Dentistry* attributed gold foil with the qualities most desirable for permanent restorations. Of porcelain inlays, the weak edge-strength in positions of occlusal stress was considered to be its most undesirable property and "The difficulties of manipulation, both to secure a good fit and the best possible shade are so great as to have caused a large percentage of operators to abandon the use of porcelain inlays, because of the time, patience and perseverence required to obtain satisfactory results in the general run of cases" (Blackwell, 1955). The author described the technique as one which was time-consuming and more exacting than any other, necessitating practically perfect work. In an indirect method a compound impression was taken after coating the cavity walls with vaseline. A 0.0001-inch platinum matrix was burnished and swaged into an amalgam die of the inlay cavity, and the fit of the matrix was checked after each firing. Porcelain powder was then built up on the matrix, vibrated, and fused at 1100 °F, several bakings being required. Following removal of the platinum matrix, hydrofluoric acid was applied to the fitting surface for 10 seconds, followed by washing with first ammonia and then water (Fig 4). At the time of placement, the dentine walls were undercut in order to enhance the retention of the inlay, which was generally cemented with zinc phosphate (Fig 5).

Other authors in the 1950s (McGehee & others, 1956) agreed that there was no other material which could compare with porcelain in reproducing the beauty of form and harmonious blend of shade and color in the restoration of lost tooth structure, but they also agreed that the porcelain inlay had no place in situations in which it would be subjected to stress, therefore confining its use to the class 5 situation. The poor adaptation to cavity walls and low crushing resistance were considered to be the major disadvantages.

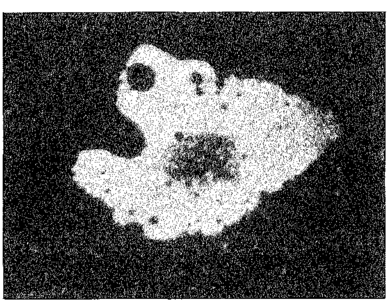

FIG 4. *Porcelain etched with hydrofluoric acid (Magnification X6)*

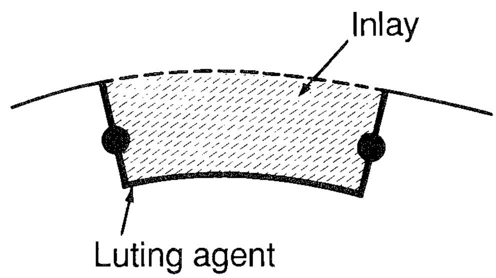

FIG 5. *Diagrammatic section of cemented inlay*

During the late 1950s and 1960s there were marked advances in the development of new techniques, materials, and equipment, e g, furnaces, alloys and porcelain frits. Improved tooth-cavity preparation using techniques based upon new, high-speed instrumentation and burs combined with the introduction of improved and more accurate impression techniques vastly changed clinical approaches and attitudes regarding porcelain restorations.

One of the most significant advances occurred with the introduction of the acid-etch technique in 1955 (Buonocore, 1955).

1960-1970

In descending order of preference, class 5, class 4, and class 3 cavities were considered to be suitable for porcelain restorations, but "abusive bite relationships" and exposure to occlusal stresses were regarded as contraindications (Schultz & others, 1966).

Methods by which porcelain inlays could be made included:

1. The direct method using platinum foil,
2. The indirect method using platinum foil. Either one of the new polysulphide materials or compositions was used as an impression

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material, and

3. The indirect method using a refractory investment material.

Once finished, the fitting surface of the inlay was grooved with a knife-edge or flame-shaped diamond point forming mechanically retentive grooves. These inlays were then cemented with a translucent silicophosphate cement.

Still the problem of marginal adaptation remained, but in 1969 Christensen and others measured the accuracy of fit of porcelain inlays fired directly into different types of refractory investment dies (Christensen, Brown & Babb, 1969). Although direct-fired inlays had by then been suggested for some years (Barcroft, 1941; Brodsky, 1933) and new materials and techniques had been developed (Joseph, 1960; Morrison & Warnick, 1961), little information was available regarding the fit of inlays made by this method. By microscopic and mercury micromeasurement, Christensen was able to conclude that it was possible to produce marginal and internal adaptation remarkably similar to cast-gold inlays for the same dies.

1970-1980

In 1978 Brinker did not have as much success as Christensen and his co-workers, but described a technique which used a platinum matrix and a new, prefired, small-particle-sized, homogenous porcelain powder, resulting in a short, low-temperature (1750 °F) sintering cycle. The advantage of the technique was that the inlay could be fired while the patient was in the chair, and fit and aesthetics were said to be excellent (Brinker, 1978).

