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EDITORIAL

Fundamentals—the Key to Success

"There is nothing like serving an apprenticeship to fortune, like earning the right to your tools. In most enterprises the temptation is always to begin too far along; we want to start where somebody else leaves off. Go back to the stump and see what an impetus you get. Those fishermen who wind their own flies before they go a-fishing,—how they bring in the trout; . . ." (Burroughs, 1881).

The urge to begin the next step before mastering the previous one is ever present; but the urge should be resisted sedulously. Fundamentals first, application later—that is the key to success. Unfortunately these days too few can discipline themselves to refrain from "embarking on what comes after without having mastered what goes before" (Pavlov, 1955).

No football team is likely to succeed whose players are not proficient at blocking and tackling, skills unlikely to be acquired during the competition on a Saturday afternoon. A requirement even more fundamental for a football player is the development of strength and stamina, qualities attained mainly by lifting and pulling weights, and other exercises, which at first glance might seem to have little relevance to playing the game.

If attention to fundamentals is important for success in a simple activity such as football, how much greater the importance for success in the intricate and complex practice of dentistry. How unfortunate it is that in recent years so many dental educators, in undue haste to advance students to treating patients, have abandoned sound principles of education by curtailing the time spent on fundamentals—such as carving teeth. By neglecting fundamentals, students enter the clinic unprepared. They then require extra assistance from clinical instructors who, under the best of circumstances, are usually overburdened. Teaching—and learning—thus become inefficient. How can an instructor, with eight to twelve students to supervise, respond to a student who announces, "I'm going to do a foil in the distal of a canine this afternoon but I have had no experience with class 3s so I would like you to show me how to do it"? Increasing clinic time for such a student is fruitless; all that is increased is the quantity of mediocre treatment, and once again the patient is the loser.

Dentists that have mastered the fundamental skills to provide a service of high quality, especially in restorative dentistry, are likely to enjoy practicing their profession. This enjoyment is based firmly on skill and confidence. Dentists that do not develop these attributes are likely to be frustrated and unhappy. The suicide rate for dentists is high. Could inadequate training be a contributing factor?

Students, if given a chance and an explanation, would surely opt for a substantial investment in fundamentals to ensure a lifetime of pleasurable and satisfying practice. We should heed the admonition of John Burroughs and Ivan Pavlov. The emphasis on teaching fundamentals in a logical and progressive pattern should be reinstituted forthwith in restorative dentistry.

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OPERATIVE DENTISTRY, 1979, **4**, *2-8.*

ORIGINAL ARTICLES

Failure Rate of Margins of Amalgams with a High Content of Copper

After one year of clinical performance, amalgams made of alloys of high copper content differ in the rate of failure of the margins, non-γ-2 admixtures giving the best results.

J W OSBORNE • E N GALE

Summary

Ten commercially available amalgams—nine high-copper and one traditional alloy—were tested in the laboratory and in patients. After one year, 496 restorations were evaluated. The clinical results indicated that Dispersalloy, Cupralloy, Phasealloy, and Indiloy had the least marginal failure. These were followed closely by Tytin, Sybraloy, Velvalloy, and Optaloy II. Micro II and Aristaloy CR exhibited the most marginal failure. A statistically significant correlation was found between marginal failure and creep (r = 0.64) and between marginal failure and slow compressive strength (r = −0.60). However, caution should be exercised when using physical properties to predict clinical performance.

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INTRODUCTION

Clinical studies have shown that amalgams differ in the rate at which their margins fail and that there is a direct relationship between good clinical performance and low creep of the amalgam (Mahler, Terkla & Van Eysden, 1973; Osborne & others, 1977). As a result of the finding that copper will reduce the creep of amalgam, manufacturers have developed new alloys containing copper. Although other metals also can reduce creep, most manufacturers have used copper, and in higher proportions than the maximum of 6% permitted by Specification No 1 for amalgam of the American Dental Association (American Dental Association, 1976). To reflect the changing times, a new specification has been adopted that will certify alloys with a higher content of copper.

Only a few of the high-copper alloys have been tested clinically; therefore the purpose of this study was to compare the clinical performance of nine commercially available high-copper alloys and a traditional alloy. A variety of alloys having a copper content ranging from 9% to 30% was selected. These include single-phase alloys as well as admixtures.

MATERIALS

The ten alloys tested in this study are listed in Table 1, along with the names of the manufacturers, proportions of mercury used, and trituration times.

Table 1. Alloys Evaluated, Mercury Content, and Trituration Time

Alloy	Manufacturer	Mercury Content (%)	Trituration Time* s
Dispersalloy	Johnson & Johnson Dental Products East Windsor, NJ 08520, USA	50.0	10
Cupralloy	Star Dental Mfg Co, Inc Conshohocken, PA 19428, USA	50.0	10
Phasealloy	Phasealloy, Inc El Cajon, CA 92021, USA	50.0	10
Indiloy	Shofu Dental Corp Menlo Park, CA 94025, USA	45.0	10
Tytin	S S White Dental Mfg Co Philadelphia, PA 19102, USA	43.5+	2
Sybraloy	Kerr Mfg Co Romulus, MI 48174, USA	45.0+	25**
Velvalloy	S S White Dental Mfg Co Philadelphia, PA 19102, USA	50.0	14
Optaloy II	L D Caulk Co Milford, DE 19963, USA	54.5	14
Micro II	L D Caulk Co Milford, DE 19963, USA	54.5	14
Aristaloy CR	Baker Dental Carteret, NJ 07008, USA	52.0	10

* Vari-Mix (M-2)
** Wig-L-Bug
+ Precapsulated

METHODS

Tests for Physical Properties

Laboratory tests for flow, 24 hour compressive strength, creep, and 7-day slow compressive strength were conducted with material from the same batch used for patients. Previous research (Mahler & others, 1970; Osborne & others, 1977) has indicated that these are the properties that correlate best with clinical data. The samples were prepared using American Dental Association Specification 1 for all tests. The crosshead speed was 0.20 in/min (0.508 mm/min) for 24-hour compressive strength and 0.001 in/min (0.0254 mm/min) for slow compressive strength.

Placement of Restorations

The amalgams were placed in 67 patients by one operator at Indiana University School of Dentistry. Patients needing at least five restorations in occlusion were carefully selected. A rubber dam was used throughout the restorative procedure. Dycal (L D Caulk Co, Milford, DE 19963, USA) was placed in deep preparations and Copalite (Harry J Bosworth Co, Chicago, IL 60605, USA) was applied to the cavity walls. All restorations were condensed by hand and carved by conventional methods. After a minimum of 48 hours all restorations were polished without generating heat. All restorations on an individual were completed during a period of five weeks or less. After one year, 496 restorations were evaluated.

