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EDITORIAL

Are Clinical State Board Examinations Archaic?

There is a continuing clamor for mobility from a vocal and persistent number of dentists. They claim that state and regional board examinations are archaic and that dentists should have the right to practice where and when they desire without the hassle and trauma of taking another state board examination. Also, these same advocates of a free and mobile society claim that state board examinations are only for "gatekeeping" purposes.

Another group who feels that state board examinations are no longer valid are some of the faculty and students in our dental schools. State boards were originally designed to weed out the poorly trained from proprietary schools or low-quality preceptorships. This was long before the era of state-owned dental schools and accreditation programs for dental schools. Faculty and dental schools frequently feel that students who graduate from an accredited school should automatically be granted a license to practice dentistry. Faculty claim that they are best equipped to evaluate the students; after all, they have had the opportunity to evaluate and observe the students in all areas of dentistry for their entire dental school career, not just the short two or three days of the typical state or regional board examination. I am strongly opposed to faculty being charged with certifying that their students are competent to practice dentistry, and we must be careful not to allow this to occur. Dental schools may be accredited on a national level, but such accreditation does not mean that each and every school graduates clinically competent dentists. Ask senior members of the Armed Forces if all schools are equal in this regard, and you will typically find their response to be negative. During my career in the Air Force, I had the opportunity to see and work with graduates from almost all of our schools. Many entered the service fresh from dental school and were perceived by many of us to be poorly trained in clinical skills, requiring a great deal of supervision and training to get them to an acceptable level. No, the faculty of the dental schools are not the ones to pronounce the clinical competence of their graduates.

It is claimed that state and regional board examinations protect the public, but do they really? From my perspective, it is likely that they do more harm to the public than good. One problem with clinical examinations is that of patient abuse, that is, patients receiving substandard care by incompetent candidates and in many, if not most, instances not being informed of the substandard care they received. Also it is generally accepted that almost all candidates who fail to pass the examination the first time will pass on a later retake. Of course by then they are no longer in dental school, and being unable to practice, are left to their own devices as they await another examination. Most do not receive or seek any assistance in their passing the exam the next time, and yet they eventually pass. On this basis, I can say in all honesty that many clinical board examinations do not protect the public. States where the examining boards evaluate with a high standard will typically have an effect on the curriculum and time allotted to clinical skills in the area being served. That is the reason examining boards are essential: they can monitor and influence what is produced by the dental school. Someone needs to keep the schools in line, not the other way around, with dental faculty telling the examining agencies how to evaluate their graduates.

As there is such a disparity in the quality of the graduates from our schools, states' rights should dictate the quality of education and the clinical skills required to practice in each state. Why should any region that prides itself on its high level of dental care be willing to accept individuals trained to a much lower level of competence? Should not all schools be required to raise the standard by which they teach? Or is that too old-fashioned a notion? National licensure would work if all students were trained to the same level of clinical competence and all were evaluated using the same criteria. However, unless it is legislated at the federal level, it will never occur, as dental schools could never agree on what "competence" is. Rather pathetic, isn't it? So let us keep our clinical board examinations until something better comes along.

DAVID J BALES
Editor

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ORIGINAL ARTICLES

Amalgam Buildups: Shear Strength and Dentin Sealing Properties

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E E PARRY • D H PASHLEY

Summary

The retentive strength and sealing properties of amalgam buildups were compared in vitro in three groups of specimens. All teeth were prepared with flat, nonretentive surfaces. In the first group, the amalgam buildups were retained by four self-threading Minim pins. In the second group, retention was provided by a circumferential slot prepared in the dentin just inside the DEJ. The third group utilized an adhesive resin for retention. Dentin permeability was measured as a hydraulic conductance before and after placement of the amalgam buildups and before and after thermocycling. All methods of retention sealed dentin very well even in the absence of cavity varnish. The 90° retentive strength was: pins, 10.3 ± 0.9 MPa; slots, 4.1 ± 0.5 MPa; resin, 3.1 ± 0.8 MPa ($\bar{x}$ ± SEM).

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INTRODUCTION

The restoration of teeth that have been largely destroyed by dental caries or fracture presents a major challenge to operative dentists. After complete excavation of the cariously involved tooth structure, there often is little coronal structure left to assist in the retention of amalgam. In the past, self-threading pins have been used to provide the retention necessary for amalgam buildups (Munk & Brokaw, 1989; Robbins, Burgess & Summitt, 1989). That method requires special equipment and increases the potential for perforation into the periodontium or

the pulp chamber. The close proximity of the pin to the pulp and the cracks produced in the dentin during mechanical insertion of the pins (Khera, Chan & Rittman, 1978) may increase the permeability of dentin and, therefore, the clinical consequences of any microleakage that occurs following the insertion of the amalgam. An alternative to the use of pins is the creation of circumferential slots. This has been shown to produce amalgam buildups that were as strong as pin-reinforced amalgam crowns (Outhwaite, Garman & Pashley, 1979). However, this procedure is also technically difficult and depends upon the proper condensation of amalgam into narrow slots without any movement of the matrix while the amalgam is undergoing setting reactions. Slot creation can also reduce the thickness of dentin remaining between the pulp chamber and the preparation. Improvements in polymer chemistry have led to the development of several materials that bond to both metals and tooth structure (Pashley, 1990). These have the potential to provide retention of amalgam to dentin even in badly broken-down teeth. Some of these materials are excellent dentin bonding agents which penetrate into the superficial 5-10 μm of the dentin surface, thereby decreasing the permeability of dentin, which would decrease the clinical consequences of any microleakage that might develop between the amalgam and the resin-treated dentin.

The purpose of this study was to compare the effects of pin, slot, and resin retention techniques on both the permeability of dentin and the shear strength of amalgam buildups in vitro.

MATERIALS AND METHODS

Tooth Preparation

All teeth were unerupted, noncarious third molars from patients between 18-28 years of age. The teeth were stored at 4 °C in isotonic saline containing 0.2% sodium azide to inhibit bacterial growth, for no more than one month prior to use. Crown segments were prepared from the teeth using two parallel sections on an Isomet saw (Buehler Ltd, Evanston, IL 60204). The first section removed the roots just below the CEJ and the second section removed the coronal enamel. The resulting crown segment contained the top portion of the pulp chamber (Fig 1) and had a flat occlusal plane. Each crown segment was cemented to a 2 x 2 x 0.6 cm block of Plexiglas with Zapit (DVA, Anaheim, CA 92807) brand of cyanoacrylate. The pieces of Plexiglas were penetrated by an 18-gauge needle, which provided communication between the pulp chamber and the apparatus used to measure dentin permeability (Fig 1).

Measurement of Dentin Permeability

The permeability of each crown segment was measured as a hydraulic conductance (Pashley & others, 1988; Tao & Pashley, 1989) by following the progress of a tiny air bubble in a micropipette (Fig 1) under standard conditions. The hydraulic conductance (Lp) units are μL of fluid movement per cm^{-2} of dentin surface area, time (in minutes) and fluid pressure in cm of H_2O. The original smear layer created by the diamond blade of the Isomet saw was removed by treatment with 0.5M EDTA (pH 7.4) for two minutes. This permitted measurement of the maximum permeability of each specimen. Next, a standardized smear layer was created on the flat occlusal surface of each specimen using a modified Ecomet III sander (Buehler Ltd) operated at 108 rpm for five seconds under running water, with a vertical force of 500 gm. A new piece of 320-grit SiC abrasive paper was used for each specimen. The permeability of the specimens was measured again after the creation of the standardized smear layers. Dentin surface areas were measured from enlarged photographic

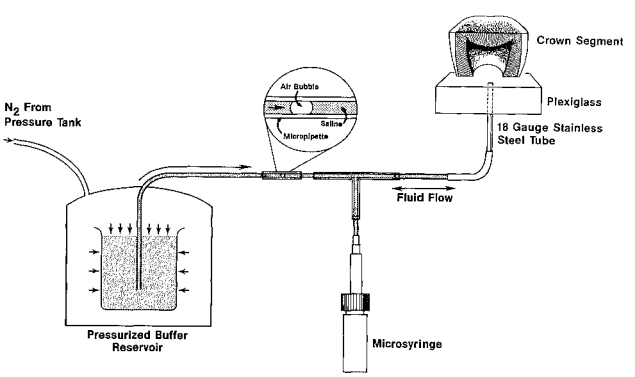

FIG 1. *Schematic of apparatus used to measure dentin permeability. The crown segment in this figure was sectioned longitudinally to reveal the flat occlusal plane and approximate location of pulp horns. Fluid flow was quantitated by following the progess of an air bubble in a micropipette.*

prints taken of each specimen next to a standard scale. All measurements of hydraulic conductances were done in quadruplicate and then averaged.

Experimental Design

The teeth were then randomly divided among three groups of nine specimens in each group. Group 1 specimens received four pin holes prepared using 0.525 x 2 mm Kodex twist drills (Whaledent International, New York, NY 10001). Group 2 specimens received a circumferential slot 0.5 mm deep, 0.5-1.0 mm wide, placed 0.5 - 1.0 mm inside the DEJ using a 33 1/2 inverted cone carbide steel bur operated in a high-speed handpiece with copious air-water spray. Group 3 specimens were treated with 10-3 solution (10% citric acid, 3% ferric chloride) for 30 seconds to remove the smear layer in preparation for bonding Amalgambond resin (Parkell, Farmingdale, NY 11735) to the surface. Dentin permeability was remeasured after each procedure (Table 1) and expressed both in absolute values and as percent reduction from the EDTA-induced maximum permeability. After placement of the amalgams, the permeability of the dentin was measured again after five days to determine how well the amalgam restorations sealed the dentin surface. Finally, after three weeks, the specimens were all thermocycled 100 times between two water baths held at 4 and 56 °C (±1 °C), with a two-minute dwell-time. The specimens were then placed in an Instron Universal Testing Machine (Instron Corp, Canton, MA 02021) to permit the measurement of the shear strength of the amalgam buildups to the dentin using a crosshead speed of 1.3 mm/minute. A flat,

FIG 2. *Photograph of the blade-type shear bar used to stress the amalgam buildups. Note the placement just above the tooth surface on the amalgam at 90° to long axis of tooth roots.*

Table 1. Effects of Experimental Variables on Dentin Permeability

	Group 1 (Pins)		Group 2 (Slots)		Group 3 (Resin)	
	Absolute[a]	% of max	Absolute	% of max	Absolute	% of max
Max permeability[b]	672.5 ± 173.2(8)	100	498.3 ± 101.5(9)	100	285.5 ± 98.5(9)	100
S L permeability[c]	105.0 ± 22.7(8)	18.0 ± 3.1	107.6 ± 20.1(9)	27.7 ± 6.2	38.7 ± 5.4(9)	23.5 ± 5.3
Pins/slots/10-3[d]	55.9 ± 13.8(8)	10.7 ± 1.9	79.3 ± 18.8(9)	21.9 ± 4.7	221.2 ± 64.1(9)	91.2 ± 16.3
Pins inserted[e]	61.4 ± 12.3(8)	11.0 ± 1.4	—	—	—	—
Amalgam inserted	15.0 ± 15.1(8)	2.9 ± 0.6	27.2 ± 14.2(9)	8.2 ± 1.8	8.0 ± 2.2(9)	6.4 ± 3.2
Amalgam thermocycled	9.9 ± 1.3(8)	2.2 ± 0.6	9.9 ± 1.2(9)	3.5 ± 1.2	7.1 ± 0.4(9)	4.4 ± 1.1

[a] Absolute permeability in $\mu M\ cm^{-2} min^{-1}\ cm\ H_2O^{-1}$

[b] Maximum permeability determined after treatment with 0.5 M EDTA, 2 min

[c] S L permeability; permeability following creation of smear layer with 320-grit SiC

[d] Pins/slots/10-3. Lists the permeability in Groups 1-3 following drilling of pins, slots, or dentin conditioning with 10-3 respectively

[e] Pins insert; permeability following pin insertion in Group 1

blade-type probe (Fig 2) was used to apply force 90° to the long axis of the tooth at the junction of the amalgam buildup and the tooth surface.

Materials

The pin kit used in this study was from Whaledent International. Dispersalloy Self-Activating Capsules (Johnson & Johnson Dental Products Co, East Windsor, NJ 08520) were used in all groups. Four Link Plus self-threading, single-shear Minim pins were placed in each specimen in Group 1 using a contra-angle handpiece. No cavity varnish was used on the specimens in either Group 1 or 2. Group 3 specimens were treated with Amalgambond (Parkell) according to the manufacturer's instructions. Briefly, the dentin surface was treated with a dentin conditioner (10-3 solution), a dentin primer (35% HEMA in water) and a 4-META-containing self-curing adhesive resin system. The amalgam was placed on the resin while it was still unpolymerized in keeping with the instructions. The matrix bands were removed and the buildups carved back to the tooth margins. Flat facets were carved on one side to facilitate force application during testing. The amalgams were stored in isotonic saline solution at 37 °C between measurements.

Scanning Electron Microscopy

Scanning electron microscopy was performed on some of the resin-retained amalgams to determine the mode of failure. The failed samples were simply rinsed with water, air-dried, sputter-coated with gold and viewed in a JEOL Model JSM-2 scanning electron microscope (JEOL, Peabody, MA 01960).

Statistical Analyses

The means and standard errors of each group were calculated following each treatment. Differences between longitudinal treatments were examined using ANOVA of repeated measures. Differences between groups were tested using a one-way ANOVA and then ranked using Duncan's multiple range test. Statistical significance was defined as $P < 0.05$. Paired comparisons were made using Student's *t*-test.