1980-1990

Interest in porcelain inlays has yet again been revived with further developments in dental materials science.

As described by Deines, the fitting surface of inlays or onlays made from laboratory-fired, low-fusing porcelain can be etched with hydrofluoric acid before the application of silane liquid, which enhances the porcelain-to-composite bond. The composite resin lute is very thin (~24 μm), thus theoretically reducing polymerization shrinkage and microleakage, and produces a bond to the etched enamel surface through the use of a glass-ionomer cement (Deines, 1986).

Glass is a softer inorganic material than porcelain, comparable with enamel in hardness. Melted glass flows readily, thus can be cast to any desired shape, and the casting accuracy is usually excellent. Castable ceramic restorations (Dicor, Dentsply International, Inc, York, PA 17404) employ a lost-wax technique and require a special, phosphate-bonded investment to fabricate the castings. The castings are converted to a partially crystalline state by a controlled-heat treatment called 'ceramming' in which nucleation and growth of mica-type crystals occur. The ceramic castings (inlays, onlays, and crowns) are then etched to enhance mechanical retention of the cement and silane-treated (Malament & Grossman, 1987; Cavel & others, 1988).

Hobo and Kyocera Bioceram Group have recently developed a castable apatite ceramic which melts at 1460 °C and flows like a molten glass. It can be cast in a well-equipped dental laboratory. The casting has amorphous microstructure and on reheating to 870 °C for one hour, crystalline oxyapatite results. This apatite is chemically unstable, but on exposure to moisture becomes the crystalline hydroxylapatite with a crystalline constituent similar to enamel. This restorative material, Cerapearl, is advocated for crowns and inlays (Hobo & Iwata, 1985).

Long-term results for the above materials are not yet available, but a recent study compared the handling characteristics and initial clinical and laboratory findings between cast apatite, cast ceramic, porcelain, and indirect- and direct-resin inlay- and onlay-type restorations.

Short-term results showed that although it was possible to simulate tooth structure almost exactly, the fit of porcelain could be poor with potential for wear of opposing teeth. Both cast ceramic and cast apatite could give good aesthetics and excellent fit with wear on opposing teeth expected to be low. It was concluded, however, that none of the five materials reviewed had been used long enough to allow definitive assessment (Clinical Research Associates, 1988).

The most recent development to date is the computer reconstruction system which allows the clinician to make and fit a porcelain inlay immediately after tooth preparation. An optical impression of the prepared tooth produces a pseudo-three-dimensional picture on a television monitor, and the dentist outlines on the screen those areas of the prepared tooth which are to be restored. A miniature milling machine

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with four axes mills to shape a small ceramic block using a water-cooled, diamond-coated disc, which takes about five minutes to complete. The dentist is then required to adjust the occlusion and polish the exterior surfaces of the inlay, which is claimed to have an accuracy of ±50 microns in all axes.

CONCLUSION

The suitability of porcelain for intracoronal restorations in posterior teeth was recognized over a century ago, and well before the introduction of amalgam to the dental profession in 1895. Even then, early ardent advocates of the technique were well aware that the permanence of any restoration depends on the integrity of its margins and that the edge-strength and clinical performance of porcelain could be "deplorable," especially when subjected to occlusal stress (Nyman, 1905).

We have seen that ceramics have always held the attention and imagination of the restorative dentist and the laboratory technician. In a search for systems which fulfill criteria demanded by the dental profession and which give consistent results, existing techniques have been modified and adapted, and we may now be seeing the fine-tuning of this research. Developments in porcelain-inlay work have been primarily directed towards reducing firing shrinkage and increasing strength, but popularity of the technique has fluctuated, reflecting developments in other fields. However, the outstanding properties of porcelain, principally those of biocompatibility and optical and aesthetic properties, have seemed to outweigh its considerable disadvantages and have remained an incentive to continue investigations into its use as a posterior restorative material.

From our own preliminary investigations (Qualtrough, Wilson & Smith, 1988), we have found patient acceptance and initial clinical evaluation of intracoronal porcelain restorations to be generally favorable (Figs 6a, 6b). Scanning electron microscopic examination of epoxy-resin replicas of restored teeth reveal, however, that marginal integrity is not always ideal (Figs 7a, 7b, 7c).

New porcelain systems must now compete with cast ceramics, cast apatite, improved amalgam alloys, and marked improvements in composite resin materials, particularly the introduction of hybrid and micro-fillers. The indirect composite resin technique offers advantages of good aesthetics, producing more accurate and porosity-free restorations than conventional composites with facility to be repaired in the mouth and no wear of opposing tooth structure (James & Yarovesky, 1983).