Evaluation of Restorations

The amalgams were evaluated from black-and-white photographs taken of each clinical restoration with a Medical Nikkor Camera at a magnification of one and one-half times. These were then printed in a 4 x 5 in (102 x 127 mm) format, yielding a picture approximately six times the original size. The prints were cropped to show only the restored teeth; pertinent information was recorded on the back. Two methods of evaluation were used:

1. The photographs were placed into five categories reflecting increasing amounts of breakdown and the results analyzed by ridit (relative to an identified distribution) as described by Mahler (1973) and the χ^2 test.
2. The photographs were ranked from best to worst (rank ordering test).

Two evaluators independently categorized and ranked the restorations.

Statistical Analysis

Several types of analysis were used to evaluate breakdown rates as well as the relationships between laboratory data and clinical data. To determine the relationship between clinical and laboratory data, correlations, which reflect the degree of relationship, were obtained.

Since the clinical photographs were rated by individuals, we need to know how well they agree in their rating. To determine the agreement or disagreement, the correlation coefficient (r) was used. Any coefficient approaching 1.0 is considered to be very impressive.

Three different methods were used to evaluate the data on marginal breakdown. Ridit means have been determined to be excellent predictors of future breakdown (Osborne & others, 1976). The lower the mean the less marginal breakdown. To determine if the amalgams performed differently from one another, two tests of significance were used. χ^2 tests were used on the categorical data used to determine the ridit means. Each amalgam was compared with every other amalgam for the frequency of placement into each category.

In addition to placing the amalgams into categories, they were ranked from least to most marginal breakdown. This type of ordering gives more information on breakdown rates than the categorical data. However, a more sophisticated statistical test, the Mann-Whitney U test, is needed to analyze the data appropriately. Again, all amalgams were compared with each other to establish the ranking of breakdown and the significance among the materials.

RESULTS

Physical

The laboratory data are summarized in Table 2. These tests show that Tytin and Sybra-

Table 2. Physical Properties of Amalgams

Amalgam	Creep		Flow	24-h Compressive Strength		Slow Compressive Strength	
	%	SD	%	lbf/in^2 (*MPa*)	SD	lbf/in^2 (*MPa*)	SD
Dispersalloy	0.25	± 0.09	0.7	59,900 (*413.31*)	± 3,500 (*± 24.15*)	51,800 (*357.42*)	± 800 (*± 5.52*)
Cupralloy	0.56	± 0.13	0.4	68,900 (*475.41*)	± 1,100 (*± 7.59*)	43,400 (*299.46*)	± 2,500 (*± 17.25*)
Phasealloy	0.69	± 0.16	0.9	65,200 (*449.88*)	± 3,800 (*± 26.22*)	51,800 (*357.42*)	± 1,400 (*± 9.66*)
Indiloy	0.22	± 0.08	0.4	64,500 (*445.05*)	± 3,200 (*± 22.08*)	53,500 (*369.15*)	± 4,200 (*± 28.98*)
Tytin	0.10	± 0.05	0.1	79,100 (*545.79*)	± 700 (*± 4.83*)	58,700 (*405.03*)	± 600 (*± 4.14*)
Sybraloy	0.05	± 0.05	0.3	72,700 (*501.63*)	± 2,500 (*± 17.25*)	59,300 (*409.17*)	± 3,500 (*± 24.15*)
Velvalloy	1.10	± 0.24	0.9	56,200 (*387.78*)	± 1,000 (*± 6.9*)	40,800 (*281.52*)	± 1,400 (*± 9.66*)
Optaloy II	1.60	± 0.15	1.2	55,900 (*385.71*)	± 600 (*± 4.14*)	39,300 (*271.17*)	± 1,400 (*± 9.66*)
Micro II	1.50	± 0.10	0.5	62,100 (*428.43*)	± 2,000 (*± 13.8*)	38,100 (*262.89*)	± 800 (*± 5.52*)
Aristaloy CR	0.94	± 0.22	0.6	67,900 (*468.51*)	± 1,400 (*± 9.66*)	38,300 (*264.27*)	± 1,500 (*± 10.35*)

loy have the highest 24-hour compressive strength, the highest slow compressive strength, and the lowest creep. Velvalloy, Optaloy II, Micro II, and Aristaloy CR have high creep and low slow compressive strength. The 24-hour compressive strengths of all amalgams are higher than their slow compressive strengths.

Clinical

The clinical data as assessed by the ridit analysis are shown in Table 3. The results of the χ^2 test, as performed on the distribution of marginal fracture, and the rank ordering test are shown in Table 4. The reliability of the rank ordering test can be ascertained by correlations obtained between the two raters for each amalgam. These correlations range from 0.96 to 0.98, which signifies close agreement between raters in the ordering of amalgams. The tests of significance can be interpreted as indicating the following: Dispersalloy, Cupralloy, Phasealloy, and Indiloy have the lowest marginal failure and the differences among them were found not to be statistically significant by both rank ordering and χ^2 tests. These amalgams were followed by Tytin, Sybraloy, Velval-

Table 3. Distribution of Marginal Fracture and Ridit Analysis

Amalgam	Categories (Both Evaluators Combined) I	II	III	IV	V	No of Restorations	Mean	SD
Dispersalloy	24	55	24	1	0	52	0.3601	0.2221
Cupralloy	22	45	24	1	0	46	0.3696	0.2317
Phasealloy	21	44	26	5	0	48	0.4030	0.2535
Indiloy	26	45	26	11	0	54	0.4155	0.2779
Tytin	15	47	26	12	0	50	0.4573	0.2663
Sybraloy	7	42	42	10	1	51	0.5276	0.2436
Velvalloy	5	41	35	15	2	49	0.5518	0.2540
Optaloy II	6	39	48	13	2	54	0.5619	0.2443
Micro II	4	15	46	24	3	46	0.6775	0.2337
Aristaloy CR	2	21	31	28	10	46	0.6997	0.2526
Total	132	394	328	120	18			
Ridit	66	329	690	914	983			
Ridit Mean	.0665	.3317	.6956	.9214	.9909			

Table 4. Statistical Evaluation of Data on Marginal Fracture

Rank Ordering $0.96 > r < 0.98$ ($p < 0.05$)	Alloy	χ^2 Test $\chi^2 = 9.5$ ($P = 0.05$)
	Dispersalloy	
	Cupralloy	
	Phasealloy	
	Indiloy	
	Tytin	
	Sybraloy	
	Velvalloy	
	Optaloy II	
	Micro II	
	Aristaloy CR	

| = Not different at level shown

loy, Optaloy II, and, finally, Micro II and Aristaloy CR. The latter two exhibited the most marginal fracture, did not differ from one another, and were significantly inferior to all the other amalgams.