RESULTS

Changes in Dentin Permeability

The permeability properties of the three groups are shown in Table 1. After EDTA treatment, the maximum permeability of each specimen was measured. Although specimen assignment to each group was random, the mean maximum permeability of Group 3 was significantly less statistically ($P < 0.05$) than the other two groups, which were not different from each other. For this reason, the data were expressed in both absolute terms ($\mu L\ cm^{-2}\ min^{-1}\ cm\ H_2O^{-1}$) and as a percent reduction from the maximum values of each specimen. Smear layer creation with 320-grit SiC abrasive paper reduced the permeability 82, 72, and 77% in Groups 1-3 respectively to 18, 28, and 23% of the maximum permeability of those samples. In Groups 1 and 2, drilling four pin holes or creation of a circumferential slot both reduced dentin permeability, although the reduction was not statistically significant (Table 1) expressed in either absolute or relative terms. Insertion of the four pins into the dentin had no significant effect on the permeability of the specimens, although one specimen was lost due to exposure of a pulp horn.

When the specimens in Group 3 were treated with the 10-3 dentin conditioner, the permeability of the specimens increased to near maximum levels due to removal of the smear layer.

Insertion of the amalgam reduced the apparent permeability of all groups. The decrease in dentin permeability following amalgam insertion was greatest in the resin-treated group because its primer increased the permeability of that group relative to the others. There were no statistically significant differences among the three groups in the final permeability either before or after thermocycling. Thermocycled pin and slot-retained amalgams exhibited slightly lower (although not statistically significant) apparent permeability than the same specimens prior to thermal stress. The resin-lined amalgam restorations were measured for their sealing quality five days postinsertion and then three weeks later after 100 thermal cycles between 4 and 56 °C. A one-way analysis of variance revealed that there was no difference between the degree of dentin sealing by the resin-lined amalgams when measured after five days or after three weeks of storage plus thermocycling ($P > 0.4$).

Strength of Retention

The force required to dislodge the amalgams from the flat, occlusal surface of the tooth specimens is shown in Table 2.

The stress was applied parallel to the flat tooth surface using a flat probe (2.8 x 5 mm, total surface area, 0.14 cm^2) applied as close as possible to the tooth/amalgam junction. An abrupt change in the slope of the line of stress versus time on the Instron machine was defined as disruption of the bond since pin-retained amalgams seldom fell off the tooth. Rather, the pin-reinforced amalgams either partially fractured (Fig 3) or, more commonly, became loose on the surface. The slot-retained amalgams all fractured cohesively through the amalgam condensed into the slots (Fig 4). The resin-retained amalgams exhibited complex failures with some adhesive failure between the amalgam and the resin and, less commonly, some cohesive fractures within portions of the amalgam (Fig 5).

The strength of the Group 1 (pin-reinforced) buildups (10.3 MPa) was significantly higher statistically than that of either of the other groups ($P < 0.05$). There was no significant difference between slot versus resin-retained amalgams (4.1 ± 0.5 versus 3.1 ± 0.8 MPa respectively, Table 2).

Table 2. Retention Strength, MPa, $\bar{x}$ ± SEM (N)

	Force at failure (kg)	S A (cm^2)	Strength (MPa)
Group 1 (pins)	72.1 ± 5.8(7)	0.718 ± 0.063	10.3 ± 0.9(7)
Group 2 (slots)	29.1 ± 2.3(8)	0.730 ± 0.047	4.1 ± 0.5(8)
Group 3 (resin)	24.9 ± 5.9(8)	0.795 ± 0.028	3.1 ± 0.8(8)

Groups connected by vertical lines are not statistically different at $P < 0.05$.

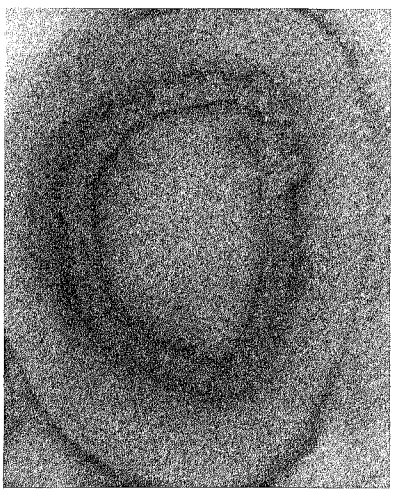

FIG 4. *All of the slot-retained restorations showed cohesive failure of the amalgam within the slots.*

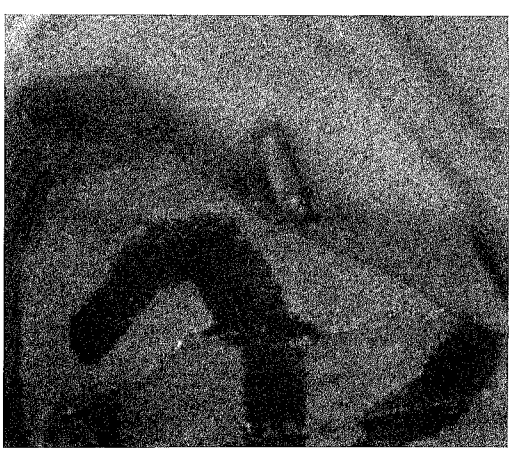

FIG 3. *Typical appearance of pin-retained amalgam that exhibited partial fracture but remained attached to the tooth*

FIG 5. *Most of the resin-retained amalgams exhibited a mixed type of failure, with some of the surface showing an adhesive failure between dentin and resin, some cohesive failure within the resin, and some cohesive failure within amalgam.*

Scanning electron microscopy of failed resin-bonded amalgams revealed a complex mode of failure. Some of the dentin surface within the bonded area revealed the presence of dentinal tubules (Fig 6), the presence of resin, and the presence of amalgam. Some regions showed that amalgam which remained attached to the underlying dentin had physically trapped resin within itself (Fig 7). Several regions of retained resin exhibited a unique pattern of cohesive failure which matched the diameter of the spherical particles of amalgam seen on the other side of the failed bond (Fig 8).

DISCUSSION

Clinicians are often forced by circumstances to restore broken-down posterior teeth with amalgam. A variety of techniques have been used in an effort to obtain sufficient mechanical retention to restore the tooth to function. Some of the methods available to clinicians were recently reviewed by Robbins and others (1989). As such teeth are often severely destroyed by caries and/or fractures, the amount of dentin remaining between the prepared dentin surface and the pulp chamber is often minimal. Thus, it was important in our study to measure the maximum dentin permeability of each specimen. This was accomplished by removing the smear layer created by the diamond saw blade with EDTA and then measuring the permeability of each tooth. However, as most amalgam restorations are placed on smear layers, all specimens had fresh smear layers created with 320-grit SiC paper. This resulted in a 72-82% reduction in dentin permeability, demonstrating how effective the smear layer is at reducing dentin permeability. Loss of cusps makes it difficult to predict where pulp horns should be, which complicates the drilling of pin holes. We had expected that the permeability of the dentin would have increased when four 1.5-2 mm-deep pin holes were prepared. Rather than an increase, we observed a decrease in dentin permeability, although it was not statistically significant. Placement of pins has been shown to cause internal stresses and cracking of dentin around the pins (Standlee, Collard & Caputo, 1970; Khera & others, 1978). We had expected the permeability of the dentin to increase after pin insertion (Webb, Straka & Phillips, 1989). That result was not seen as there was no change in the permeability of those

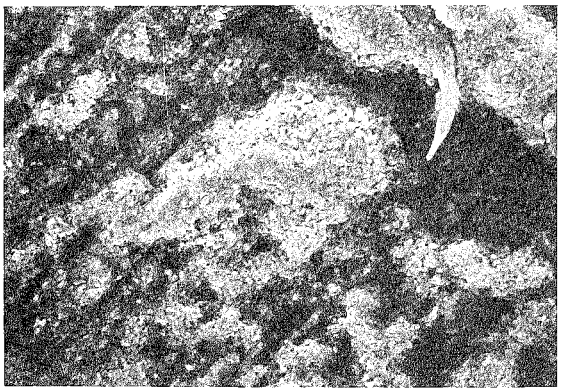

FIG 6. *Scanning electron micrograph of dentin side of failed resin-retained amalgam. Note the presence of some open dentinal tubules (small arrows) as well as amalgam.*

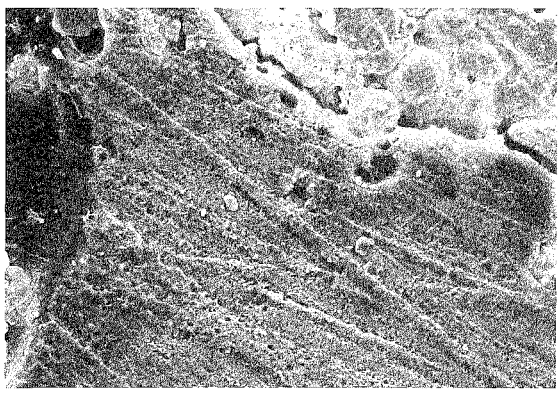

FIG 7. *Resin physically trapped within amalgam that fractured cohesively*

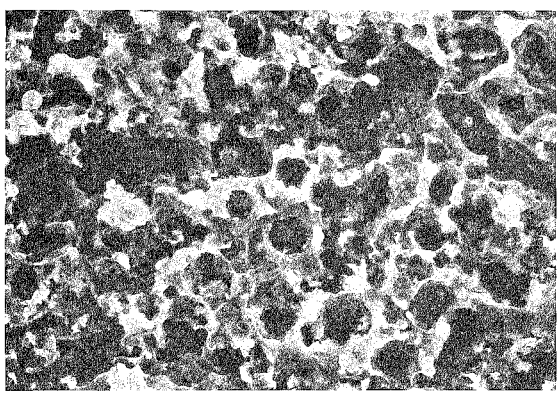

FIG 8. *Cohesive failure of resin resulted in a globular pattern which matched the size and regularity of the spherical particles of amalgam on the other side of the failed bond*

specimens (Student's *t*-test $P > 0.9$) following pin-placement.

Similarly, it was expected that creation of a circumferential slot would decrease the thickness of dentin and thereby increase dentin permeability. The data indicated that this did not occur. There was no statistically significant difference between the permeability of the teeth in Group 2 before or after creation of the slots. This was due, in part, to the fact that the slot was created just inside the DEJ far removed from pulp horns; the slot was also lined with a smear layer, which decreases dentin permeability.

The specimens in Group 3 were treated with a 4-META-containing resin marketed as Amalgambond. In this system, the smear layer is removed by treatment of the dentin surface with a combination of citric acid and ferric chloride (10-3 solution). This treatment increased the permeability of the teeth to nearly maximum values. However, as soon as the adhesive resin and amalgam were placed on the dentin, the tubules became well-sealed as the apparent permeability of the system fell to very low values (Table 1). In fact, placement of amalgam in all groups produced statistically significant ($P < 0.01$) reductions in dentin permeabilty, which indicated that the amalgam buildups sealed the dentin well. This was particularly impressive in Group 1 and 2 (pins and slots) specimens, which were restored in the absence of any liners or varnishes. Cavity varnish was purposely omitted to permit evaluation of the direct sealing ability of amalgam (Ben-Amar, 1989). Had we used varnish, we would not have known whether the seal was due to the amalgam or to the varnish. Presumably, the use of varnish would result in further improvement in the sealing of dentin. The absolute permeability was lowest in the Amalgambond-treated specimens, but the use of an adhesive resin is analogous to using a cavity varnish, which has been shown to improve the sealing of amalgams (Derkson, Pashley & Derkson, 1986; Sandoval, Cooley & Barnwell, 1989). Remarkably, thermocycling had no effect on the sealing qualities of any of the experimental groups (Table 1). They all remained rather tight even after exposure to the extreme temperatures that were employed.

The strength of the various retention techniques to shear stress revealed that pins provided better resistance to lateral displacement than either slots or resin-treatment (Table 2), which were not statistically different. The 10 MPa values for the shear strength of pin-retained amalgams are much lower than our previously reported values (approximately 25 MPa), which were obtained at 45° and include a significant frictional resistance (Outhwaite & others, 1979, 1982). Davis and others (1983) obtained 45° strengths with four Minim pins, which were similar to those of Outhwaite and others (1979). We elected to use 90° shear stress because most studies of the bond strength of adhesive resins to dentin and/or amalgam are done at 90°. Staninec and Holt (1988) obtained tensile bond strengths of 3.4 MPa between Panavia-treated dentin and/or amalgam. Shimizu, Ui, and Kawakami (1986) reported Super-Bond-mediated shear bond strengths of 5.6 ± 0.8 MPa ($N = 6$) between bovine dentin and amalgam. Super-Bond is very similar to Amalgambond but also includes a polymethylmethacrylate powder component. Nucci, Prati and Montanari (1989) obtained a shear bond strength of 5.2 MPa between Super-Bond/Amalgam and human dentin. Our bond shear strengths between Amalgambond and amalgam were somewhat less than those obtained by other investigators using Super-Bond. To our knowledge there are no reports yet in the literature on Amalgambond-mediated shear-bond strength of amalgam to dentin. Barzilay and others (1988) compared the shear bond strength of Super-Bond with another 4-META-containing product called Cover Up from Parkell, but their amalgam had already set up and was sanded smooth. They obtained shear bond strengths between amalgam and an overlying opaque layer of resin of 10.3 and 3.7 MPa respectively.

Scanning electron microscopy of the resin-retained amalgams stressed to failure revealed a complex interface that resulted from condensing amalgam on to an unpolymerized resin surface. There was a good deal of entrapment of resin within amalgam and vice versa. The spherical amalgam particles were often imbedded in resin (Fig 8). It would be interesting to compare the bond strength of non-4-META-containing resins with those of 4-META resin systems to determine how much of the bond strength is due to mechanical versus chemical retention. It is not clear how much strength is needed for a buildup to be clinically successful. Resin retention of amalgam is technically easier to accomplish than the preparation of pins or

slots. Only further testing will reveal whether this method will be successful clinically.

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Factors Influencing Bond Strengths between Unetched Glass Ionomers and Resins

K HINOURA • H SUZUKI • H ONOSE

Summary

The use of glass-ionomer cements as a base beneath composite resins has become a popular restorative procedure often referred to as the "sandwich technique." Originally etching of the glass-ionomer surface was recommended to help create the necessary bond between glass-ionomer cement and composite resin. This study investigated the bond strength of various composite resins and their bond agents to unetched glass ionomer. The pH of the bond agents was measured and related as bond strength. The influence of time elapsed between mixing the glass-ionomer cement and placement of the bond agent was also studied.