To date, porcelain inlays have yet to be evaluated for the replacement of class 2 amalgam alloys or gold inlays. McLean noted that despite all the advances made over the last 30 years in operative dentistry, only gold and porcelain survive as permanent restorative materials which can preserve a dentition for a lifetime when meticulous attention to detail is applied (McLean, 1988). The search for the ideal intracoronal restorative material continues.

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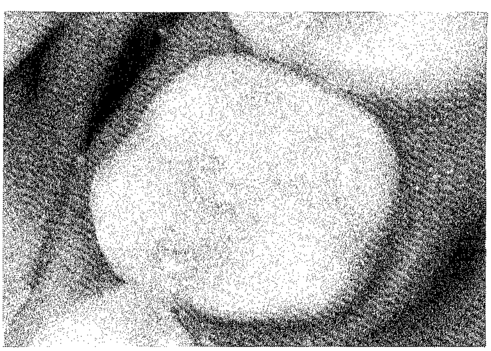

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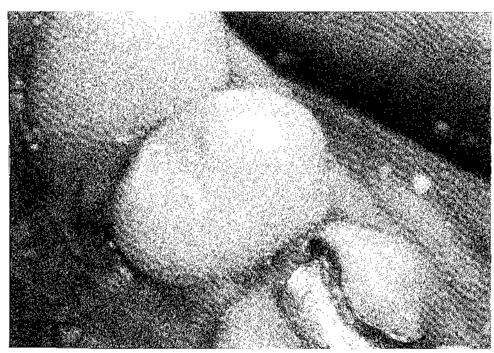
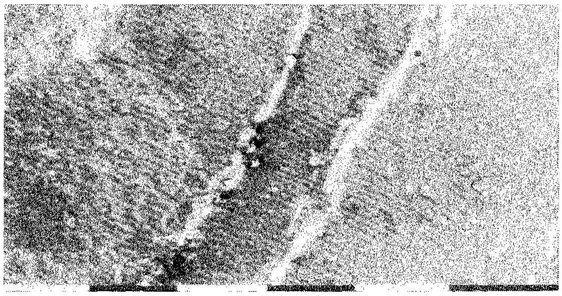


FIG 6. *Porcelain inlays: A) class 1, B) class 2*

a.



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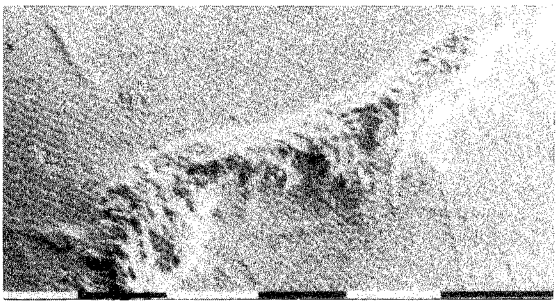

c.

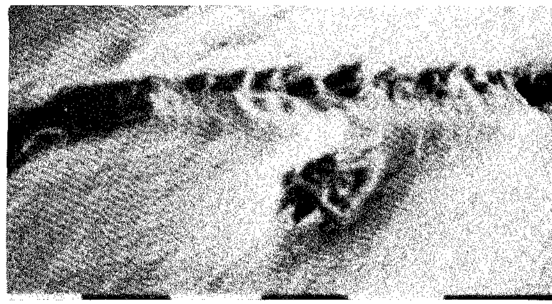

FIG 7. *Scanning electron micrographs showing A) bridge of luting cement, B) excess of lute, C) imperfect marginal adaptation, black and white lines = 0.1 mm*

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A Review of Dentinal Bonding in Vitro: The Substrate

A M DIAZ-ARNOLD • V D WILLIAMS • S A AQUILINO

Summary

This article reviews common substrates and testing conditions used in dentinal bond strength studies in vitro. The available literature supports the use of freshly extracted, hydrated human teeth for studies in vitro. No one testing condition has proven superior accuracy over the others. Evidence is presented to support the implementation of infection control measures when handling the substrates.

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Introduction

Numerous dental materials claim adhesion to dentin. Studies in vitro form the foundation for those claims; however, no standards exist for dentinal bond-strength testing in vitro and investigators use varied methodologies for determining bond strength. Thus, it is difficult to compare bond-strength values between studies.

Uniformity in adhesion testing should begin with the substrate. This article reviews current theories pertaining to substrates used in dentinal bond-strength testing. Three questions are considered: 1) What substrates are used for dentinal adhesion tests in vitro?; 2) How are the substrates handled and stored?; and 3) Is there danger of infection for personnel handling the substrates? Our aim is to identify areas where further research is needed.