Between the χ^2 test and the rank ordering test there was high agreement of clinical performance; the lone exception being that the difference between Tytin and Velvalloy was statistically significant ($P < .05$) in the rank ordering test but not in the χ^2 test. There were no statistically significant differences among Phasealloy, Indiloy, and Tytin, or among Sybraloy, Velvalloy, and Optaloy II.

Correlation of Physical Properties with Clinical Performance

The results of the correlation matrix are presented in Table 5. Only two laboratory tests had statistically significant correlations with marginal failure as expressed by ridit means. The correlation coefficient (r) between creep and marginal failure is 0.64, which is statistically significant at the 0.05 level of probability. The correlation between slow compressive strength and marginal failure is inverse, r = −0.60, which barely meets the 0.05 level of probability. Neither flow nor 24-hour compressive strength had a statistically significant correlation with marginal fracture. The correlation between creep and the other three laboratory tests of material properties is statistically significant in the expected directions. The correlation between flow and 24-hour compressive strength is statistically significant but not the correlation between flow and slow compressive strength. Whereas the correlations between 24-hour compressive strength and all other laboratory data are statistically significant, the correlation between 24-hour compressive strength and marginal fracture is not statistically significant.

DISCUSSION

Three points should be made about these clinical and laboratory data.

First, previous studies (Mahler, Van Eysden & Terkla, 1975; Osborne & others, 1977) show a higher correlation between marginal failure and creep than has been found in this study. Mahler's data on six alloys gave a correlation coefficient of 0.93 and Osborne's data on ten alloys 0.79, both statistically significant at the 0.01 level of probability. These two studies indicate that creep accounted for between 62% and 86% of the variance. However, both studies were dominated by traditional alloys containing γ-2 phase. In this study, three alloys—Velvalloy, Optaloy II, and Micro II—have γ-2 phase in the matrix. Optaloy II and Micro II have 9% Cu, which is insufficient to tie up all their γ-2 phase. If the data are analyzed for the remaining seven non-γ-2 alloys in this study, the correlation coefficient between creep and marginal failure is 0.41, which is not statistically significant. In retrospect, in the previously reported data (Osborne & others, 1977) the four high-copper alloys evaluated in that study do have a statistically significant correlation between creep and marginal failure, but in the wrong direction. Obviously, creep, when used as a predictor of clinical performance, cannot determine differences in non-γ-2 alloys.

Second, Tytin and Aristaloy CR are manufactured from the same patent and, therefore, have the same composition—Ag 59.8%, Sn 27.3%, and Cu 12.9%. Yet clinically they show distinctly different rates of marginal failure. It is true that these alloys have different configurations of particles and different Hg/alloy ratios. It is also interesting that Aristaloy CR is triturated five times longer than Tytin, and that trituration can affect clinical performance. Contrary to popular belief, the results of previ-

Table 5. Correlation between Physical Properties and Clinical Performance

Variables	Flow	24-h Compressive Strength	Slow Compressive Strength	Marginal Fracture
Creep	0.68+	−0.67+	−0.89+	0.64+
Flow		−0.85	−0.55	0.13
24-h Compressive Strength			0.62+	−0.14
Slow Compressive Strength				−0.60+

+ $P < .05$

ous clinical studies indicate that shorter trituration times produce better marginal integrity for certain traditional alloys (Osborne & Gale, 1974; Cochran & others, 1978). The combination of higher mercury content and longer trituration produced an inferior clinical result, even though the composition was the same.

Third, there is a debate on the superiority of single-phase, high-copper alloys over the admixtures or double-phase systems. Theoretically, the single-phase alloys should have little or no pockets of γ-2 phase in the early formation of the amalgam as are found in early double-phase alloys. However, if Micro II and Optaloy II are left out of the clinical results because they contain about 2–3% of γ-2 phase, which never disappears, then the results favor the double-phase system. Dispersalloy, Cupralloy, and Phasealloy, all double-phase systems, rank one, two, and three; whereas Indiloy, Tytin, Sybraloy, and Aristaloy CR, all single-phase systems, rank four through seven.

Long-term studies are under way to see if these one-year clinical results are good predictors of long-term clinical performance.

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Adhesion and Dentin

Some progress is being made in devising methods of bonding resins to dentin.

JEFFREY O HOLLINGER • EDWARD M MOORE, JR

Summary

Terms needed for an understanding of the phenomenon of adhesion are introduced and explained. The problems of achieving adhesion of a resin to dentin are discussed and some possible solutions advanced.

Introduction

Dental adhesive resins have become an accepted part of restorative dentistry. There are many advantages of a resin system that bonds to hard tooth structure: mechanical retention need not be prepared in a tooth prior to insertion of the adhesive restoration, and a direct union of resin and tooth structure could obviate leakage around restorations.

An adhesive resin will form a clinically effective bond with enamel. However, most restorative tasks involve not only enamel but also dentin. Difficulties have arisen when adhesive techniques used for enamel bonding were applied to dentin. The purpose of this article, therefore, is to describe the phenomenon of adhesion and explain the terms that are needed to understand the mechanism of binding a material to dentin.

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Definitions

Adhesion is interfacial bonding that results from attraction between dissimilar molecules (Smith, 1975); cohesion, in contrast, occurs between the same type of molecules.

Forces of Attraction

Chemcial or physical forces may produce a bond between atoms or molecules (Buonocore, 1975a). Chemical or primary attraction arises from intramolecular relationships. Metallic bonds are an example. Physical or secondary forces of attraction are intermolecular. These are a consequence of Van der Waals' forces and hydrogen bonding.

Importance of Smooth Surfaces

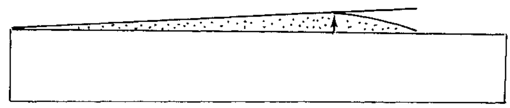
Adhesion depends upon contacting molecules being within two to three ångströms of one another (Buonocore, 1975a). In dentistry, it is impossible to produce a surface that is smooth at the molecular level. How does this affect adhesion? If two irregular surfaces (the prepared tooth and the restorative material, for example) are apposed, molecular forces of attraction operate only where the tips of the asperities on the contiguous surfaces meet. The resultant bond is gossamery and clinically worthless.

To achieve molecular intimacy the rough surfaces must be altered. A liquid may be introduced between two irregular boundaries to eliminate voids and depressions and thus increase the surface area of the two materials in contact. This may produce an incredibly strong bond. We have merely to visualize the bond strength between two flat sheets of glass with a water interface to be impressed by the magnitude of an adhesive union. In this illustration the liquid (water) is termed the adhesive; the material (glass) to which the adhesive is applied is the adherend.