Bond strengths varied from 65.5 kg/cm^2 for G-C Dentin Cement with Pyrofil Light Bond A to 3.2 kg/cm^2 for G-C Dentin Cement with Bis-Fil-M. The pH range was from 2.28 for Pyrofil Light Bond to 7.62 for Durafill Bond. Low correlation coefficients between bond strength values and pH indicated only limited relationship between the two. The bond strength decreased as the time lapse between the end of the mix and application of the bond agent increased.

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Introduction

Composite resins are becoming more widely used as restorative materials because of their physical properties and esthetics. However, composite resin may be harmful to the pulp, and there is marginal leakage especially around the cervical margin. On the other hand, glass-ionomer cements have certain characteristics that are attractive to the dentist.

This has led to the development of the so-called "sandwich technique" in which the cement is acid-etched to permit bonding to the overlying composite resin (McLean & others, 1985; Hinoura, Moore & Phillips, 1987; Mount, 1989a). This procedure takes advantage of the adhesive properties and biocompatibility of the glass-ionomer cement and the superior surface and esthetics of the composite resin. The technique involves using the glass-ionomer cement as a base to replace dentin. This exposed surface of the glass-ionomer cement and the enamel cavity margin are acid-etched prior to placement of the composite resin.

For the success of this technique, there should be a reasonable bond between the glass-ionomer cement and composite resin. A previous study (Sneed & Looper, 1985; Hinoura, Moore & Phillips, 1987; Welbury & others, 1988; Mount, 1989b) showed that etching the surface of glass-ionomer cement markedly increased the bond strength to the bonding agent/composite resin.

Many factors may potentially affect the quality of the bond strength between the two materials (the composite and glass ionomer), including the time at which the glass ionomer is etched after commencing the mix, the duration of etch, the effect of using different glass-ionomer materials, and whether or not an intermediate unfilled resin layer is used.

The purpose of this study was to evaluate the bond strengths of various composite resins and their bonding agents to unetched glass-ionomer cements. Also the effect on the union of application time of the bond agents to the cement was evaluated. In addition, the pH of these bond agents was measured using a pH electrode in order to examine the relationship between pH and bond strength.

Table 1. Glass-Ionomer Cements

	Manufacturer	Mixing Ratio Powder/Liquid
Dentin Cement	G-C International Corp, Tokyo, Japan	2.2 g / 1.0 g
Base Cement	Shofu Dental Corp, Tokyo, Japan	2.6 g / 1.0 g

Table 2. Composite Resins and Bonding Agents

	Bonding Agent	Manufacturer
Silux	Scotchbond	3M Dental Products St Paul, MN 55144
P-30	Scotchbond	3M Dental Products
Photoclearfil A	Clearfil Photobond	Kuraray Co, Ltd New York, NY 10001
Ful-Fil	Prisma-Bond	L D Caulk Co, Div of Dentsply Intl Milford DE 19963
Prisma-Fil	Prisma-Bond	L D Caulk Co
Command Ultrafine	Bondlite	Kerr/Sybron Romulus, MI 48174
Lite-Fil A	Lite-Fil Bond	Shofu Dental Corp Menlo Park, CA 94025
Pyrofil Light Bond A	Pyrofil Light Bond	Sankin
Occlusin	ICI Bond	ICI Americas, Inc Wilmington, DE 19897
Bis-Fil-M	Resin Bond	BISCO, Inc Downers Grove, IL 60515
Durafill	Durafill Bond	Kulzer, Inc Irvine, CA 92714

Materials and Methods

Two glass-ionomer cements and 11 composite resins were employed as shown in Tables 1 and 2. G-C Dentin Cement and Shofu Base Cement were mixed on a paper pad, as recommended by the manufacturers.

The bond strength was determined by subjecting paired cylinders of the materials to a tensile-type stress. Since the material was being evaluated for use as a restorative material, the test chosen was one that made use of a bulk of material, rather than a thin film. A two-part Tefron mold, 12 mm high and 4 mm in internal diameter, was used to form and hold the cement and the resin. A 45° chamfer was machined at one end of each half of the mold

Table 3. pH of Various Bonding Agents

	Mean (pH)
Pyrofil Light Bond	2.28
Bondlite	2.58
Scotchbond	2.67
Photoclearfil A	2.75
Lite-Fil Bond	5.72
ICI Bond	6.62
Resin Bond	6.72
Prisma-Bond	6.98
Durafill Bond	7.62

in order to retain the materials during loading (Fig 1). The glass-ionomer cement was inserted into the 6 mm x 4 mm mold and placed against a flat glass plate on the end opposite the chamfer. After the glass-ionomer cement had set for seven minutes at 23 °C ± 1 °C, the other mold half was aligned with the half filled with cement and held in position with plastic electrical tape.

After the mold halves were assembled, the bonding agent was placed with a small sponge over the cement and cured for 20 seconds using its respective activator light. Each composite resin was then condensed in three increments, each of which was cured for 30 seconds. The finished specimens were allowed to set for one hour, at which time all assembled specimens were transferred to distilled water and stored at 37 °C.

After 24 hours the electrical tapes were removed and the molds were screwed into the threaded caps by which they were attached to the testing machine. Each test group consisted of 10 specimens. Tensile bond strengths were determined using an Instron Testing Machine (Instron Corp, Canton, MA 02021) with a crosshead speed of 0.5 mm per minute.

In addition, the pH of the bonding agents was studied. These bonding agents were mixed and measured immediately using the pH electrode (Orion Research, Inc, Boston, MA 02129) and pH meter. Three specimens were tested for each material.

Results

Table 3 shows the pH of various bonding agents. Pyrofil Light Bond had the lowest pH

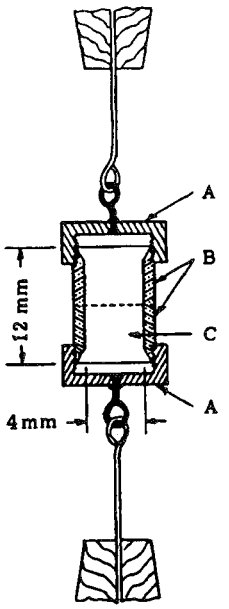

FIG 1. *Cross section of the apparatus used to measure the tensile bond strength (A) threaded cap with wires attached for insertion in the grip of the testing machine (B) two-component mold (Tefron) with a 45° chamfer (C) resin or glass-ionomer cement*

(2.28 ± 0.37); and Pyrofil Light Bond, Bondlite, Scotchbond, and Clearfil Photobond were grouped together in the lowest pH group. The highest pH was obtained with Durafill Bond.

The tensile bond strengths between G-C Dentin Cement and 11 composite resins are shown in Table 4 and Figure 2. The results were studied with analysis of variance followed by Student's *t*-tests with critical values at 0.05. Values connected by vertical lines were not significantly different ($P < 0.05$). The highest bond strength was obtained using Pyrofil (65.5 kg/cm^2 ± 8.03).

Table 5 and Figure 3 show the tensile bond strengths between Shofu Base Cement and 11 composite resins. Bond strengths varied from 61.4 kg/cm^2 for Pryofil Light Bond A to 8.2 kg/cm^2 for Bis-Fil-M. In this case, Pyrofil Light Bond A, Silux, and P-30 were grouped together in the highest bond strength group.

For both cements specimens whose bond strengths exceeded approximately 30 kg/cm^2 failured cohesively in the cement. This means that the bond strength is greater than the

tensile strength of the cement.

Figure 4 shows the correlation between the tensile bond strength to G-C Dentin Cement and pH of the bonding agent. A liner regression analysis between bond strength and pH showed a correlation coefficient of 0.654.

The correlation between the tensile bond strength to Shofu Base Cement and pH of the bonding agent is shown in Figure 5. A liner regression analysis gave a correlation coefficient of 0.568.

Table 4. Tensile Bond Strength to G-C Dentin Cement and pH of Their Respective Bonding Agents

	Mean kg/cm^2	pH of Bond Agent
Pyrofil Light Bond A	65.5	2.28
Silux	60.1	2.67
P-30	57.8	2.67
Photoclearfil A	55.1	2.75
Prisma-Fil	48.1	6.98
Ful-Fil	45.5	6.98
Lite-Fil A	45.4	5.72
Command Ultrafine	37.7	2.58
Occlusin	28.9	6.62
Durafill	28.5	7.62
Bis-Fil-M	3.2	6.72

Table 5. Tensile Bond Strength to Shofu Base Cement and pH of Their Respective Bonding Agents

	Mean kg/cm^2	pH of Bond Agent
Pyrofil Light Bond A	61.4	2.28
Silux	54.6	2.67
P-30	49.6	2.67
Lite-Fil A	43.0	5.72
Prisma-Fil	39.5	6.98
Ful-Fil	39.4	6.98
Durafill	38.3	7.62
Photoclearfil A	37.6	2.75
Command Ultrafine	35.1	2.58
Occlusin	24.8	6.62
Bis-Fil-M	8.2	6.72

The effect of application time of Scotchbond to G-C Dentin Cement on the bond to Silux was evaluated and these results are shown in Figure 6 and Table 6. The application times after cement mixing were 4, 5, 7, 10, 12, and 15 minutes. The setting time of this cement is indicated by the manufacturer to be three minutes and 45 seconds. The highest bond strength was obtained with a four-minute Scotchbond application, and the bond strength decreased as the time lapse between the end

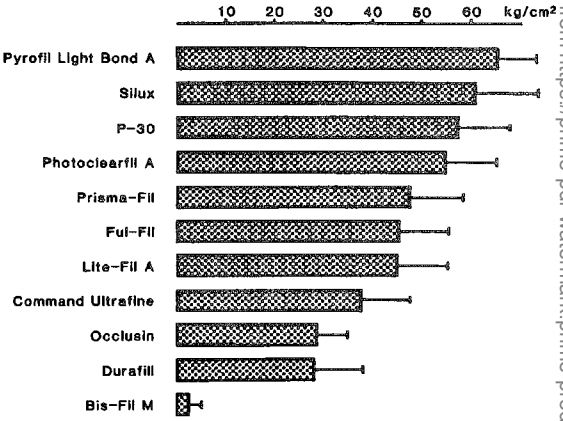

FIG 2. *Bond strength to unetched G-C Dentin Cement*

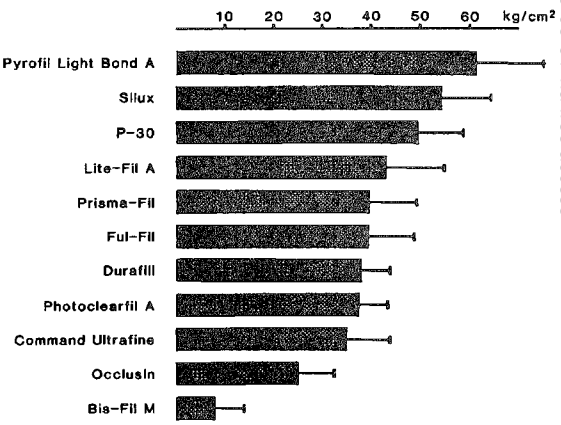

FIG 3. *Bond strength to unetched Shofu Base Cement*

Table 6. The Effect of Time of Application of Scotchbond to G-C Dentin Cement on the Bond to Silux

Time after Mixing (minutes)	Bond Strength (kg/cm^2)
4	76.9 (8.98)
5	70.6 (12.67)
7	60.9 (13.34)
10	56.2 (13.46)
12	50.2 (10.59)
15	43.1 (8.14)

( ) = SD

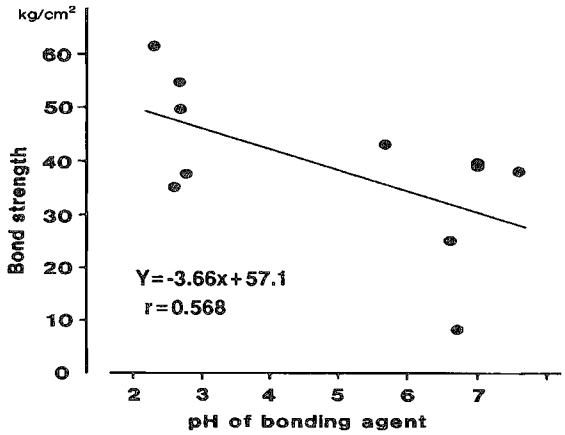

FIG 5. *Bond strength to Shofu Base Cement vs pH of respective bonding agent*

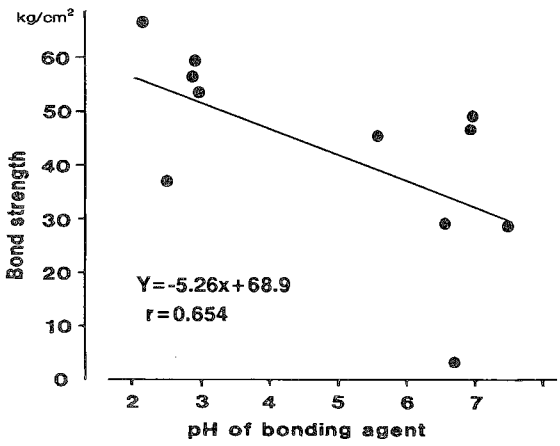

FIG 4. *Bond strength to G-C Dentin Cement vs pH of respective bond agent*

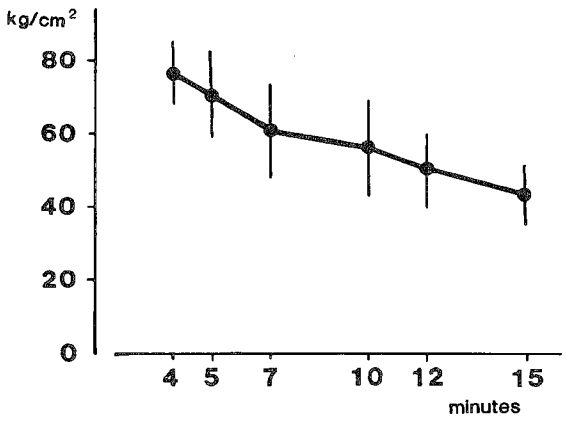

FIG 6. *Bond strength between Silux and G-C Dentin Cement*

of mixing and application of the bond agent increased.