What substrates are used for dentinal adhesion tests in vitro?

Causton (1987) reported that living, human dentin is the best substrate. Difficulty with bond-strength studies in vivo has led to almost exclusive use of extracted teeth for testing in vitro. The

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limited availability of human teeth and the increased awareness of infection hazards with human substances has intensified the search for a suitable alternative substrate. Bovine teeth, because of their availability and size, have been used as substitutes for human dentin. The use of freeze-dried, bovine dentin has been proposed (Causton, 1987). While freeze-dried dentin could provide a universal, standard substrate for research in vitro, no data exists to support the claim that reconstituted, freeze-dried, bovine dentin can provide comparable results to living, human dentin.

Adhesion to dentin occurs by reaction with either the organic or inorganic phases of dentin (Asmussen & Munksgaard, 1988; Gwinnett, 1989). Alternative substrates should have morphologic and biochemical makeups similar to both phases. Bovine coronal dentin has larger dentinal tubules than human dentin. Similar bond morphology to human dentin is attained only when superficial dentinal layers are used. Bovine root dentin and dentin nearer to the pulp produce markedly different results (Nakamichi, Iwaku & Fusayama, 1983). Differences also exist between the enamel/dentin junction of human and bovine teeth. The enamel/dentin junction of bovine teeth is more resistant to acid attack yet more permeable to adhesion promoters (Causton, 1987). Although morphological differences between bovine and human dentin have been reported, investigators frequently use both substrates. A recent study utilized both substrates to correlate microleakage and bond strength of dentin adhesives (Tsai & others, 1989). Bovine dentin was used for the bond-strength portion while human dentin was used for the microleakage portion. The authors stated that their methodology shows no functional differences between bovine and human dentin.

Further research is needed to determine a suitable and practical substrate for testing restorative material adhesion to dentin. If direct comparisons to living, human dentin are to be made, experiments must be designed to determine differences in the morphology, biochemistry, and relative bond strengths between human, nonhuman, living, and preserved dentin.

How are substrates handled and stored?

While the majority of bonding studies refer to the use of freshly extracted teeth, several investigators have examined the effect of post-extraction time on the bond strength to dentin. Outhwaite, Livingston, and Pashley (1976) showed that post-extraction time had no significant effect on hydraulic conductance through dentin. Most research indicates that post-extraction time does not significantly affect dentinal bond strength (Peddey, 1981; Aboush & Jenkins, 1983; Jorgensen & others, 1985; Kimura, Shimizu & Fujii, 1985; Williams & Svare, 1985; Mitchem & Gronas, 1986; Stackhouse & others, 1986; Pashley & others, 1988). However, Causton and Johnson (1979) showed that post-extraction time affected the shear bond strength of polycarboxylate to dentin. Beech, Tyas, and Solomon (1986) stated that post-extraction time can affect bond strength, but it depends on the adhesive system used.

The effect of storage conditions (media and time) on dentinal bond strength has also been examined. Commonly reported storage media for extracted teeth include: "water," tap water, distilled water, double-deionized water, saline, 0.9% saline, 30% sterile saline, thymol (0.025% or 0.05%) in distilled water, 10% formalin, 0.1% benzalkonium chloride, and 1.0% chloramine.

Studies have examined the effect of storage conditions before surfacing the dentin (Causton & Johnson, 1979; Jorgensen & others, 1985; Kimura & others, 1985; Williams & Svare, 1985; Mitchem & Gronas, 1986; Stackhouse & others, 1986; Pashley & others, 1988; Wieczkowski & others, 1989), after surfacing but before application of the restorative material (Williams, Leary & Aquilino, 1988), and after application of the restorative material (Hirasawa & others, 1983; Munksgaard & Asmussen, 1984; Söderholm & others, 1984; Chan, Reinhardt & Boyer, 1985; Aquilino, Williams & Svare, 1987; Huang & Söderholm, 1987; Newman, Porter & Szojka, 1987; Zidan, Al-Jabab & Gómez-Marín, 1987). The effect of temperature has also been reported (Nolden, 1985; Barakat, Powers & Yamaguchi, 1988). Extracted teeth have been subject to temperatures from 5 - 60 °C. Teeth have also been subject to conditions which simulate intrapulpal pressure in vivo (Derkson, Pashley & Derkson, 1986; Mitchem & Terkla, 1987). While the storage conditions stress the dentinal bond, no scientific evidence exists to substantiate that these stresses in vitro are similar to those encountered in vivo.