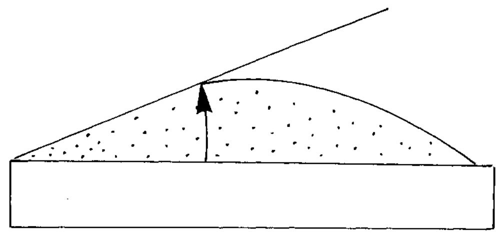
Wetting

A requirement for adhesion is that the adhesive must flow over the adherend. The term 'wetting' is used to describe this ability. The extent of the wetting, or the efficiency of the adhesive, depends upon its viscosity, the shape of the irregularities on the surface of the adherend (de Bruyne, 1962), and the contact angle at which the adhesive meets the boundary of the adherend (Zisman, 1963). The contact angle is formed between the surface of the adhesive drop and the surface of the adherend upon which it is resting. A small contact angle is desired, since this indicates the potential of complete wetting of the adherend by the adhesive (Figs 1 & 2).

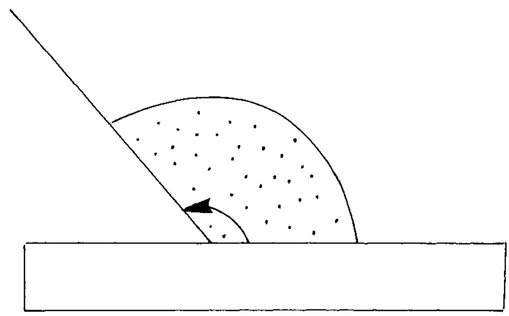
High energy of the surface of the adherend favors adhesion. Contamination can lower the energy of the surface. Wetting is achieved when the surface energy of the adherend is greater than that of the adhesive.



A low or small contact angle. Liquid wets surface thoroughly.



Larger contact angle. Surface not wet as thoroughly by liquid.

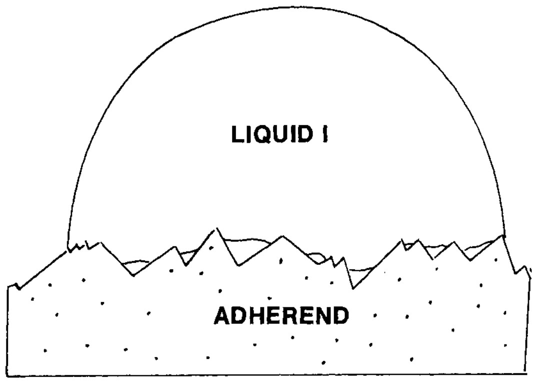


Large contact angle, indicative of poor wetting of surface.

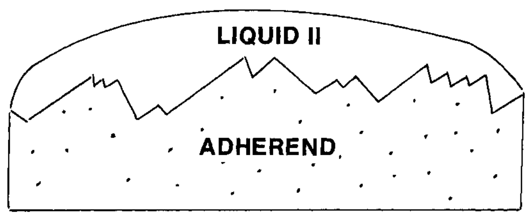
FIG 1. Contact angles of adhesive with adherend. Adapted from Buonocore, M G, 1975b.

Effect of Water

How will water present in the oral environment affect adhesion? Water is strongly attracted to most substances due to its polarity and tendency to form hydrogen bonds. Attempts to produce an adhesive bond when water contaminates one of the surfaces to be bonded will result in bond failure. Molecules of water can penetrate progressively along contacting margins and disrupt and destroy adhesion. Although water is a universal necessity



Liquid with large contact angle. A viscous liquid results in the entrapment of air in the voids and crevices of the adherend.



A low contact angle for LIQUID II. Low viscosity results in extensive intermolecular contact with no entrapment of air.

FIG 2. Effect of viscosity on wetting. (Top) An undesirable relationship between the adherend and the adhesive, LIQUID I. (Bottom) A desirable relationship between the adherend and the adhesive, LIQUID II.

for life, for dental adhesion water is a villain to be avoided.

Adhesion to Dentin

In dentistry, an adhesive union would have many practical applications. It is understandable, therefore, that researchers have sought to develop techniques to establish adhesion to the hard structure of teeth. Buonocore (1955) first demonstrated that etching enamel with phosphoric acid improved the bonding of acrylic resins. Numerous other studies have demonstrated similar findings (Buonocore, 1963; Gwinnett & Buonocore, 1965; Gwinnett & Matsui, 1967; Buonocore, Matsui & Gwinnett, 1968; Brauer & Termini, 1972).

Initial efforts to get resin to adhere to dentin were disappointing (Buonocore, 1975b). For an adhesive bond to dentin, it is necessary to modify the resin system to compensate for the differences in structure between enamel and dentin (Bhaskar, 1976).

The complexities of a dental resin adhering to dentin are accentuated by the heterogeneity of the dentin surface. Freshly cut or abraded dentin consists of small, isolated zones of inorganic packets enveloped by an organic component (Retief, 1970). If a composite resin were to bond to the organic phase (primarily collagen) of dentin, the strength of the junction would reflect the strength of the bond of either resin to collagen or collagen to collagen. Vital collagen has a tensile strength of 100 lbf/in^2 (690 kPa) and cannot be expected to maintain a functional, adhesive joint with a composite material (Lee & Swartz, 1970). Bowen has determined that the shrinkage of polymerization of resins can exert forces on the prepared cavity walls that range from 250 to 1000 lbf/in^2 (1725 to 6900 kPa). The magnitude of shrinkage depends upon the size of the prepared cavity and the volumetric shrinkage of the resin (Bowen, 1967). If the adhesive union between the resin and the dentin exceeds 100 lbf/in^2 (690 kPa), it is conceivable that during polymerization shrinkage the collagen could be torn from the walls of the cavity.

If adhesion predicated solely upon a collagen to resin bond is impractical, can the resin adhesive be induced to unite to the inorganic component of dentin? Would this provide results that are clinically favorable? Enamel is composed of rigid, rod-like prisms of tightly bound crystallites, but the architecture of dentin differs significantly (Buonocore, 1975a; Bhaskar, 1976). Dentin consists of small crystallites, randomly scattered and imbedded in an organic matrix. If some of the organic matrix were pretreated to expose the inorganic phase, the surface created would provide extremely tenuous bonding. Buonocore (1975b) says this arrangement has little or no strength in compression, tension, or shear.

In spite of the inadequacy of an adhesive bond to collagen, this bond is vastly superior to one with the inorganic phase of dentin. It has been proposed that treating dentin with certain zirconium salts (ammonium zirconyl carbonate) may produce a cross-linking of collagen bonds, which may increase tensile strength (Lee & Swartz, 1970). This technique should be investigated further.