Discussion

It is interesting to note that Pyrofil Light Bond A has the highest bond strength and that its respective bonding agent, Pyrofil Light Bond, had the lowest pH. Silux had the second-highest bond strength, and Pyrofil Light Bond A and Silux were grouped together. Silux's bonding agent, Scotchbond, was in the lowest pH group.

Our previous (Hinoura, Moore & Phillips, 1987) study reported that the adhesion between glass-ionomer cement and composite resin was enhanced either by acid-etching or roughening of the cement surface, with etching resulting in a modest increase in the bond strength as compared to the roughened surface. Etching or roughening the surface of glass-ionomer cement before application of

composite resins and bond agents produced bond strengths comparable to the bond strength between glass ionomers and dentin. In that study, G-C Bond, Visio-bond, and Scotchbond were employed and the mean bond strength to the unetched surface was 21.6 kg/cm^2. In the current study, the mean for the unetched was 41.2 kg/cm^2. Since the previous study had a different mean strength between unetched glass-ionomer cements and composite resins, there is a possibility that bonding agents have been developed that have some chemical bond to glass-ionomer cements.

There are, of course, many factors which influence bond strength values. A previous study (Hinoura & others, 1989) reported that the best bond strength was obtained using the lowest viscosity bonding agent, and the bond strength of this union reflects the tensile strength of the cement. There is a possibility that a low pH bonding agent dissolves the glass-ionomer cement surface and that there will be mechanical attachment.

Bonding primers containing acid are now on the market, like Scotchbond 2. This primer self-etchs the dentin and a higher bond strength is obtained. It was hypothesized in this study that low pH bonding agents etch the glass-ionomer cement surface, and the matrix of the hardened glass-ionomer cement dissolves in acid, resulting in a rough and porous surface. The bonding agent penetrates into the surface irregularities and hardens. However, the low correlation coefficients measured between bond strength and pH would indicate a limited relationship with pH.

Conclusions

In considering the effect of application time of Scotchbond to G-C Dentin Cement on the bond to Silux, the best bond strength was obtained with four minutes of Scotchbond application. The bond strength decreased as the time lapse between the end of the mix and application of the bond agent increased. The reason for this tendency may be that the acid resistance increases with cement maturation, so there is a mechanical union at the early stages of hardening of the cement. It is obvious that additional research is needed to investigate the bond strength after longer elapsed times, for example, 24 hours or one week.

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Porosities in Five Automixed Addition Silicone Elastomers

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Summary

Five automixed and one hand-mixed addition silicones were evaluated by counting the number of voids produced in impressions made. It was concluded that although automixing produced fewer voids than hand-mixing, certain automixed materials were better than others.

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Introduction

The presence of voids in elastomeric impression materials has been recognized as a common occurrence (Stackhouse, 1983). Surface voids at critical areas such as margins and line angles can affect the fit of the final cast restorations. A great amount of effort has been made to identify contributory factors and in formulating strategies to address this inherent problem of surface voids in impressions. These include modifying the method of mixing impression materials (Stackhouse, 1983; Keck, 1985; Scrabeck, Eames & Hicks, 1986), as well as varying the type of syringes (Kishimoto, Shillingburg & Duncanson, 1980) and the dimension of syringe-tip diameters (Stackhouse, 1985). However, Kishimoto and others (1980) and Stackhouse and others (1987) found that operator experience contributed more to voids in impressions than the type of syringe or material used. Smear-mixing generally produced fewer voids than stir-mixing (Stackhouse, 1983; Keck, 1985). Mechanical spatulation under vacuum produced even fewer impression voids, but its application to elastomeric impression materials in a clinical setting had been questioned (Scrabeck & others, 1986). Harrop and Middaugh (1967) and Going (1968) discovered

that void formation at the margins and within tooth preparations could be prevented simply by blowing compressed air to achieve better adaptation of the syringed material.

The automatic mixing system was introduced to overcome the problems associated with hand-spatulation of impression materials. Basically it provides more uniform ratios and homogeneous mixes of base and catalyst impression pastes, and a better safeguard against contamination (Keck, 1985). Automixing also substantially reduced the number of voids formed in impressions (Craig, 1985; Keck, 1985; Chong, Soh & Wickens, 1989). Several addition silicone impression materials are now available with prototype automatic mixing systems. This study examined the formation of voids in impressions of five automixed addition silicone impression materials prepared by automixing and hand-mixing. Comparisons were made with one hand-mixed addition silicone impression material.

Materials and Methods

One hand-mixed and five automixed addition silicone impression materials of medium-viscosity were selected for the study (table). Automixing of the impression material was achieved by extruding the base and catalyst impression pastes from their cartridges through the disposable mixing tip attached to one end of the cartridge barrels. Each automixed material was dispensed through the manufacturer's mixing tip and back-loaded directly into a reusable metal impression syringe (ESPE, Seefeld/Oberbay, West Germany). This was achieved by inserting the mixing tip into the impression syringe, extruding the impression material, and allowing it to fill up the barrel of the syringe. The impression material was then dispensed in sequence onto a model consisting of six stainless steel cylinders (samples) of 8 mm in diameter, 5 mm high and mounted 8 mm apart (Fig 1). The automixed material was also loaded into the Perspex lid, which was used as the impression tray and seated over the cylinders.

Impression Materials Evaluated

Product	Type of Material	Code	Manufacturer
Express	automixed	EX	3M Dental Products St Paul, MN 55144
Imprint	automixed	IM	3M Dental Products St Paul, MN 55144
Mirror 3 Extrude	automixed	MR	Kerr/Sybron Dental Products Romulus, MI 48174
Omnisil	automixed	OM	Coe Laboratories, Inc Chicago, IL 60658
Reprosil	automixed	RP	L D Caulk Co, a Division of Dentsply International, Inc Milford, DE 19963
Hydrosil	hand-mixed	HY	L D Caulk Co, a Division of Dentsply International, Inc Milford, DE 19963

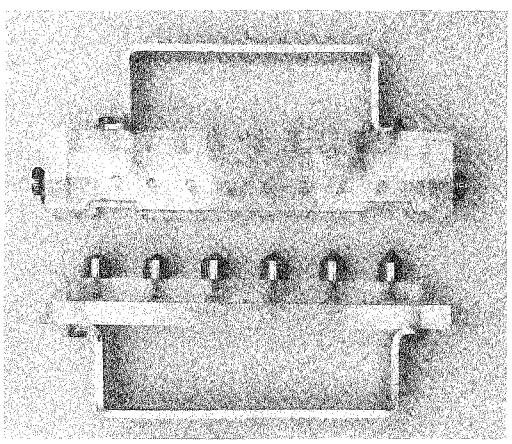


FIG 1. *Model of stainless steel cylinders with lid*

The hand-mixed material (Hydrosil) was dispensed according to recommended ratios and stir-mixed initially with the edge of a rigid metal spatula for 15 seconds, followed by smear-mixing on the mixing pad for another 15 seconds. The mixed material was loaded into the metal syringe and similarly dispensed onto the stainless steel cylinders. All the automixed impression materials were also hand-mixed in the same manner for comparison.

All impressions were made in a random manner. Six impressions were made for each impression material. Each impression produced six samples, giving a total of 396 samples. After the recommended setting time, the polymerized impression material was carefully removed from the model to avoid introducing surface

tears. A specially designed cutting device (made up of a weighted assembly holding a microtome blade) was used to section each sample longitudinally into symmetrical halves. The number of voids at a predetermined site (demarcated by a plastic template with a 5 X 2 mm window) on one of the two halves of each sample was counted under a binocular microscope (Stereo Star, Leica, Inc, Buffalo, NY 14240) at X7 magnification (Fig 2). Counting was carried out on three separate days by one operator. To standardize perception of voids, any break in the surface continuity regardless of its size or shape was included in the count.

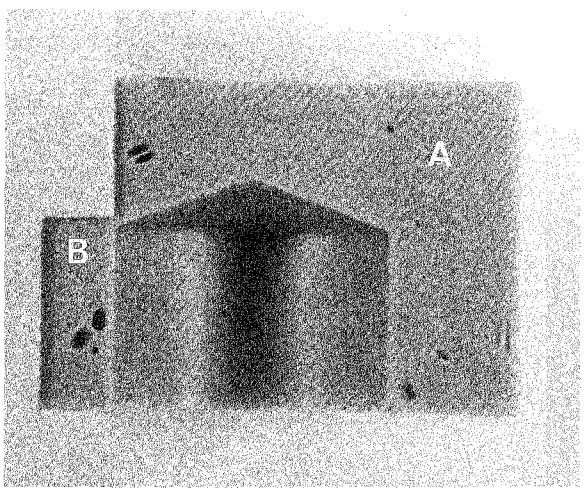


FIG 2. *The cut surface of an impression sample (A) with the plastic template demarcating the 5 x 2 mm area of measurement (B), magnification X7*

Tukey's studentized range test was used to establish differences in the mean number of voids between the one hand-mixed material and the five automixed materials, between the hand-mixed material and the automixed materials prepared by hand-mixing, and between the five automixed materials. Student's *t*-test was used to compare differences in the mean number of voids for the five automixed materials prepared by automixing and hand-mixing.

Results

The mean number of voids for each impression material and type of mixing method was derived by dividing the total void count with the number of sample counts made over the three days. None of the impression elastomers prepared either by automixing or hand-mixing produced void-free impressions (Fig 3). The hand-mixed material (HY) produced more voids than three of the automixed materials (RP, OM, MR) but fewer voids than IM or EX; however, the differences in the mean number of voids between the hand-mixed material (HY) and the automixed materials were not statistically significant. Among the automixed materials, three of them (RP, OM, MR) produced significantly fewer voids than EX ($P < 0.05$).

The hand-mixed material (HY) produced significantly fewer voids than all the automixed materials prepared through hand-mixing ($P < 0.05$). Similarly, those impression samples produced by the automixed materials via automixing resulted in significantly fewer voids ($P < 0.001$) than those produced via hand-mixing (Fig 4).

Discussion

This study confirmed the findings of previous studies which showed that none of the elastomers produced void-free impressions (Stackhouse, 1983; Scrabeck & others, 1986; Chong & others, 1989). Hand-mixed impressions of the automixed materials were made for comparison so that the voids produced in the impressions would be accounted for by the mixing technique and not the materials themselves. All of the automixed materials prepared through automixing produced significantly fewer voids than similar materials prepared through hand-mixing. Craig (1985) showed that hand-mixed elastomers did not perform well when dispensed through automatic mixing tips. This perhaps indicates that only impression materials manufactured for automixing are meant to be mixed and dispensed through these automatic mixing tips.

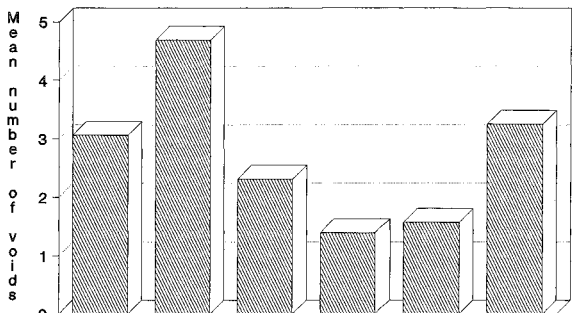
The hand-mixed material (HY) used in this study performed as favorably as some of the automixed materials. This result differed from a previous study (Chong & others, 1989), where the automixed material was better than all the hand-mixed materials. A possible explanation could be that the hand-mixed material used in this study was easier to mix and, thus, fewer bubbles were incorporated into the material prior to the syringing phase.

Three of the automixed materials (RP, OM,

MR) produced fewer impression voids than the hand-mixed material (HY), but two others (IM, EX) had more voids. One of the advantages of automixing is to reduce air incorporation during hand-spatulation. One would question the desirability of the latter two automixed materials if their performance was worse than the hand-mixed material.

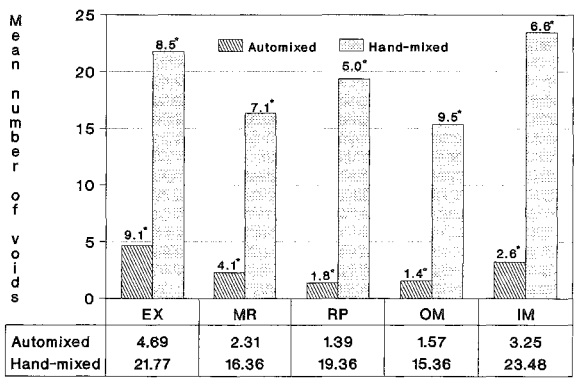
In order to reduce possible extraneous factors, the same syringe-tip diameter, type of syringe, and method of loading and syringing were used throughout the study. Hand-mixing of impression materials was carried out by an experienced dental assistant and syringing of materials done by one investigator to reduce between-operator variability.

One previous investigation showed that there was no consistent pattern in either the location or size of voids formed in impressions (Stackhouse, 1983). In this study it was also noted that the sizes of the impression voids varied greatly. Thus a predetermined 10 mm^2 site on the cut surface of the impression, sample was chosen to facilitate and standardize the counting process. The chosen site enabled the detection of a wider representation of voids in the impression, which might be of clinical relevance. Moreover, this site on the cut surface of the impression also enabled the detection of subsurface porosities, which may only appear as pin-point exposures on the external impression surface but become apparent as protuberances or blebs on the stone casts when they are poured up. A magnification of X7 was chosen to count the voids, as it was shown in a recent study (Chong & Soh, 1990) that at this magnification there was a significant reduction in the between- and within-operator variability for the examination of surface defects in impressions.