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All investigators agree that the dentin/restorative bond must be exposed to solutes to simulate conditions in vivo. Unfortunately, the complex intraoral environment prevents duplication in vitro of conditions in vivo. To date, no one testing condition in vitro has proven superior accuracy over the others. The precision of testing conditions in vitro can also be questioned since coefficients of variation up to 360% have been reported (Causton, 1987).

Is there danger of infection for personnel handling dentinal bonding substrates?

Studies in vivo in dental aerobiology report bacterial aerosols generated during dental procedures. Bacterial counts have been reported with the use of the air-turbine handpiece, with or without evacuation, and without the use of rubber dams (Stevens, 1963). Bacterial aerosols have been found up to four feet from the surface (Belting, Haberfelde & Juhl, 1964). It has been demonstrated that the use of rubber dam isolation and an efficient evacuation system can reduce the hazard of bacterial aerosols (Brown, 1965). Potential pathogens (*Staphyloccus albus*, *Streptococci*, *Pneumococci*, and diphteroids) have been shown to survive as aerosols (Larato & others, 1966). The microorganisms can survive more than 24 hours and can be recovered from the respiratory system of patients or staff exposed to them (Miller & Micik, 1978).

Research using extracted teeth (Pagniano & others, 1985) has isolated species of *Micrococcus*, *Staphylococcus*, *Klebsiella*, *Enterobacter*, *Citrobacter*, *Lactobacillus*, *Corynebacterium*, *Pseudomonas*, *Alcaligenes*, *Xanthobacter*, *Proteus*, and *Shigella* from a preclinical dental laboratory during the preparation of typodont and extracted teeth. Fungal species of *Penicillium*, *Aspergillus*, *Rhodotorula*, and *Botrytis* were also isolated. The extracted teeth were stored in solutions of alcohol, formalin, and other unknown liquids. Since most of the species identified were not typical of the oral ecology, it was theorized that the microorganisms contaminated the teeth after extraction and remained viable in the storage solutions.

A follow-up study showed that storage of extracted teeth in a disinfecting solution (Roccal II, Lehn & Fink Division of Sterling Drugs, Montvale, NJ 07645) significantly decreased the microbial and fungal content of aerosols produced during cavity preparation (Pagniano & others, 1986). Thus, the authors recommended sterilization of extracted teeth (autoclave, 121 °C/30 min) prior to storage in disinfectant.

Shaffer, Barkmeier, and Gwinnett (1985) evaluated the effects of disinfection and sterilization methods on enamel surface morphology and adhesion of dental composite. Extracted teeth were autoclaved (121 °C/20 min), stored in 2% glutaraldehyde (23 °C/24 hrs), or stored in 1% sodium hypochlorite (23 °C/24 hrs). Enamel surfaces were then prepared for composite bonding. The specimens were subjected to a shear force after seven-day storage in 37 °C distilled water. Bond-strength results showed no significant differences between the three disinfection/sterilization methods and the untreated controls. Scanning electron microscopy did not reveal significant changes in enamel surface morphology.

The effect of glutaraldehyde, 1% NaOCl, and autoclave sterilization on dentin shear bond strength has been investigated (McGuckin & Pashley, 1989). Preliminary results indicated that sterilization/disinfection methods may influence the variability of dentin shear bond strengths.

Conclusions

Presently, no exact substitute for living, human dentin exists. Morphological differences are apparent between human and bovine teeth. Although most studies state that post-extraction time does not significantly affect bond strength to dentin, efforts should be made to use teeth that have been recently extracted and kept hydrated. It is known that air-turbine handpieces are capable of producing bacterial aerosols. Sufficient data exists to support the use of surgical masks, gloves, protective eyewear, and exhaust systems during handling of extracted teeth. Sterilization techniques would reinforce protection against herpes, hepatitis, and HIV. More research is needed to determine an optimal sterilization technique. The technique employed should be cost-effective and time-efficient. Effects on enamel and dentin surfaces should be fully investigated.

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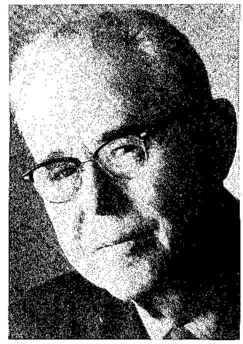
OPERATIVE DENTISTRY, 1990, 15, 76, 77