It is known that treating enamel with phosphoric acid strengthens the adhesive junction with composite resins. Etching dentin with acid has been investigated to determine if similar beneficial results can be obtained (Buonocore & Quigley, 1958; Brauer & Huget, 1972). Since phosphoric acid is a strong inorganic acid, the weaker, organic citric acid has been investigated as an etchant for dentin (Smith, 1975). Citric acid has been shown to dissolve peritubular zones of dentin (Vojinović, Nyborg & Brännström, 1973). This effectively widens the lumen of the dentinal tubules and enhances penetration of the adhesive into the dentin (Eriksen, 1974). What effects will acid etching have upon vital dentin and the pulp? Research has unequivocally incriminated composite resins as causing pathosis of the pulp (Brännström & Nyborg, 1972; Stanley & others, 1972; Dickey, El-Kafrawey & Mitchell, 1974; Ericksen, 1974; Stanley, Going & Chauncey, 1975; Udolph & others, 1975). Furthermore, research indicates that a massive ingress of bacteria accompanies the widening of the tubules (Vojinović, Nyborg & Brännström, 1973). Some investigators question the efficacy of pretreating dentin with acid (Buonocore, Matsui & Gwinnett, 1968). Others have shown that etching dentin prior to the application of the adhesive does increase bonding strength (Buonocore & Quigley, 1958; Brauer & Huget, 1972). Vojinović (1973) says:

> . . . the acid treatment of vital dentin may considerably increase the liquid surface and the wetting of the dentin by the liquid in the dentinal tubules. This might impair rather than increase the adhesion of a resin material to dentin. In vitro studies of adhesion to acid treated dentin have been performed on dry dentinal surfaces without considering the liquid phase and the hydrodynamics of the dentin in vital teeth. Judging from present findings it must be questioned whether cavity cleansers containing acids or other solutions removing plugs and peritubular dentin from apertures of the tubules can be recommended for routine clinical use.

Are the impediments to clinically successful adhesion of dental resin to dentin too great to overcome? Bowen (1965a, b) has developed a compound for producing adhesion between dentin and a composite resin. This compound is termed a coupling agent and may be described as a "polyfunctional molecule that promotes adhesion by modifying the surface of the substrate to which the material is to be bonded . . . a new surface is . . . created . . . on the substrate by reacting with it through one portion of the molecule, leaving the other portion to react chemically or physically with the adhesive" (Smith, 1975). The coupling agent Bowen synthesized is an adduct of N-phenylglycine and glycidyl methacrylate (NPG-GMA). Purportedly, the N-phenylglycine portion forms a chelate with calcium (Bowen, 1975).

The chelate bonds the resin molecule to the hydroxyapatite of the surface dentin. The methacrylate residue copolymerizes with a composite resin to unite it to the tooth surface. It has been shown that NPG-GMA promotes a significant increase in water-resistant bonding of a resin polymer to dentin (Bowen, 1965a, b). In a study by Chandler & others (1974) NPG-GMA was placed under an experimental composite resin. After three and a half years the teeth with the NPG-GMA coupling agent showed appreciably better margins than those of the control group.

Why should a coupling agent that chelates to calcium effectively initiate an adhesive bond to dentin? Allegedly, the inorganic component is a poor choice for bonding; yet the calcium-NPG-GMA chelate does appear to be clinically acceptable. Further investigation to determine why this method is successful should be undertaken.

Differences in Dentin

Just as there are various social cultures and nationalities, there are also different types of dentin. Is it possible that a resin adhesive might adhere to one type of dentin and not to another? Is it also reasonable to expect that etching one form of dentin with acid will not affect the underlying pulp?

In teeth whose pulps have been irritated by caries, abrasion, erosion, or tooth preparation, the dentin undergoes certain changes which Stanley (1976) refers to as the formation of reparative or irregular dentin. This dentin is identified by twisted and entwined dentinal tubules which are reduced in number and may even disappear. Additionally, odontoblasts damaged by abrasion may degenerate. In time, calcium salts are deposited around the processes of the degenerating odontoblasts and obliterate the tubules. Bhaskar (1976) labels this formation sclerotic dentin. Both of these types of dentin provide a barrier to physical or chemical irritants to the pulp.

Conclusion

There are many difficulties associated with establishing a physiologically compatible bond of adhesive resin with dentin. Predictable clinical success may be anticipated if the clinician selects the proper dentin for bonding. Current techniques of adhesive resins (particularly those using the NPG-GMA system) appear to offer the best potential for success when sclerotic dentin is present.

The opinions or assertions contained herein are those of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or Department of Defense.

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Mercury Emission during Amalgam Condensation

Mercury vapor is emitted in measurable quantities during the condensation of amalgam but is not thought to be hazardous unless other sources of mercury are prevalent to an unusual extent.

WILMER B EAMES • C OWENS PALMERTREE, JR

Summary

During the process of condensing amalgam, mechanically or by hand, mercury vapor is emitted in concentrations greater than 0.05 mg/m^3—the threshold limit value (TLV) recommended by the Occupational Safety and Health Administration (OSHA). The mercury that is released mixes with the ambient air, which already may contain residues of spillage. Part of the mercury may be exhausted in well-ventilated offices, but the confined conditions found in the average operatory may provide a cumulative effect.

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C OWENS PALMERTREE, a student in the class of 1979

Introduction

Dentists and their office personnel are becoming more acutely aware of the ever-present problems associated with higher-than-average levels of mercury vapor inherent in the practice of dentistry (Hefferren, 1974; American Dental Association, 1974; U S Department of Health, Education, and Welfare, 1973; Buchwald, 1972; Cuzacq, Comproni & Smith, 1971; Gronka & others, 1970). Furthermore the Occupational Safety and Health Administration (OSHA) has recommended a threshold limit value (TLV) of 0.05 mg/m^3 for mercury vapor. This vapor in small amounts is colorless, odorless, and tasteless. It can be detected only by monitoring devices utilizing spectrophotometry or chemicals that bind the mercury for later analysis. It is the purpose of this study to measure, by spectrophotometry, the amount of mercury vapor present when amalgam is condensed. By extrapolation, estimates can be made of the amount of mercury vapor likely to be present in specific clinical situations.

Materials

The five mechanical condensers compared in this study are listed in Table 1. They were selected as representative of instruments emitting energy in the form of impact and vibratory impulses, as previously reported (Eames & others, 1977). In addition we tested the Cavitron though it has not been considered safe as a condensing instrument by the Council on Dental Materials and Devices of the American Dental Association. The alloy used for the tests was New True Dentalloy (S S White, Philadelphia, PA 19102, USA).