	HY	EX	MR	RP	OM	IM
Mean	3.06	4.69	2.31	1.39	1.57	3.25
SD	3.73	9.10	4.10	1.79	1.40	2.59

FIG 3. *Means and standard deviations of voids produced in the six addition silicone impression materials*



	EX	MR	RP	OM	IM
Automixed	4.69	2.31	1.39	1.57	3.25
Hand-mixed	21.77	16.36	19.36	15.36	23.48

FIG 4. *Means and standard deviations (*) of voids in the automixed addition silicones produced by automixing and hand-mixing*

Conclusions

One hand-mixed and five automixed addition silicones were evaluated by counting the number of voids produced in impressions made. Results showed that no mixing technique produced completely void-free impressions. The hand-mixed material used in this study performed as well as some of the automixed materials, but some automixed impression materials produced significantly fewer voids than other automixed materials, indicating that certain automixed materials were better than others.

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A Clinical and Histological Evaluation of Conservative Pulpal Therapy in Human Teeth

M FITZGERALD • R J HEYS

Summary

Three intermediary base materials, a zinc oxide-eugenol (Cavitec) and two calcium hydroxide liners (Life and Dycal), were selected at random for use as a base beneath amalgam or composite restorations on humans following complete caries removal. Life and Dycal, selected at random, were also used as direct and indirect pulp capping agents as clinically indicated. Clinical evaluations of signs and symptoms were made before treatment and at one-week, six-month, and one-year intervals following treatment. Histological evaluations were performed on three complete caries removal teeth and 18 direct pulp capping teeth six months following treatment. No significant differences in clinical symptomatology resulted between the materials in the complete caries removal group or the indirect and direct pulp capping groups.

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INTRODUCTION

Direct and indirect pulp capping procedures have been the center of continuing controversy over the past few decades. In cases where it is suspected that complete caries removal may result in exposure of the dental pulp, indirect pulp capping may be performed (Fisher, 1981). This procedure involves the removal of carious tissue until a thin layer of the carious dentin is left in the deepest part of the carious lesion, thus avoiding exposure of the underlying pulp. This remaining carious dentin is then covered

by a layer of a calcium-hydroxide-containing base and the tooth restored. If vital pulpal tissue is exposed during the complete caries removal procedure, a direct pulp cap can be performed by placing the calcium-hydroxide-containing base over the exposure site and then restoring the tooth (Baume & Holtz, 1981). Both indirect and direct pulp capping procedures have been demonstrated to be clinically effective (Fisher, 1981; Baume & Holtz, 1981; Nyborg, 1955 & 1958; Stanley & Lundy, 1972; Negm, Comb & Grant, 1981; Sawusch, 1982). However, their clinical effectiveness relative to each other in permanent teeth is not well documented.

Both of these treatments use calcium-hydroxide-containing intermediary bases for augmenting pulpal healing. Various commercially available hard-set calcium-hydroxide-containing intermediary bases have been extensively tested in animal model systems (McWalter, El-Kafrawy & Mitchell, 1973 & 1976; Pitt Ford, 1980; Hörsted, El Attar & Langeland, 1981; Fitzgerald, 1979; Heys & others, 1981; Cox & others, 1982). However, their clinical efficacy relative to each other in humans is not well documented. Furthermore, it is unclear as to whether calcium-hydroxide- or zinc-oxide-eugenol-containing materials are the intermediary bases of choice in the clinical treatment of moderately deep carious lesions following complete caries removal.

It is believed by some that zinc-oxide-eugenol-containing intermediary bases have a sedative effect on irritated, nonexposed pulp tissue. Pure eugenol is capable of blocking action potentials in nerve fibers (Trowbridge, Scott & Singer, 1977; Kozam, 1977) and freshly mixed zinc oxide-eugenol has been demonstrated to inhibit intradental nerve activity in cat tooth pulps while calcium hydroxide does not (Trowbridge, Edwall & Panapoulus, 1982). However, it is not known if proprietary formulations containing zinc oxide-eugenol are capable of delivering enough free eugenol to achieve such effects. Others believe that these zinc-oxide-eugenol intermediary bases should not be used in nonexposures after deep caries removal because they may interfere with pulpal healing (Brännström, Nordenvall & Torstenson, 1981).

This study was designed to address these issues by:

(1) comparing the relative success of two commercially available calcium-hydroxide-containing intermediary bases, Life and Dycal, in direct and indirect pulp capping treatments;

(2) comparing the relative clinical success of direct and indirect pulp capping treatments; and

(3) comparing a zinc-oxide-eugenol- (Cavitec) and two calcium-hydroxide-containing intermediary bases (Life, Dycal), as pulpal obtundents when used in moderately deep carious lesions following complete caries removal.

METHODS AND MATERIALS

Patients with large carious lesions who were willing to participate in this study were selected from registered clinic patients, or those presenting for urgency treatment at The University of Michigan School of Dentistry. Appropriate teeth were selected for restoration using a current set of radiographs and clinical examination. During the restoration sequence the treated teeth were assigned to one of three groups:

Indirect Pulp Capped--Radiographic evidence of a deep carious lesion in which pulp exposure was anticipated if complete caries removal was performed;

Complete Caries Removal--Radiographic evidence of a deep carious lesion in which pulp exposure was NOT anticipated if complete caries removal was performed; and

Direct Pulp Capped--All teeth in which the pulp was exposed during the course of complete caries removal.

Teeth that were periodontally compromised or had a previous history of spontaneous pain were not included in this study. The test materials were randomly selected at the time of treatment. The resultant distribution of treatment types and materials in the 151 treated teeth can be seen in Figure 1.

Clinical symptomatology was recorded for each tooth immediately prior to treatment and at one-week, six-month, and one-year recall visits. Teeth responding positively to tests 2 through 5 from the following clinical tests commonly used to diagnose pulpal condition (Dummer, Hicks & Huws, 1980; Seltzer, Bender & Ziontz, 1963; Stark & others, 1977)

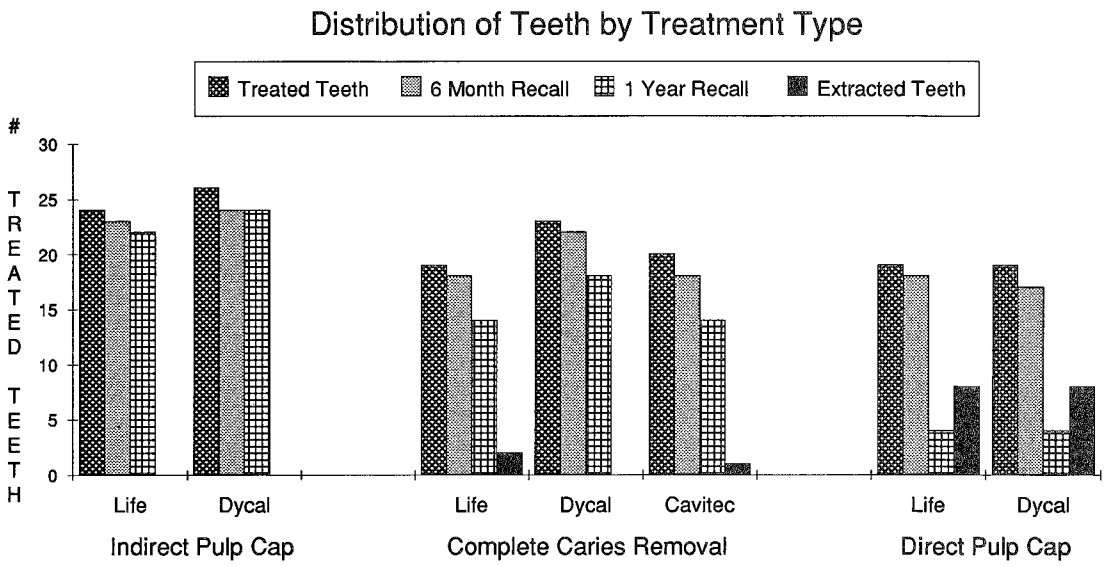

FIG 1. *Distribution of teeth treated by treatment type*

were classified as clinically symptomatic. Electric pulp tests were used to eliminate teeth that did not respond at all prior to treatment (indicating a potential devitalized tooth) and to monitor degree of reactivity following treatment.

Clinical tests used:

(1) A digital electric pulp tester (Analytic Technology, Redmond, WA 98052, Model 067322) was used according to the manufacturer's directions to measure pulp-vitality response of the test tooth and a contralateral untreated control tooth. Teeth that did not respond to electric pulp testing during the pretreatment evaluation were excluded from this study.

(2 & 3) The response of the test tooth to heat and cold was measured by warming modeling compound (Moyco Modeling Compound #55071, Moyco Industries, Inc, Philadelphia, PA 19132) to approximately 56 °C or using a stick of ice and applying it to the buccal surface of the test tooth for five seconds. Intensity and duration of any patient sensitivity during or immediately following application was recorded.

(4) Response of the test tooth to percussion was evaluated using a mouthmirror handle to percuss the test tooth and adjacent teeth. Any patient sensitivity was recorded.

(5) History of sensitivity associated with the test tooth was noted by recording any history of pain to heat, cold, sweets, percussion or any other stimulus that could be recalled by the patient. Any teeth with a history of spontaneous pain without associated stimulus were excluded from the study.

Following anesthesia, the operating field was isolated with a rubber dam whenever possible and the lesion excavated to an intact dentinoenamel junction using an ultra-high-speed air-turbine handpiece with a carbide round and/or straight fissure bur under an air-water spray coolant.

Teeth in the indirect pulp capping group had caries removed with spoon excavators and low-speed rotary instrumentation using steel round burs to a point at which, in the operator's clinical judgment, further excavation would result in carious exposure. After the preparation was cleaned and dried with the air/water spray of the operatory unit, one of two commercially available calcium-hydroxide intermediary bases (Life, Kerr/Sybron, Romulus, MI 48174, Base-01227, Catalyst-01267 and Dycal, L D Caulk Co, Milford, DE 19963, Base-100980, Catalyst-100980) was then randomly selected and placed as an indirect pulp capping agent over and slightly beyond the remaining carious dentin.

Teeth in the complete caries removal group had caries completely removed as described above and either Life, Dycal, or a zinc-oxide-eugenol-containing intermediary base (Cavitec, Kerr/Sybron, Base-01210, Catalyst-01220), selected at random, was placed.

If the pulp was exposed during treatment, caries removal was completed, the cavity washed and dried with the air/water spray of the operatory unit, hemostasis achieved with sterile cotton pellets, and then either Life or Dycal, selected at random, was placed as a direct pulp capping agent directly over and slightly beyond the exposed pulp.

All teeth were then restored with either 1) two coats of varnish (Copalite, Cooley & Cooley, Ltd, Houston, TX 77006), zinc-phosphate cement (Tenacin, L D Caulk Co) placed to restore pulpal and axial walls to within 0.5 mm of the dentinoenamel junction, and amalgam (Sybraloy, Kerr/Sybron) for posterior teeth or, 2) an acid-etched and bonded composite resin (Simulate, Kerr/Sybron, Base-01302, Catalyst-02304, Etchant-9115) for anterior teeth. Cavitec, because of its eugenol content and potentially adverse effect on the setting reaction of composite resin, was not used in anterior teeth. In addition to the recall visits at one week, six months, and one year, a telephone follow-up was made 24 and 72 hours postoperatively to solicit information regarding patient comfort. Radiographs of the treated teeth were taken at each recall visit.

Three of the complete caries removal teeth and 16 of the direct pulp capped teeth were extracted six months following treatment. These teeth had been scheduled for extraction prior to treatment and were restored to obtain histological evaluation of pulpal response to these treatments. Immediately following extraction, the apical one-third of the root was removed and the coronal portion placed in a phosphate-buffered paraformaldehyde-glutaraldehyde fixative for two days. The teeth were then demineralized in 0.5M EDTA, processed for histological evaluation following routine histological procedures outlined by Cox and others (1982), and serially sectioned at 5 mm through the entire pulp. Alternate slides were stained with Hematoxylin and Eosin and a modified Preece Trichrome for histologic examination. Seven additional nontreated carious and noncarious teeth were also extracted and processed as controls. All teeth were clinically evaluated as described previously just prior to extraction and histologically evaluated according to the evaluation criteria listed in Table 1.

All preoperative and postoperative clinical evaluations were assembled and paired to histological evaluations when possible. Clinical data were grouped to create two types of clinical responses: sensitive and not sensitive. All teeth with patient history of sensitivity or tested sensitivity to heat, cold, or percussion were recorded as being sensitive. Teeth with no history of patient sensitivity or tested sensitivity

Table 1. Criteria for Grading Tooth Pulp Histology

INFLAMMATORY CELL RESPONSE

1. None-to-slight inflammatory response in the coronal pulp. A few scattered lymphocytes may be present.
2. Moderate cellular infiltrate of neutrophils and/or monocytes in the coronal pulp
3. Severe inflammatory response with the presence of neutrophils and/or monocytes involving at least 1/3 of the coronal pulp
4. Total necrosis of the coronal pulp

SOFT TISSUE ORGANIZATION

1. Normal or close-to-normal cellular morphology at the exposure site or adjacent to the cut tubules and throughout the coronal pulp
2. Incomplete cellular organization at the exposure site or adjacent to the cut tubules. The remaining coronal pulp, however, is normal.
3. Definitive cellular degeneration in at least the coronal third of the pulp

HARD TISSUE ORGANIZATION--EXPOSED PULPS

1. Organization of a calcified tissue directly against some portion of the medicament interface
2. Organization of a calcified tissue at some distance from the medicament interface
3. No evidence of any calcified tissue formation at the exposure site

HARD TISSUE ORGANIZATION--NONEXPOSED PULPS

1. No additional or abnormal increase in reparative dentin thickness adjacent to the cut tubules
2. A thin rim of new reparative dentin directly adjacent to the cut tubules
3. A large bulk of new reparative dentin directly adjacent to the cut tubules

to heat, cold, or percussion were recorded as being not sensitive. Chi-square and Fisher's exact probabilities were used for statistical analysis of the clinical and histological data at the 0.05 confidence level.