Hollenback Prize for 1990



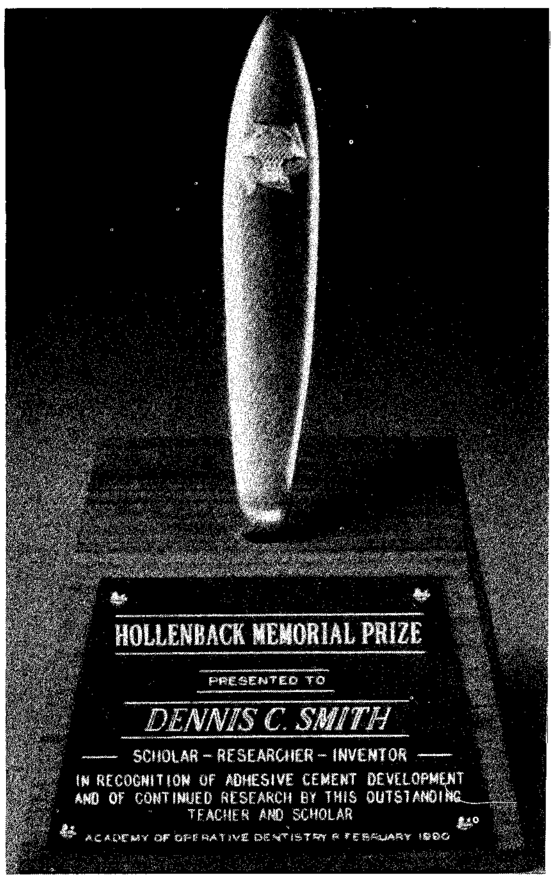
George Hollenback

The Hollenback Memorial Prize is awarded annually by the Academy of Operative Dentistry in honor of Dr George Hollenback, a skilled and inquisitive dentist who believed that his profession could and should be improved through research efforts. In addition, he had appreciation for the technical and scientific foundations on which our profession is based. It was through this awareness that he investigated and encouraged others to study materials, the methods of their use, and to seek new materials which would result in rendering improved service to our patients.

This year's recipient of the Prize is Dr Dennis C Smith, professor and head of the Department of Biomaterials and director of the Centre for Biomaterials, University of Toronto. Dr Smith is well known by the membership of this Academy and was the first Buonocore Lecturer. We are indeed honored to present him with this Prize.

Professor Smith is a native of Lincoln, England, and was granted his initial degrees in chemistry from the University of London (BSc with Honors, 1950; MSc, 1953). In 1952 he moved to the University of Manchester where he became an assistant lecturer in the Department of Dental Materials. While teaching at Manchester, he worked towards and received his PhD. Over the next 17 years, he developed the department into a world-renowned laboratory and established himself as the authority in materials science. In 1969 he moved to Toronto, Canada, where he continues to study, teach, and investigate factors which lead to improvements, not only in dental materials but also in medical materials science.

Dr Smith lectures throughout the world and has had Visiting Professorships in 15 universities in five different countries. He has published some 150 scientific articles in refereed journals and has authored or contributed chapters to seven other books. Among his writings is the four-volume work *Biocompatibility of Dental*



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Materials and Posterior Composite Resin Dental Restorative Materials. His research efforts cover a wide range of subject areas including all the basic dental materials and the tests to which they are subjected as well as the chemistry of poly(methyl)methacrylate and various cements. His research in bone fracture and bone cement is well-known, and he was instrumental, along with Dr John Charnley, in the development of acrylic cements for fixation of artificial hip prostheses. His invention of polycarboxylate cements has been an outstanding contribution to dentistry. This has, of course, led to the development of glass-ionomer cements. His bibliography lists 28 different areas of research.

It is most appropriate that one of this stature should receive many high honors. These include the Hinman Dental Leadership Medal, the Wilmer Souder Award in Dental Materials from the International Association of Dental Research, the Clemson Award to Basic Research in Biomaterials, the Mitch Nakayama Memorial Award from the Japanese section of the Pierre Fauchard Academy, the International Lecturer of the Year Award from the Academy of International Dental Studies, and the distinguished Doctor of Science from the University of London for research in dental and biomaterials in 1979. He was the first Associate Member of the British Dental Association and an honorary member of the International College of Dentists.

Aside from his research and teaching responsibilities, Dr Smith has considerable duties relating to materials both in government and in research organizations. He is a member of the Governing Council of the University of Toronto and a member of the Research Board. He is the Director of the newly created Centre for Biomaterials. He is a member of the Advisory Committee on Medical Devices, Department of National Health and Welfare, the Canadian Advisory Committee of the International Standards Organization, Technical Committee for Dentistry, and the Canadian Standards Association Committee on Dentistry. He has served as chairman of the Canadian Dental Associations Council of Dental Materials and Devices, was the founding president of the Biomaterials Society of Toronto, founding president of the Implantology Research Group of the International Association of Dental Research, and was

Dennis C Smith

president of the Dental Materials Group of that organization.