Table 1. Condensers

Amalgam Condensaire	Teledyne Dental, Densco Div Denver, CO 80207
Amal-Pac	Midwest American Des Plaines, IL 60018
Kerr Amalgam Vibrator	Kerr Mfg Co Romulus, MI 48174
Electro-Mallet	McShirley Products, Inc Glendale, CA 91201
Shofu Auto Plugger	Shofu Dental Corp Menlo Park, CA 94025

Methods

Mercury vapor released during condensation by hand and by several mechanical condensers was measured by means of a Beckman Mercury Vapor Meter Model K-23B (Beckman Instruments Inc, Fullerton, CA 92634, USA) and recorded with a Bausch Strip Chart Recorder (Houston Instrument, Division of Bausch & Lomb, Bellaire, TX 77401, USA) using a paper speed of 1 in/12.5 s (25.4 mm/12.5 s); see Figure 1.

The vapor meter was placed 5.5 cm above the specimen die which was enclosed by a square of rubber dam within a plastic enclosure with an open front and top (Fig 2). The open face allowed access to the die for condensing amalgam and the open top allowed the mercury vapor to reach the mercury meter. This enclosure represents an attempt to simulate the human mouth.

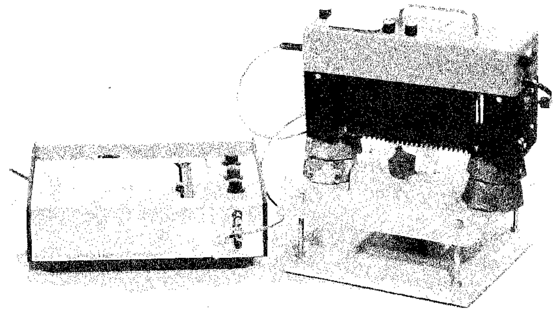

FIG 1. Experimental arrangements showing mercury meter, force gauge, and strip chart recorder

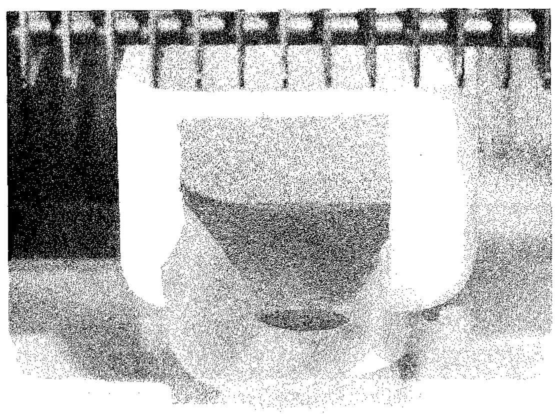

FIG 2. Specimen die in condensing enclosure

The alloy and mercury were placed in screw capsules (Kerr Mfg Co, Romulus, MI 48174, USA) and triturated with a heavy pestle in a Wig-L-Bug (Crescent Dental Mfg Co, Lyons, IL 60534, USA). Six samples were recorded for each of the condensers used. Each sample received five thrusts of 3 lbf (13.2 N) per increment with the exception of the Cavitron samples, which received ten thrusts of 2 ozf (56 g) per increment. The force of the thrusts was measured with a Dillon Force Gauge (W C Dillon & Co Inc, Van Nuys, CA 91409, USA). At least 20 minutes elapsed between the making of each sample to allow residual mercury vapor to clear from the laboratory. The door to the room was left open at all times to allow maximum airflow through the area from a central air conditioning vent located in the ceiling over the condensing stand. The mercury meter was calibrated outside the laboratory twice a day, once after the initial 30-minute warmup and again shortly after noon.

A polar planimeter was used to calculate the area under the curve recorded on the strip chart. The readings obtained were compared to standard areas and the amount of mercury vapor was calculated. This value, divided by the length of time required to make the sample, gave an average reading of mercury vapor emitted in $mg/m^3/min$. By extrapolating from these data, the amount of mercury vapor released during a day by a dentist condensing 10 amalgam restorations can be compiled. To obtain this value, the mean amount of mercury released for a given condenser is multiplied by 10 for the number of samples and multiplied by the average time needed with that condenser. The figure obtained is divided by the remaining time in the day, that is, the total number of minutes in a working day less 10 times the average time to condense one sample. The formula for calculating the total amount of mercury emitted in a working day is shown in Figure 3. In addition we computed the levels of mercury that would be allowed under TLV limitations when compounded by emissions of mercury during the condensation of amalgam.

$$\frac{(\bar{x}\text{ mg Hg/m}^3) \times (10\text{ samples}) \times (\text{avg time})}{\left(\frac{8\text{ hr} \times 60\text{ min}}{\text{min/workday}}\right) - \left(10 \times \text{avg time/amal}\right)}$$

FIG 3. Formula for calculating the accumulation of mercury during a working day

Results

All the condensers used in this experiment emitted mercury vapors in excess of the 0.05 mg/m^3 threshold limit value (TLV) recommended by the Occupational Safety and Health Administration (OSHA) (Fig 4). The only con-

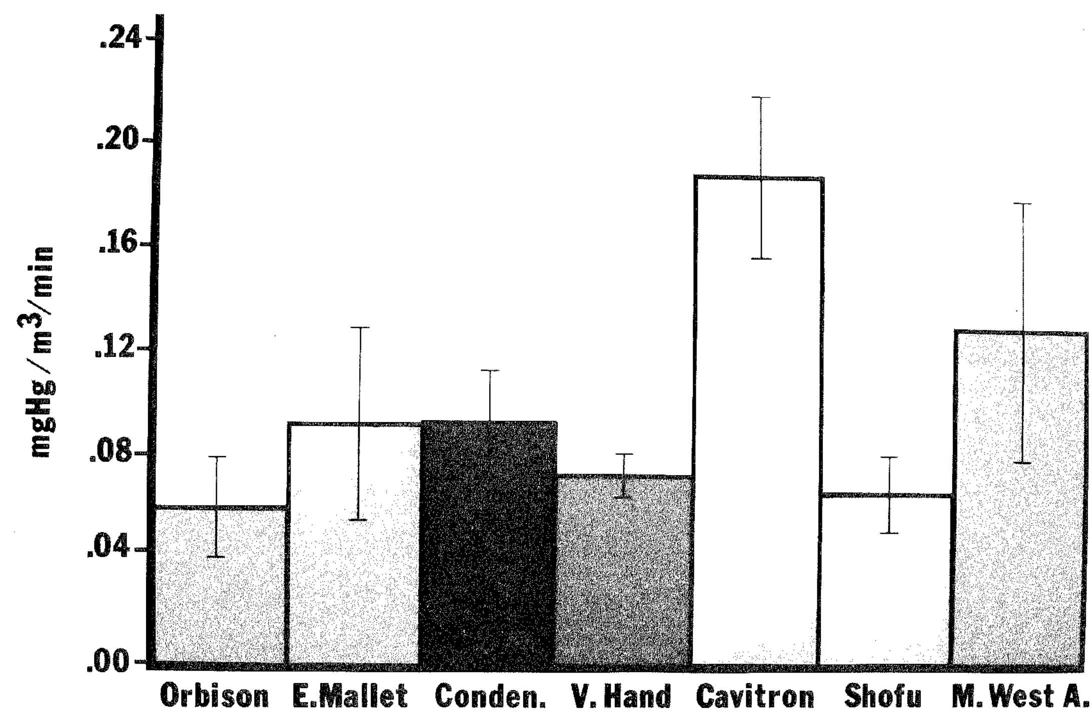

FIG 4. Mean values of mercury emission during condensation of amalgam, comparing seven methods