RESULTS

Demographic Data

The distribution of the 151 teeth treated in the present study may be seen in Figure 1. These teeth were distributed between 55 patients, 29 male and 26 female, whose ages ranged from 20 to 60 years (mean 27 ± 5). Of these 151 teeth, 11 were lost from the study by the six-month recall (one extracted at one week, 11 from patient attrition) and an additional 43 by the one-year recall (19 planned extraction at six months, 24 from patient attrition). This represented a 7.3% and 23.1% attrition rate for the first six months and one year respectively. With the exception of the one tooth extracted at one week to comply with the patient's request to extract a tooth with severe sensitivity, there were no cases of prolonged sensitivity to heat, cold, or percussion in any of the teeth either before or after treatment.

Clinical Evaluation

There were no statistically significant differences in clinical symptomatology between teeth treated with Life or Dycal in direct pulp capping, complete caries removal, or indirect pulp capping procedures at the pretreatment, one-week, six-month, and one-year time periods (Table 2). Also there were no statistically significant differences in clinical symptomatology between teeth treated with Life, Dycal, or Cavitec in complete caries removal, nonexposed teeth (Table 2). There were no statistically significant differences in clinical symptomatology between direct pulp capping, indirect pulp capping, or complete caries removal teeth at any of the recall times irrespective of the calcium-hydroxide-containing intermediary base used (Table 3). Comparison between different treatment times (Table 4) indicated significant increases in clinical sensitivity of calcium-hydroxide-treated teeth from pretreatment to one week posttreatment for the direct pulp capping teeth. There were significant decreases in clinical symptomatology from pretreatment to six months and from six months to one year after treatment in indirect pulp capping teeth and from one week to six months posttreatment in direct pulp capping teeth. Of the 151 teeth treated, there was only one case of severe sensitivity (one week following treatment, direct pulp capping with Dycal), and only 11 with moderate sensitivity. At six months and one year there were no cases of moderate or severe clinical symptomatology. Electric pulp test measurements showed no significant changes over time for the treated teeth.

Histologic Evaluation

In the histologic evaluation, all seven control teeth, irrespective of presence or absence of clinical caries, had normal cellular morphology with no inflammation present (Figure 2). The complete caries removal teeth six months following treatment were also very similar in histological appearance to the controls (Figure 3). There was normal cellular morphology, and no inflammatory reaction was noted in any of the three complete caries removal teeth.

There were no statistically significant differences in histological response to the calcium-hydroxide intermediary bases, Life and Dycal, in direct pulp capping teeth after six months of treatment (Table 5). Both the Life- and Dycal-treated teeth had dentin bridges that consisted of tubular dentin, amorphous dentin, amorphous debris, cellular inclusions, and dentin chips in varying amounts and combinations (Figs 4 & 5). Characteristically, the new odontoblasts along the dentin bridge were few in number and squamous-shaped (Fig 4). There was no relationship between the histologic response and clinical symptomatology (Table 6). At the time of extraction, only four of the 19 extracted treated teeth had clinical symptomatology. All four were direct pulp capping teeth, one treated with Life and three with Dycal. One of the three Dycal-treated direct pulp capping teeth was a tooth extracted one week following treatment because of acute, lingering sensitivity to heat and cold. This tooth had moderate inflammation and incomplete pulpal organization near the exposure site. However, the deeper pulp was normal. The other three teeth as well as 13 of the 15 remaining asymptomatic teeth had no inflammation and normal or close-to-normal

pulpal morphology. Two of the asymptomatic teeth were direct pulp capping teeth with necrotic pulps. One of these tested vital with the electric pulp tester immediately prior to extraction while the other tested devital.

DISCUSSION

Although the clinical evaluation methods used in the present study are viewed as being the most reliable noninvasive methods presently available (Dummer & others, 1980), they all involve an unavoidable disadvantage as suggested by Seltzer and others (1963) and Stark and others (1977): reduced objectivity due to the subjective nature of pain. This subjectivity has an important impact on all aspects of clinical evaluation because, in the final analysis, they all involve some parameter of pain.

There were no statistically significant differences in clinical symptomatology between Life and Dycal in direct pulp capping and indirect pulp capping teeth one week, six months, or one year following treatment. These findings are not surprising given that they both are calcium-hydroxide-containing intermediary bases. However, the lack of a difference between the calcium-hydroxide and zinc-oxide-eugenol intermediary bases in the complete caries removal group was unexpected. Although eugenol has been suggested as a possible obtundent of postoperative dental pain (Trowbridge & others, 1977; Kozam, 1977; Trowbridge & others, 1982), there were no statistically significant differences in clinical symptomatology seen in the complete caries removal teeth. The calcium-hydroxide-containing intermediary bases were clinically indistinguishable from the zinc-oxide-eugenol-containing intermediary base (Cavitec) in this category. This suggests that any possible obtundent effect of Cavitec may be clinically nonfunctional in complete caries removal treaments when an intact dentin layer is present. Possibly this is due to either the absence of adequate concentrations of free eugenol being released from the Cavitec or the remaining dentin acting as a barrier preventing the free eugenol from affecting neural transmission within the pulp. If the former is the case, then a wet mix of eugenol with zinc-oxide powder might have a different clinical effect.

Because of the greater pulpal trauma induced during a direct pulp capping procedure, it was expected that direct pulp capping teeth would be more symptomatic soon after treatment than indirect pulp capping teeth. However, there were no significant differences in clinical symptomatology between direct pulp capping and indirect pulp capping teeth. This lack of significant differences may be due to the categorization of clinical symptomatology into symptomatic and asymptomatic categories instead of separately evaluating responses to each of the clinical tests. This categorization was done to ensure adequate numbers of cases per cell in the contingency tables, thus permitting proper chi-square and Fisher's exact probability analysis. It could be that this categorization masked an actual difference in intensity of type of clinical symptomatology. This can be determined by using larger numbers of treated teeth to permit a comparison of clinical symptomatology on an intensity scale for each parameter tested (i e, heat, cold, percussion). Another possible reason for the lack of clinical difference may reside in the indirect pulp capping procedure itself. Indirect pulp capping-treated teeth, in the present study, received extensive caries-removal treament and were restored with a permanent restoration after all but a minimum layer of affected dentin was removed from the preparation. The remaining affected dentin was left in the preparation and effectively sterilized with the calcium-hydroxide- or zinc-oxide-eugenol-containing material (Aponte, Hartsook & Crowley, 1966; Fairbourn, Charbeneau & Loesche, 1980; Knight & Marchelya, 1981). Consequently there was no attempt to reenter the tooth at a later time to remove affected dentin left during the original restorative procedure. This treatment protocol, however, does result in instrumentation of the tooth close to the amount used in the direct pulp capping teeth and thus could be a reason for similar postoperative clinical symptomatology.

The six-month and one-year success of the treatments in the present study did support findings of previous studies (Stanley, 1972; Sawusch, 1982; Tronstad, 1974; King, Crawford & Lindahl, 1965; Jordan & Suzuki, 1971). Clinical success, as measured by lack of clinical symptomatology and vital tooth response to electric pulp testing was 83% (38 of 46) for indirect pulp capping teeth and 74% (26 of 35)

for direct pulp capping teeth six months following treatment, and 85% (39 of 46) and 75% (6 of 8) respectively one year following treatment. These percentages are comparable to those of other direct pulp capping (Stanley, 1972; Sawusch, 1982; Tronstad, 1974) and indirect pulp capping (Sawusch, 1982; King & others, 1965; Jordan & Suzuki, 1971) studies in humans.

The comparison of tooth sensitivity between different treatment times by treatment type does suggest that there may be time-dependent differences in clinical symptomatology changes between direct pulp capping and indirect pulp capping treatment types (Table 4). In both indirect pulp capping and direct pulp capping teeth there was a significant increase in symptomatology from pretreatment to one week following treatment. However, the indirect pulp capping teeth demonstrated a significant reduction in symptomatology at six months as compared to pretreatment while the direct pulp capping teeth did not. This observation suggests that while direct pulp capping and indirect pulp capping teeth are clinically indistinguishable at any given time period, indirect pulp capping teeth tend to become less symptomatic at six months than they were at pretreatment, while direct pulp capping teeth do not. These trends, however, need to be further substantiated with additional studies of greater sample size.

In the histologic evaluation, all tissue evaluated after six months of treatment, with the exception of the two necrotic pulps, regardless of treatment type or intermediary base used, was generally characterized by little to no inflammation and normal or close to normal soft tissue morphology (Table 5). Histological pulpal responses to direct pulp capping with Life and Dycal were indistinguishable (Table 5). Because of the lack of clinically significant differences and indistinguishable histological results, there probably is no clinically relevant difference between Life and Dycal in direct pulp capping teeth. These results indicate an apparently large capacity of the tooth pulp to recover from substantial operative and biological insults, and substantiate the findings of Nyborg (1955 & 1958), Stanley (1972) and Cvek (1978). However, as noted by Haskell and others (1978) and Cox and others (1985), the long-term success of these treatments may not be as positive. Further study using longer evaluation times is needed to adequately address this issue. It is interesting to note that one of the teeth that had total pulpal necrosis tested vital with the electric pulp tester just prior to extraction. This once again points out the lack of a reliable relationship between clinical signs and symptoms and pulpal histology as reported by others (Nyborg, 1958; Wheeler, 1949; Kapur, Shapiro & Shklar, 1964; Sayegh & Reed, 1967) and further emphasizes the difficulty in inferring actual pulpal condition from the present clinical data.

CLINICAL APPLICATIONS

The clinical and histological results of the present study, combined with the findings of other clinical studies suggest that:

1) an indirect pulp capping procedure should be more desirable than a direct pulp capping procedure because it has a greater chance of clinical success (King & others, 1965; Stark, Nicholson & Soelberg, 1976; Fisher, 1977; Fisher, 1981; Sawusch, 1982);

2) direct pulp capping can be clinically successful for periods of at least one year and likely longer (Nyborg, 1955; Stanley & Lundy, 1972; Tronstad, 1974; Sawusch, 1982); and

3) in nonexposed teeth with complete caries removal, Life and Dycal was similar to Cavitec in reducing short-term postoperative clinical symptomatology.

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Table 2. Comparison between Clinical Symptomatology and Test Material by Treatment Type

	Pretreatment		One Week Posttreatment		Six Months Posttreatment		One Year Posttreatment	
	Asymp	Symp	Asymp	Symp	Asymp	Symp	Asymp	Symp
Indirect Pulp Cap								
Life	9	15	10	14	18	5	18	4
Dycal	10	16	13	13	21	3	21	3
	(P = 0.59)		(P = 0.38)		(P = 0.33)		(P = 0.45)	
Complete Caries Removal								
Life	14	6	14	5	17	1	13	1
Dycal	14	9	11	12	16	6	15	3
	(P = 0.38)		(P = 0.08)		(P = 0.08)		(P = 0.40)	
Direct Pulp Cap								
Life	11	8	6	13	12	6	2	2
Dycal	15	4	8	11	14	3	4	0
	(P = 0.15)		(P = 0.37)		(P = 0.25)		(P = 0.21)	
Complete Caries Removal								
Life	14	6	14	5	17	1	13	1
Dycal	14	9	11	12	16	6	15	3
Cavitec	14	6	13	7	16	2	14	0
	(X^2 = 0.76)		(X^2 = 0.21)		(X^2 = 0.14)		(X^2 = 0.15)	

Asymp = Number of asymptomatic teeth
Symp = Number of symptomatic teeth
P = Fisher exact probability
X^2 = Chi-squared probability

Table 3. Comparison between Clinical Symptomatology and Clinical Treatment by Test Material

	Pretreatment		One Week Posttreatment		Six Months Posttreatment		One Year Posttreatment	
Life	Asymp	Symp	Asymp	Symp	Asymp	Symp	Asymp	Symp
IPC	9	15	10	14	17	5	18	4
DPC	11	8	6	13	12	6	2	2
	(P = 0.15)		(P = 0.36)		(P = 0.35)		(P = 0.21)	
Dycal								
IPC	10	16	13	13	21	3	21	3
DPC	15	4	8	11	14	3		0
	(P = 0.01)		(P = 0.41)		(P = 0.49)		(P = 0.62)	
Life & Dycal								
IPC	19	31	23	27	38	8	39	7
DPC	26	12	14	24	26	9	6	2
	(P = 0.004)		(P = 0.26)		(P = 0.26)		(P = 0.40)	
Life & Dycal								
IPC	19	31	23	27	38	8	39	7
CCR	28	15	25	17	33	7	28	4
DPC	26	12	14	24	26	9	6	2
	(X^2 = 0.01)		(X^2 = 0.12)		(X^2 = 0.59)		(X^2 = 0.70)	

IPC = Indirect pulp cap
DPC = Direct pulp cap
CCR = Complete caries removal

Table 4. Comparison of Tooth Sensitivity between Different Treatment Times in Teeth Treated with Life or Dycal

	Indirect Pulp Cap Treatment		Complete Caries Removal Pretreatment		Direct Pulp Cap Treatment	
	Asymp	Symp	Asymp	Symp	Asymp	Symp
One Week Posttreatment						
Asymp	12	11	18	7	13	1
Symp	7	20	10	7	13	11
	(P = 0.05)		(P = 0.29)		(P = 0.01)	
Six Months Posttreatment						
Asymp	17	21	24	9	20	6
Symp	0	8	3	4	4	5
	(P = 0.02)		(P = 0.14)		(P = 0.08)	
One Year Posttreatment						
Asymp	17	21	22	5	3	2
Symp	1	7	0	5	1	2
	(P = 0.09)		(P = 0.001)		(P = 0.50)	