Above all, Dennis is a family man. He and Eileen, his wife of 35 years, are the parents of six children: Christopher is an electronic data transfer specialist and has his own company; their eldest daughter, Frances, is a financial executive with Canada Trust; Hilary is a legal secretary in Vancouver and is returning soon to Toronto; Gregory is a computer systems analyst with his own company in Tokyo; Helen is also in computer systems and is a supervisor at a bank in Toronto; and Dominic is an interrupted student who is taking this year off for a world tour.

At one time, Dennis was quite active in sports, but now he is content with music and woodworking. His most active engagement in the latter is the extensive reconstruction of his house.

There are few peers to Dr Smith, with his extensive research interests, his willingness to share his knowledge and expertise by writing and lecturing, his inventiveness, and his dedication to education. It is, therefore, a high honor for the Academy of Operative Dentistry to present this year's Hollenback Memorial Prize to Dr Dennis C Smith.

RICHARD D NORMAN

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DEPARTMENTS

Press Digest

Injection pressure of anesthetics using 30-gauge needles with or without side perforation. *Rieu, R, Bouvier, C, Fuseri, J & Proust, J P (1989) *Journal of Endodontics* 15(10) 453-456.

(*Institut de Mecanique des Fluides, UM 34 CNRS, Marseille, France)

This study in vitro was designed to record needle-point pressures of 30-gauge dental needles with side perforation, without side perforation, and with side perforation but with a blocked needle tip. The results from the model used suggest that the injection pressure at the tip of the needle is essentially the same whether a side perforation on the needle wall exists or not. It was also observed that if the tip is blocked, solution can flow into the tissues through the side perforation at a pressure equivalent to that observed with unclogged tips. The authors suggest that this "may be of special interest for intraosseous and intraligamentary (periodontal ligament) injections."

Incidence of Hepatitis B among USAF dental laboratory technicians. Wilcox, C W, *Mayhew, R B, Lagree, J D & Tiffany R L (1990) *Journal of Dental Research,* Abstracts, March.

(*8530 Donegal Dr, San Antonio, TX, 78250)

Through their physical separation from the dental operatory, it is easy to assume that laboratory technicians have a minimal risk of acquiring Hepatitis B; however, it has been suggested that their exposure is potentially greater than even that of dental assistants. The purpose of this study was to survey, serologically, the exposure history of USAF dental laboratory technicians to HBV and to compare the incidence to that found in the general military population. Blood samples from 145 technicians, with an average age of 26.9 (SD = 6.9) in four locations in the USA and Europe were tested for the presence of HBV core antibody using a standard enzyme immunoassay (EIA) procedure. These results were compared to those of 397 military members in non-medical fields of equivalent age and rank. There was no statistical difference in a comparison of the probability of detecting anti-HBV in each population ($P = 0.69$) where the incidence among the technicians was 2.7% and the military population 0.76%. This raises some question as to the need for mass immunization of dental laboratory technicians for HBV along with the associated costs. Use of a "barrier" system for prosthodontic items coming into the laboratory could affect this incidence.

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

(*Department of Dental Materials Science, Oregon Health Sciences University, School of Dentistry, 611 SW Campus Dr, Portland, OR 97201)

The purpose of this study was to evaluate the physical and mechanical properties of a hybrid restorative material composed of 13 wt% of a light-cured resin liquid added to 87 wt% of a glass-ionomer liquid. The results were that the one-hour mechanical properties of the cured-hybrid material exceeded those of glass ionomer while maintaining the glass ionomer's adhesion to dentin. In addition, one of the more interesting aspects of this study was the absence of surface crazing upon desiccation of the hybrid in comparison to the conventional glass ionomer. This could be a significant clinical benefit.

Bacteraemia and tissue damage resulting from air polishing. *Hunter, K M, Holborow, D W, Kardos, T B, Lee-Knight, C T & Ferguson,

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M M (1989) *British Dental Journal* 167(8) 275-278.

(*School of Dentistry, University of Otago, Dunedin, New Zealand)

This clinical study investigated the production of a bacteremia from a dental prophylaxis using one of the commercially available air polishing devices. A conventional rubber-cup-and-paste method was used as a control. There was no statistically significant difference in the number of bacteremias observed between the two groups in the absence of any gingivitis. This suggests that patients who are at risk for antibiotic coverage with a conventional prophylaxis would also require coverage for the air polishing protocol.

Book Reviews

CONTEMPORARY DENTAL HYGIENE PRACTICE, VOLUME 2

Patricia A Phangan-Schostok, RDH, BS, MEd, EdD and Karen L Maloney, RDH, BS, MEd

Published by Quintessence Publishing Co, Inc, Chicago, 1989. 120 pages, 202 photographs/illustrations. $28.00.