Table 2. Computer Analysis of Values Using Duncan Multiple Range Test

1	2	3	4	5
Orbison 0.0609	Shofu 0.0660	Vertical Hand 0.0746	Electro-Mallet 0.1051	Cavitron 0.1898
Shofu 0.0660	Vertical Hand 0.0746	Condensaire 0.0954	Midwest 0.1296	
Vertical Hand 0.0746	Condensaire 0.0954	Electro-Mallet 0.1051		

Values represent mean mercury in mg/m^3.

densing method that proved to be statistically different from the others when grouped under the Duncan Multiple Range Test was the Cavitron; see Table 2.

The amount of mercury vapor released during a day by a dentist condensing 10 amalgam restorations is shown in Table 3, along with the allowable levels of mercury when compounded by the emission of mercury during the condensation of amalgam.

Discussion

One might question the clinical significance of the amount of mercury emitted when an amalgam restoration is condensed. However, when the daily amount of mercury emitted is compounded by adding mercury vapor already present in ambient air due to spillage and scraps of amalgam, there is a potential hazard. The particles of mercury released must fall if they are not evacuated completely by the flow of air. This is unlikely, and the mercury is apt to settle on the office carpet, curtains, equipment, and counters. If these areas are dusted or vacuumed, or even if the carpet is walked on, residual mercury is volatilized and becomes a part of the baseline value of mercury in the office, thus adding to the total amount of mercury in the air.

Table 3. Amount of Mercury Released during a Day and Additional Amount Allowable To Keep within the Limits of the Threshold Value of 0.05 mg/m^3

Method of Condensation	Mercury from Condensation mg/m^3/d	Safety Margin mg/m^3
Mechanical condensers (average of 5)	0.0075	0.0425
Cavitron	0.0183	0.0317
Hand condensing	0.0056	0.0440

Conclusions

The entire procedure for manipulating amalgam, from trituration through condensation, emits measurable amounts of mercury.

Mercury particulate is cumulative as it settles from ambient air to the floor, counters, and operatory equipment.

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DENTAL PRACTICE

More and Better Foils: Forward by Fundamentals Rather than Back to Basics

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Presented at the annual meeting of the American Academy of Gold Foil Operators, Honolulu, 20 October 1978.

INTRODUCTION

In this era of multiple-restoration dental appointments and third-party dental contracts, is there still a place for direct gold restorations? If so, what is it? What forces influence the use of the direct golds? These questions will be addressed in the first part of this article.

Since there is need for exchange of knowledge of technical procedures, the second portion of the article will summarize the philosophy and technics followed by the Associated Ferrier Study Clubs.

The title above borrows an expression from the advocates of positive thinking. They believe it is more constructive to work on the premise of moving forward with fundamentals rather than wistfully harping back on the good old days and preaching back to basics.

In stressing forward rather than back, we in no way deprecate our great heritage in operative dentistry. We are privileged to have as a foundation for our highly important phase of dental health service the amazing efforts and contributions of countless unselfish, brilliant, clinical and didactic teachers. It is difficult, and perhaps unfair, to name any of them specifically, because, inadvertently, others will not be mentioned. However, I am thinking of such early members of our profession as G V Black, E K Wedelstaedt, A C Searl, Robert Arthur, and

Maintaining well-ventilated working areas and exercising reasonable care in preventing spillage may preclude hazardous sequelae.

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US DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (1973) Criteria for a recommended standard: occupational exposure to inorganic mercury. Public Health Service, National Institute for Occupational Safety and Health, HSM 73–11024.

S C Barnum, who organized our procedures, discovered the property of cohesiveness of foil, brought us the rubber dam, and standardized instrumentation.

The dental generation succeeding them includes names familiar to those of us who have been in dentistry for some time, such as Ferrier, Prime, Hollenback, Woodbury, True, Rule, and Baird; also E M Jones, George Ellsperman, Lester Meyers, Alex Jeffery, and James Metcalf. Their protégés, along with the members of their study clubs throughout this country and Canada, and the efforts of the American Academy of Gold Foil Operators, have done much to provide an increase in technical competence and an exchange of ideas and technics. With such a background, we are justified in looking forward, holding to fundamentals, and applying them to the conditions of a rapidly changing world.

DETERRENTS TO EXCELLENCE IN DENTAL SERVICE

Those who are interested in the finest in conservative restorative procedures have an uphill battle today. Perhaps they always have had. There are powerful, subtle forces diluting your efforts. There is not time to elaborate on these obstructive forces to any extent, but it may be worthwhile to turn the spotlight briefly on them.

Changes in Training

First, there has been substantial change in the approach to preprofessional and professional training, and in the attitudes of many of its recipients. For example:

- There is more emphasis on "doing your own thing."
- The concept of apprenticeship and continued training has been rejected.
- There is relatively little concern for tradition or past achievement.
- Less attention is being given to clinical competence.
- Undergraduate education is being subjected to many whimsical changes and innovations. These undermine, to varying degrees, the foundations for most students.
- In the present flurry to predicate renewal of licensing on compulsory postgraduate training, there is a vast increase in the number and scope of offerings of continuing dental education. While many of these have merit, many others are but token efforts. The latter dilute the long-term activities of study clubs that have been so helpful for so many years.

Pressures on Dentistry

Second, there are many pressures and forces on today's practice and the conditions surrounding it. These forces can be classified as **external** and **internal**.

The **external** considerations are:

a. The increasing influence exerted by the expanding insurance programs on dental practice. Many of these programs do not recognize conservative treatment, such as gold foil and intracoronal castings.

b. The great changes in our mode of life; the ever-increasing influence and control by government and politicians; the amount of time required of officers of our dental organizations to handle administrative problems, instead of concentrating on stimulating dental programs, all have an effect on dental practice.