	Indirect Pulp Cap One Week Posttreatment		Complete Caries Removal One Week Posttreatment		Direct Pulp Cap Posttreatment	
	Asymp	Symp	Asymp	Symp	Asymp	Symp
Six Months Posttreatment						
Asymp	20	18	20	13	13	13
Symp	3	5	3	4	1	8
	(P = 0.35)		(P = 0.33)		(P = 0.04)	
	20	19	16	11	2	3
One Year Posttreatment	3	4	1	4	1	2
Asymp	(P = 0.50)		(P = 0.13)		(P = 0.71)	
Symp						

	Indirect Pulp Cap Six Months Posttreatment		Complete Caries Removal Six Months Posttreatment		Direct Pulp Cap Six Months Posttreatment	
One Year Posttreatment	Asymp	Symp	Asymp	Symp	Asymp	Symp
Asymp	34	5	26	1	5	0
Symp	3	4	3	2	0	3
	(P = 0.02)		(P = 0.06)		(P = 0.02)	

Asymp = Number of teeth with no positive clinical signs or symptoms
Symp = Number of teeth with at least one positive clinical sign or symptom

Table 5. Comparison between Test Material and Histological Evaluation on Direct Pulp Cap Treated Teeth Six Months following Treatment

		Life	Dycal	Fisher Exact *P**
INFLAMMATORY RESPONSE**	1	7	6	0.7333
	2	0	0	
	3	0	0	
	4	1	1	
SOFT TISSUE RESPONSE**	1	7	6	0.7333
	2	0	0	
	3	1	1	
HARD TISSUE RESPONSE**	1	6	5	0.5000
	2	0	1	
	3	1	1	

*Computed by combining responses 2, 3, and 4 into one category to form a 2 x 2 contingency table
**See Table 1 for definitions of categories

Table 6. Comparison between Clinical Signs and Symptoms at Time of Extraction and Histological Evaluation on Direct Pulp Cap Treated Teeth Six Months following Treatment

	CLINICAL SIGNS AND SYMPTOMS		
	Asymptomatic*	Symptomatic**	Fisher Exact *P***
INFLAMMATORY RESPONSE****			
1	13	3	0.5304
2	0	1	
3	0	0	
4	2	0	
SOFT TISSUE RESPONSE****			
1	13	3	0.5304
2	0	1	
3	2	0	

* Asymptomatic = no positive clinical signs or symptoms
** Symptomatic = at least one positive clinical sign or symptom present
*** Computed by combining responses 2, 3, and 4 into one category to form a 2 x 2 contingency table
**** See Table 1 for definitions of categories

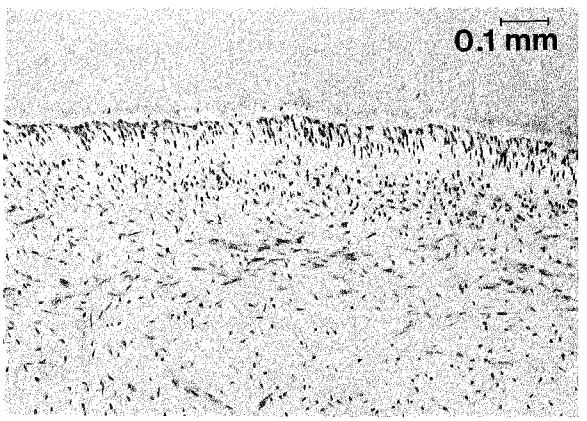

FIG 2. *A typical untreated control tooth showing no inflammation and well-defined odontoblastic, cell-free, and cell-rich zones in the coronal pulp*

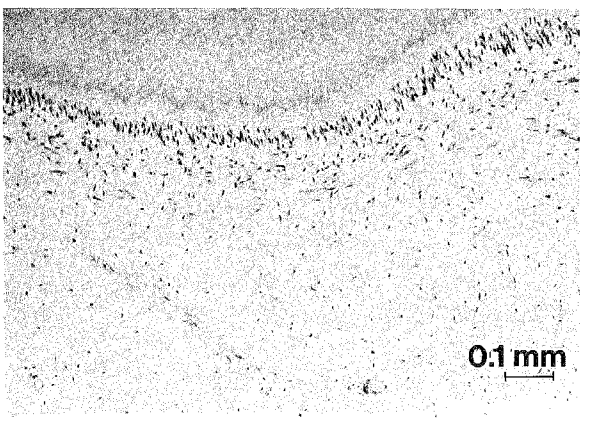

FIG 3. *A Cavitec-treated complete caries removal tooth six months after treatment showing no inflammation and well-defined odontoblastic, cell-free, and cell-rich zones adjacent to the cut tubules*

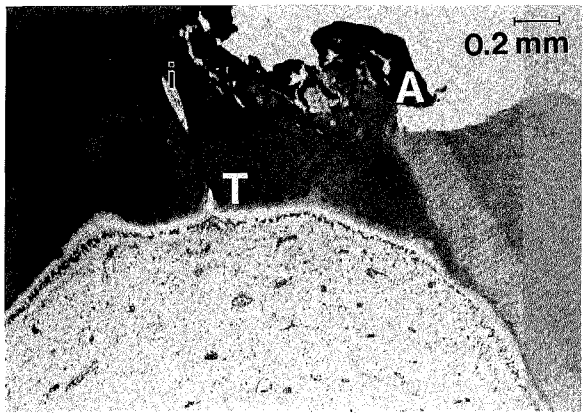

FIG 4. *A direct pulp capped tooth treated with Life six months after treatment showing bridging against the capping agent (A), tubular dentin (T), and cellular inclusions (i) in the dentin bridge*

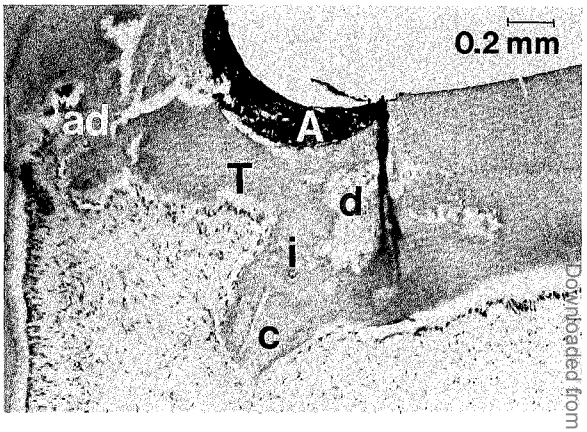

FIG 5. *A direct pulp capped tooth treated with Dycal six months after treatment showing bridging against the capping agent (A), amorphous debris (d), dentin chips (c), amorphous dentin (ad), and tubular dentin (T) as well as cellular inclusions (i) in the dentin bridge*

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POINT OF VIEW

Contributions always welcome

Unwarranted and Unprofessional: the Superfluous Removal of Clinically Acceptable Amalgams

HOWARD S KATZ

Publicity over silver amalgams and their safety is not a new matter. The most recent, controversial hyperdramatization of the subject was the CBS journalistic program "60 Minutes," a portion of which was devoted to a biased attack on one of the best-researched materials dentistry uses today. Unfortunately, because of this and other often sensationalized and even erroneous information, the public, and even members of our own profession, may be left with the impression that silver fillings are universally, indisputably, and totally dangerous to our health.

Exaggerated and aggressive claims by anti-amalgamists, unsubstantiated and only peripherally scientific, have often suggested that amalgam--and more specifically the mercury therein--can lead to a plethora of diseases and conditions from A to Z, including psychological disturbances; insomnia; irritability; memory loss; drowsiness; depression; tremors; cardiovascular disease; neurologic, allergic, or collagen disorders; immunological problems; headaches; gastrointestinal distress; chromosomal damage; alterations in the red and white blood cells, etc. The list is as long as the imagination is broad.

These accusations are simply not true. Amalgam is the most commonly used dental restorative material, with more than 200 million teeth restored each year. It has been used for a long time and its properties are well understood. Collectively, the mercury and the metals in a set, hardened amalgam are rigid and strong enough to withstand the forces exerted during chewing, while minimizing the potential for corrosion, tarnish, shrinkage, and leakage. The clinical record of success with dental amalgams is superb. In the hands of a good dental operator, it is not uncommon to see fillings last for decades, despite intense and prolonged pressure, constant bathing in moisture, and exposure to an array of microorganisms.

The attack against amalgam is linked to its mercury component. Unfortunately, when the public thinks of mercury, major ecological catastrophes, death due to industrial pollution, and the poisoning of our environment come to mind. Mercury in silver amalgam is guilty by association and raises fears of heavy metal poisoning. But the elemental form of mercury used in amalgam is not the form responsible for these disasters.

There are three forms of mercury, each with the potential for toxicity:

1. elemental or metallic mercury, which exists as a liquid or vapor and is the form of the mercury in amalgam prior to trituration,
2. inorganic mercury formed as complexes in compounds, which is the form mercury takes

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in hardened amalgam, and

3. organic compounds of mercury, which are the most toxic and which are totally absent from dental amalgams. These organic compounds are the forms associated with the major cataclysm of mercury poisoning.

One of our main concerns is mostly with inorganic mercury vapor released principally during trituration, insertion and carving of the amalgam, and also to a lesser extent from hardened restorations in the mouth. The now 'famous' University of Calgary experiments and several others have demonstrated, using radioactive tracer techniques, that mercury from set and hardened amalgam fillings set even years earlier can be detected on the breath and was paralleled by an increase in mercury levels in the blood. During chewing, the concentration reported increased 15-fold. The highest concentration occurred in patients with large, cracked, corroded, or pitted restorations, underlying one of the needs to change deteriorated amalgam fillings.

Mercury vapor can therefore be released from set amalgams and can be absorbed into our blood, primarily via our lungs and to a lesser extent, through our skin, and accumulate in the kidney, liver, and especially the brain, where it remains long after its elimination from other body sites. It even crosses the placenta to get to the fetus, and is clearly present in breast milk. Some alarmist researchers suggest a high risk of malformed infants for mothers with long-term exposure to high levels of mercury vapor, and that certain enzyme activities in our bodies may be affected, leading to psychological disturbances such as insomnia, irritability, memory loss, drowsiness, depression, and tremors. But what is forgotten is that these were experiments with very high mercury vapor and chronic exposure.

The inorganic forms of mercury, particularly the inorganic form used in dentistry, carries the least potential for harm, even if it leaches out from set fillings.

Firstly, acute toxicity is very rare. Even if we were to swallow large amounts of elemental mercury, little would result. The old-style oral mercury thermometers were often broken, spilling their mercury contents. Children often would fracture the thermometers by biting on them, swallowing the mercury. Oral consumption has therefore not been dangerous. In one report, a whopping 500 grams was swallowed with no adverse reaction.

But what about chronic exposure to low-level mercury? It is here that anti-amalgamists press their strongest case. Studies at the University of Calgary have indicated that there is a chronic release of mercury from set amalgams, and that this mercury can be absorbed into various organ sites. This is not new information, and in the case of the University of Calgary, these studies were not peer-reviewed and furthermore, according to the FDA,were very flawed. Furthermore, what is not mentioned is that these very tiny amounts of mercury that can chronically be absorbed and sometimes chemically altered by the body can readily be detoxified much like the body can easily detoxify small amounts of medications. If the amounts of mercury chronically absorbed in dental work were dangerous to health, dentists, obviously at a far greater risk than the patient, with years and often decades of chronic exposure in their workplace and even, for that matter, in their mouths, would universally long ago have shown all or part of these symptoms. We all know that this simply has not been so.

But what about those miraculous 'cures' demonstrated on "60 Minutes"? Remember the woman who walked into the dental office with the use of a cane but after the removal of the amalgams left the office unaided and went dancing that very night! If you believe that this is truly an example of a physiological cause and effect, then you are a candidate for purchasing the Brooklyn Bridge. At best, these are anecdotal cures of effects: if you remove the amalgams, life becomes rosy again. When a patient truly believes in something, that tremendously powerful suggestion can often work 'miracles.' We even see it in faith healers who, with the laying on of their hands and with shouts of "HEAL! HEAL!" have obtained clinical cures. I suggest the cause and effect with faith healers is not unlike the cause and effect with the apparent 'remove the amalgam and save the world' cures.

Three or four miraculous cures were typified in "60 Minutes." But did you notice that no mention was made of the huge numbers of patients in whom the removal of all their amalgams, with considerable profit to the dentist, resulted in absolutely no clinical change whatsoever? Hardly what you would call fair journalistic ethics. What grabs the

headlines, however, is the dramatic. There is nothing spectacular to be gained by discussing the thousands of failures. The only patients in whom amalgam should be avoided are those with a true allergy, but these are very few and very far between. It is possible that the 'cures' are related to allergy. But do we ban the product because it has allergic potential? Patients die every year from penicillin. Do we ban it? Every drug has the potential to be toxic--every one! Do we ban all drugs?

To be frightened into exchanging perfectly clinically acceptable amalgam restorations superfluously for composite restorations, gold or porcelain inlays, is one of the biggest consumer frauds in dentistry. And especially in the case of composite resins, the change becomes rather stupid. We switch a patient needlessly from a safe, predictable material to a weak, greatly inferior substance. Ironically, if we are trying to protect the patient from 'unsafe' and 'dangerous' amalgams, we may miss the boat with resins. These posterior resins are developed and churned out as fast as possible for use by the profession almost overnight. There are few clinical trials, especially in the area of biocompatibility. Very little clinical information is known about resins in comparison to what is known about amalgams. Some resins have clinical trials of less than two years! And on that basis would you consider it safe as a replacement for amalgam? Come on! And this is in addition to the obvious fact that posterior resins are physically inferior to amalgams. They are far more difficult to handle and manipulate, even in the hands of expert practitioners, increasing the possibility of voids, poor packing into the cavity preparation, incomplete hardening of the material, and more gaps from contraction and shrinkage. The seal at the periphery of the filling is more susceptible to leakage and redecay, and it does not provide the antibacterial activity associated with amalgam. In large restorations these materials cannot support the occlusion as well as amalgams, wear more readily, have poorer interproximal contacts, and can be expected to last only fractionally as long as amalgams.