This book is the second in a two-volume series which emphasizes the technical development of the dental hygienist. Volume 1 focuses on the preventive and periodontal practice of dental hygiene. Volume 2 presents a broader perspective of the practice of dental hygiene and includes chapters on dental radiography, basic restorative therapy, pain control, and professional opportunities for dental hygienists.

The breadth of topics included in the chapter on dental radiography is extensive; however, it lacks some of the definition necessary for an introduction to this area of dental hygiene practice. The illustrations and radiographs are complete and an excellent supplement to the text. A highlight of the chapter is the self-assessment exercise on radiographic interpretation. The chapter on pain control also includes an extensive range of topics; however, supplementation for the beginning student would be required. The text is supported by laboratory exercises and evaluation criteria for nine block injections. The issues of dosage and toxicity are inadequately addressed in each of the sections of the chapter. The discussion of medical complications is limited with no reference to emergency management in this volume. The scope of the chapter on restorative therapy is limited to isolation procedures, temporary restorations, and amalgam finishing and polishing. This chapter is not supplemented with self-assessment exercises, laboratory exercises or evaluation criteria. Although the chapter on professional opportunities provides very good information and perspective on career alternatives, it is not in keeping with the procedural orientation of the book.

The combination of procedures and topics included in this book is unique and will significantly impact on its utility in dental hygiene education. This book would be inadequate for a dental hygiene program that teaches the full range of restorative expanded functions. At the other end of the spectrum, the book would be too extensive for a dental hygiene program that does not teach restorative expanded functions or pain control. However, if there is a content match between this book and an educational program, it may serve as a valuable resource. In addition, individuals interested in continuing education and professional updating in the topic areas included in the book should seriously consider this book for review and self-assessment.

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FUNDAMENTALS OF DENTAL RADIOGRAPHY
Third Edition

Lincoln R Manson-Hing, DMD, MS

Published by Lea & Febiger, 1989. 269 pages,

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426 illustrations, paperback. $29.00.

The primary objective of the book, as stated in the preface, is "to provide the student and experienced dental radiographers with basic information for the safe and effective use of x-rays in the dentist's office." The book is not intended to promote any particular system but to provide a broad spectrum of usable techniques and give practical information on dental radiographic equipment, materials, and interpretation. The book concisely explains the physical nature of radiation, its biological effects on human tissue, significant anatomical landmarks required in exposing and interpreting dental radiographs, and equipment used for radiographic exposure and processing. Approximately one-half of the text, comprising 11 chapters and 130 pages, is dedicated to a comprehensive discussion of the various dental radiographic exposure techniques. Avoiding potential technical errors is also included. The numerous clinical photographs and illustrations provide thorough visualization of the techniques described.

The concluding two chapters on infection and quality control give practical methods for establishing barrier techniques and equipment handling to prevent cross contamination. In addition, there are suggestions for simple and inexpensive methods for testing the safety and efficiency of the equipment. A 102-question test with separate answer sheet provides a self-evaluation of the reader's comprehension of the text material.

This book's major strength is in presenting the various techniques, such as both the bisecting-the-angle and the paralleling technique for periapical films, thus allowing dentists or assistants to review the specific techniques they were originally taught, and to learn alternative approaches. It provides a thorough yet practical source for establishing and maintaining an office dental radiographic service which will be both safe and diagnostically accurate and is therefore highly recommended.

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A COLOR ATLAS OF COMPLETE DENTURE FABRICATION

Hiroshi Muraoka, DDS

Published by Quintessence Publishing Co, Inc, Chicago, 1989. 210 pages, 796 illustrations. $120.00.

There are 14 chapters in the text, organized by the sequence of procedures that the author would follow in treating a complete-denture patient. Chapters 1 and 2 describe the clinical and radiographic examination of the edentulous patient. Chapters 3 to 7 describe the fabrication of interim dentures and their modification. Chapters 8 through 14 describe fabrication of definitive prostheses, starting from making final impressions to insertion of dentures, with detailed description of laboratory procedures. The last part consists of a supplement section describing two special techniques and a list of dental materials and their manufacturers as used in the text.

The purpose of the book is to describe the author's philosophy and techniques of complete denture fabrication. Each clinical and laboratory procedure is well-illustrated step by step with photographs and line drawings of excellent quality. The material presented on fabrication and modification of interim dentures is especially helpful in treating difficult denture patients. The text is well-organized and presented in orderly sequence.

Since this text describes only the author's clinical technique, it is most useful for general practitioners who would like to increase their knowledge in complete denture construction.

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