The cynic might argue that many dental practitioners are pushing their patients to change perfectly good amalgams for resins because of the bucks involved and not because of a true belief in their health. A recent new dental journal, trying to sell itself and subscriptions to the profession, makes the hard sell for aesthetic dentistry: "The doctors who will prosper in this multi-billion dollar market are those who will make their mark early. Doctors who are slow to respond will have to share the crumbs"(American Health Consultants, 1990).

The National Institute of Dental Research in the United States has stated that silver amalgams are safe and effective. There is no scientific evidence to justify the discontinuation of their use or their routine removal from restored teeth without apparent cause. This view is supported and endorsed by the Canadian and American Dental Associations, by every provincial and state dental association, and by every major prominent dental society and group. And this support is worldwide. The Canadian Dental Association's policy on this matter is clear: "There are no definitive studies or case reports published in referred scientific journals supporting the statements that dental amalgams are the cause of mercury toxicity. There is no data to suggest that the removal of amalgam restorations should be performed in an attempt to treat patients with non-specific chronic complaints." Furthermore, the Canadian Dental Association concludes that on the basis of the latest and most up-to-date research knowledge and professional standards, "there is no reason why a patient should seek, or be counselled to have serviceable amalgam restorations removed on the basis of any possible or perceived health risk. To recommend to a patient, or to the public, the removal of clinically serviceable amalgam restorations on the basis of substituting a material that does not contain mercury is unwarranted and unprofessional" (Canadian Dental Association, 1990).

This is quite precise and to the point.

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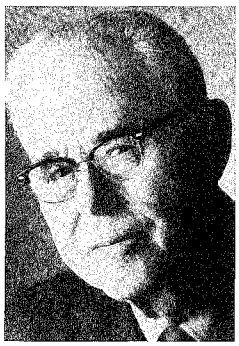
Hollenback Prize for 1991



George Hollenback

The Hollenback Memorial Prize was established by the Academy in honor of the late George W Hollenback for his many years of distinguished work in the field of dentistry. This annual prize is given for research which has contributed substantially to the advancement of restorative dentistry. Research of a broad range is to be considered, spanning the investigative spectrums from fundamental to applied, and encompass all levels of investigation. Such a researcher is this year's recipient.

Dr Robert G Craig is a native of Michigan and received his education in that state with bachelor's and master's degrees in chemistry and a PhD in 1954 in physical chemistry. Following the conferring of his bachelor's degree, he worked for several years in analytical research in upper New York, and following his PhD, worked for a year at Texaco. Since that time he has been at Michigan, where he rapidly moved through the academic ranks to full professor in 1964. He chaired the Dental Materials Department for 18 years, until school reorganization occurred in 1987. His wide interests in research are exemplified by a list of nearly 250 publications and an even larger number of abstracts relating to such areas of materials research as the following: evaluation of free energy; radiation effects on materials; studies on properties of enamel, dentin, and cementum; thermal conductivity and thermal analysis of materials; aging of materials; stress analysis; wear; bonding; viscosity of various materials and conditions affecting viscosity; color and color stability; implants and implant materials; cutting abilities of various products; and reactions of cells to various dental materials. These reports cover all the restorative and prosthetic materials and involve techniques unique to the University of Michigan. Dr Craig is also co-author of several texts in his field.

Since he is a chemist, one would expect that clinical evaluations would not be of interest to

Robert G Craig

him. That is not the case. His interest in and influence on the clinical conduct of research has been profound. This is evident in the research originating at Michigan as well as that developed from his influence on his graduates located at other institutions.

His skills as a teacher and mentor are well known. One cannot visit any dental school in the US or any 'modern' country without seeing evidence of the research and teaching of Dr Craig. For the most part, the initial and much of the current dental materials research in South America is an outgrowth from Michigan. England, Europe, Asia, and the Middle East have strong ties to the University of Michigan and to Robert Craig. This is also the case as one examines research in our industry. His influence has not only been felt by students coming to Michigan, but also has been shown by his numerous speaking engagements throughout the world. He has had a significant role in promoting dental materials and research in that field.

His role as a leader in materials research is well established, not only as head of his unit at Michigan, but throughout the world. He has successfully directed strong, individual researchers at the University and has had the most successful funded graduate training program in dental materials. He presently heads a materials institute program at the university. He has served on all the important programs and committees in materials and has been an officer for most of these at one time or another. Whenever he is asked to contribute, he is there, no matter what the role he is to play.

It is an honor for the Academy of Operative Dentistry to present the Hollenback Prize for 1991 to such a distinguished and accomplished teacher and researcher.

RICHARD D NORMAN

DEPARTMENTS

Press Digest

The editor wishes to thank the second-year Comprehensive Dentistry Residents at the Naval Dental School, National Naval Dental Center, Bethesda, Maryland for their assistance in the preparation of the following abstracts.

Comparison of wet and dry finishing of resin composites with aluminum oxide disks. Dodge, W W, *Dale, R A, Cooley, R L & Duke, E S (1991) *Dental Materials* 7 18-20.

(*Department of General Practice, University of Texas Health Science Center, Dental School, 7703 Floyd Curl Drive, San Antonio, TX 78284)

A laboratory study of two microfilled, one small-particle, and one hybrid resin material. One microfill was significantly rougher when finished wet, but no other material showed a difference. Hardness remained constant over time regardless of finishing technique, while only one resin remained color stable over the test period regardless of finishing technique. This argues for proper technique selection based on your choice of restorative materials.

The relationship between balancing-side occlusal contact patterns and temporomandibular joint sounds in humans: proposition of the concept of balancing-side protection. *Minagi, S, Watanabe, H, Sato, T & Tsuru, H (1990) *Journal of Craniomandibular Disorders* 4(4) 251-6.

(*Okayama University Dental School, Department of Removable Prosthodontics,2-5-1 Shikata-cho, Okayama City 700, Japan)

This study evaluated balancing-side contact patterns and temporomandibular joint sounds in 430 young adults. Occlusal contact was evaluated in the cuspid edge-to-edge position of each lateral excursion. Balancing-side contact was classified as A, simultaneous with working-side contact without clenching; B, balancing-side contact with clenching only; C, no balancing-side contact with or without clenching; or D, exclusively balancing-side contact. Joint sounds were evaluated during opening, closing, and side-to-side movement. Each joint was judged by palpation and stethoscopic auscultation either to have sounds or not. In the absence of balancing-side contact (Group C), there was a significant positive correlation between the prevalence of joint sound and the age of the subject ($r = 0.975$, $P > 0.001$). These data support the hypothesis that balancing-side occlusal contact may be protective of the TMJ. This study is one of the first to ascribe value to balancing-side contacts.

Effect of crown margins on periodontal conditions in regularly attending patients. *Bader, J D, Rozier, R G, McFall, W T Jr & Ramsey, D L (1991) *Journal of Prosthetic Dentistry* 65 75-79.

(*University of North Carolina, School of Dentistry, Chapel Hill, NC 27599)

After three decades of research, there is a nearly unanimous conclusion that margins of cast restorations placed at or below the gingival margin will cause some increase in gingival inflammation and probing depth. Almost all of the human studies to date have been performed on dental school patient populations. The results obtained may not necessarily be applicable to the larger population of regular users of dental services. The purpose of this study was to evaluate the periodontal conditions among 831 regularly attending patients in 35 private dental practices. Plaque, gingival inflammation, calculus, and probing depth were assessed on facial and mesiofacial surfaces of the Ramfjord teeth. There were significantly deeper probing depths and greater gingival inflammation with subgingival cast restorations for nearly all surfaces examined. In patients receiving regular preventive dental care,

subgingival margins are associated with unfavorable periodontal conditions.

An in vitro evaluation of fluorescein for testing the permeability of white spots on tooth enamel. *Shern, R J, Kennedy, J B & Roberts, M W (1990) *Pediatric Dentistry* 12 308-311.

(*National Institute of Health, Building 10, 1N-114, Bethesda, MD 20892)

The clinical differentiation of white spots on enamel can be difficult. Incipient caries often cause white spots that are porous; healed lesions and hypocalcifications are not porous. Several methods for detecting the location and extent of incipient caries have been described. This study compared fluorescein to potassium iodide on detecting porosity of incipient dental caries. Artificial lesions were created on extracted teeth by etching with lactic acid for 24 and 48 hours. The volume of dye uptake was calculated. The disclosants exhibited good intra- and interclass correlation (r = 0.91). Fluorescein has clinical advantages in that it does not discolor teeth and is nontoxic.

Shear bond strength of composite resin to porcelain. *Sorensen, J A, Engleman, M J, Torres, T J & Avera, S P (1991) *The International Journal of Prosthodontics* 4(1) 17-23.

(*University of California, Los Angeles, School of Dentistry, Los Angeles, CA 90024)

This in vitro study evaluated the effect of porcelain surface treatment on the shear bond strength of composite resin adhered to nine different types of porcelains. A variety of feldspathic porcelains with low and medium alumina content were tested. Porcelain/composite resin samples were subjected to a seven-day immersion in 37 °C water, thermocycled 1000 times between 5 °C and 50 °C, and then tested in shear. A three-minute etching using hydrofluoric acid significantly increased the bond strength of most of the feldspathic porcelains with low and medium alumina content. Silane application to all types of etched porcelain had no significant effect on bond strength. At present, the minimum in vivo bond strength necessary for retention of adhesive ceramic restorations in the oral environment is not known. The lowest mean bond strength of etched porcelain in this study was 9.37 MPa, and the highest was 19.35 MPa.

Resin-to-enamel bond strengths with various etching times. *Gilpatric, R O, Ross, J A & Simonsen, R J (1991) *Quintessence International* 22(1) 47-49.

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This study examined the minimum etching time needed to achieve adequate retention of composite resin to enamel in vitro. Adequate bond strength was defined as being equal to the bond strength obtained with a 60-second etch. The mesial and distal surfaces of extracted molars were etched for 5, 10, 15 or 60 seconds with 37% phosphoric acid. Scotchbond 2 was applied and cured, then composite was applied. After four days the composite was sheared in an Instron Testing Machine. There was no statistically significant difference between any of the four test periods. The bonds exceeded 2,600 psi. If microleakage is not increased with decreased etching time, this technique would be clinically useful.

Microleakage of three cement bases. *Heys, R J & Fitzgerald, M (1991) *Journal of Dental Research* 70 55-58.

(*The University of Michigan, School of Dentistry, Department of Restorative Dentistry, 1011 North University, Ann Arbor, MI 48109-1078)

This in vivo animal study evaluated the ability of three cement bases to resist bacterial penetration in a restoration exhibiting microleakage at 5 and 16 weeks. IRM, copal varnish + zinc phosphate cement, and glass-ionomer cement (GIC) were evaluated against a resin-only control. Both IRM and GIC were capable of minimizing bacterial penetration. These data are of clinical interest since the bactericidal properties of GIC have been questioned recently in in vitro studies.

Book Review

ATLAS OF CLINICAL ORAL DIAGNOSTIC IMAGING

Tomomitsu Hagashi

Published by Ishiyaku EuroAmerica, Inc, St Louis, 1990. 270 pages, 1000 illustrations. $42.50.

This book is in essence a collection of typical cases of pathology but presented in a systematic order and with hints on different imaging techniques that can be employed. For each chapter there are concluding summary tables that present condensed information about the lesions, their common features, and radiographic signs. With few exceptions the cases are accompanied by simple line diagrams serving as guides for reading the radiographs.

The book has 15 chapters: "Dental Anomalies," "Facial Clefts and Dental Caries," "Periodontal Diseases," "Osteomyelitis of the Jaws," "Odontogenic Cysts," "Non-odontogenic Cysts," "Odontogenic Tumors," "Non-odontogenic Tumors and Fibro-osseous Lesions," "Malignant Tumors," "Lesions of the Maxillary Sinus," "Temporomandibular Joint Disorders," "Trauma," "Soft Tissue Calcifications," "Foreign Bodies," "Accidentally Swallowed Objects," "Salivary Gland Disorders and Non-salivary Gland Tumors," and "Systemic Diseases Manifested in the Jaws."

The reference list encompasses most of the classical and current textbooks in oral radiology except for one or two. The book also has an index.

The large number of disease entities that may appear within the jaws results in a limited possibility to present a wide variety of one and the same entity. Thus generally only one case is presented for each lesion or disease. On the other hand, each chapter concludes with a table containing the most salient features and radiographic signs of the lesions. Each chapter is started with a classification, but not all of the entities are represented by actual cases. In an appendix of two pages, radiographic descriptions are listed and reference given to where in the text fitting examples can be found. Panoramic radiographs and intraoral radiographs are the dominating illustrations, but a wide variety of other types of images are presented when motivated. Thus bone scintigrams and CT-images are found frequently, MR-images occasionally, and ultrasound images in soft tissue lesions of the head and neck in a few cases.

The book was written with the dental student and the general dental practitioner in mind and, for these, I think the book offers an easily read and understandable text in which valuable hints are given with respect to radiographic examination technique. While generally the illustrations are of good quality, some exceptions are found, and the reduction of the size of the panoramic and other extraoral radiographs sometimes makes it difficult to observe the features of the lesion. Whether higher quality printing would have redeemed this condition is uncertain. Problems like these are encountered frequently in other textbooks as well and there is, in my opinion, no textbook that yet has overcome these difficulties. Also, most textbooks do not manage to present more than one or a few cases of the same type of lesion, and usually these examples are in accordance with what is generally considered to be typical. The more atypical presentations are hardly ever shown, leading sometimes to a false belief in specific signs of a disease or lesion.

Although there is a limited number of cases, this book could be useful for the dental student and the dentist, especially in consideration of the supplementary tables and notes on technique that accompany the different chapters. There are a few typographical and language errors, but these do not disturb the general impression of the hard work the authors spent realizing a good idea for a textbook in radiographic diagnosis or imaging. The specialist in and/or teacher of radiology may benefit from the book by its approach to the problem of conveying information to the dental student and dental profession about radiographic diagnosis, its methods, and their application.

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