The **internal** influences affecting our practices include:

a. The problems of equipping and maintaining practice facilities. Many new manufacturers of equipment flash across the dental sky, then fade away to be replaced by others. It is costly to discard equipment that can be serviced no longer. Quality supplies and instruments are increasingly difficult to obtain. The executive officers of the conglomerates that, more and more, control the manufacturers find it difficult to attune to a relatively limited market for their quality products. Consequently the trend is to discontinue specialty items such as well-made rubber dam retractors, separators, finishing strips, and discs.

b. Another internal factor is the trend to group practice and the concept of expanded duties for auxiliaries. Although these modifications in dental practice bring certain advantages, they also, unfortunately, dilute the personal relationship of doctor to patient. To this, there is a divided reaction by practitioners and by patients.

Well, what to do? The conditions are with us. We cannot wish them away. How do we work with and around them? There is some temptation for those who are established and secure to feel that they can ride out the storm with their present practice, their reserve supplies, durable equipment, and their relative independence. Perhaps so, but what of those who are coming along tomorrow? Theirs will be a difficult dental world.

To meet the challenge, we should consider it our professional and moral obligation to do everything possible to keep alive the concepts of (1) training for, and providing, the finest service of which we are capable, and (2) indoctrinating the willing learner in the methods and technics that have produced results that are long-lasting, conservative, functional, and esthetic. Academies such as ours and operating study clubs are highly important in meeting this obligation. Practicing dentists can exert considerable influence by assisting educators who are willing to accept their services. Young people in dentistry can profit greatly by listening to and emulating the teachings of those who have been so fortunate as to learn from the early "greats."

PROMOTION OF DIRECT GOLD RESTORATIONS

What technics and precepts should we have in mind as we contemplate an increase in the use of direct gold restorations? Can we hold to many of the old tenets? Is there anything new to be learned?

There is much room for renewed emphasis, undergraduate and postgraduate, on essentials such as:

- Conservation of tooth structure
- Thoroughness in cavity preparation
- Training in modification and finishing of rather crude instruments
- Increased attention to the theory and practice of proper manipulation of the direct golds. (There is still need for basic research in this field.)

In addition to these considerations of technic, one of the most pressing needs is to modify dental insurance programs so that they will include the best of conservative restorative therapy. It is distressing that most of the current plans accept the redoing of multiple, complete crowns in as little as two years, yet they exclude conservative restorations such as small gold foils, intracoronal cast restorations, and fired porcelain inlays, which would provide many years of preventive restorative service. The present situation encourages waste of manpower, the needless sacrifice of tooth structure, and increase in costs to carrier and public alike.

FERRIER TECHNICS

What technics are the members of the Ferrier Study Clubs following? Basically, Ferrier's concepts hold as true today as they have for the past fifty years. Some new doors have been opened, of course; considerable research has been done; countless hundreds of restorations have been placed and observed through the years. A few additions or changes evolve when operators with individual characteristics work with any procedure. Some of these changes have been essential to cope with changes in instruments and materials available today. Others have come about with the constant striving for improvement in longevity, esthetics, and quality of dental restorations. A few may have occurred as a result of the innate urge to change for the sake of change.

Each of the phases of our procedures could be discussed at length, if space permitted. One of the advantages of the study club method of continuing dental education is that time can be spent on the consideration of details in procedures. The participating members learn more, master more, and gain the reward of personal satisfaction by regularly operating before peers and teachers.

Condensing the salient features of the Ferrier technic, the essential rubber dam is supported with a headband type of holder rather than with a frame. Gingival retractors are modified and refined as necessary. The retractors are carefully blocked or stabilized with compound. Incidentally, one of the most difficult steps in the technic to learn is the proper, nontraumatizing placing and stabilizing of the 212 retractor; yet, as taught by Ferrier, it is an efficient, precise procedure, devoid of frills.

The study club operators are fortunate in having good, Ferrier-designed separators and in knowing how to use them. For awhile it appeared that these instruments were to be lost in the general shuffle to seek only the large-volume market. Now we have found a new ally in the manufacturing field. Almore International, Inc of Portland, Oregon, is now making these essential instruments.

As to cavity design, the preparations remain conservative for both the class 3 and class 5 restorations. There is some increase in the use of the lingual approach for class 3s, but since the basic Ferrier design, properly executed, is so inconspicuous and is so much easier to fill, it is given first consideration. High-speed rotary instruments have some use in foil preparations, but the slower speeds, plus refinement and finish with hand instruments, predominate.

The various types of gold other than foil are used to some extent. However, lengthy clinical experience supported by laboratory studies by outstanding research workers such as the honorary members of our own Academy—George Hollenback, Jean Hodson, Ralph Phillips, and others—lead us to concentrate on foil, with limited use being made of mat and powdered golds. For class 5s, Ferrier and the Seattle Dental Study Club routinely used a combination of noncohesive and cohesive foil. In recent years, some of the study club members have discontinued using the noncohesive lining of the peripheral walls of the preparation. However, it is a technic that has many advantages and should not be lost.

One phase of technic that is highly important is the control of the compaction of the gold. It is not emphasized quite as much as it should be. The amount and direction of the compacting force need continuing study and attention. In our area of the country, the emphasis in compaction is on the use of the hand mallet by the assistant to supplement the hand pressure of the operator. Mechanical and electronic devices are used only minimally.

Attention to detail in finishing restorations to proper form and contour, without damage to surrounding, supporting tissues, is extremely important. We have to be continually aware of the potential danger of excessive separation of teeth, of undue compacting force, of uncontrolled discing, of overinstrumentation, of ditching cementum, and of losing mesiodistal dimension.

We give high priority to the wishes of the patient in respect to esthetic, inconspicuous restorations, but we do not sacrifice the sound rules of cavity preparation, such as outline and convenience form, to the request to show no gold.

CONCLUSION

Those who are interested in providing the ultimate in conservative, long-lasting, restorative therapy can fulfill their desire by continuing to increase their expertise in the science and art of working with gold foil.

They have a great opportunity to work for the benefit of the public by fighting for the inclusion of conservative procedures in insured programs.

They can serve the profession and the public by contributing time and effort to undergraduate and postgraduate dental education.

We can look back to our predecessors with gratitude and appreciation; we can move **forward with fundamentals** into the new dental picture with confidence and enthusiasm. You who are dedicated to fine restorative dental service can and should assume leadership in that movement.

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SPECIAL ARTICLE

Skinner Memorial Lecture

Amalgam —Yesterday, Today, and Tomorrow

EVAN H GREENER

From a position in Thorne Hall in April 1978 it is possible to evaluate the present in terms of the past and attempt to construct the future.

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EVAN H GREENER, B Met E, MS, PhD, chairman. Dr Greener has been chairman of the department of biological materials, Northwestern University Dental School, since 1964, when he succeeded Dr Eugene Skinner. Dr Greener's research is mainly in direct restorative materials and of late has been centered on corrosion and creep of dental amalgams. During the academic year of 1977–78, when this paper was conceived, he was visiting professor and senior Fogarty International Fellow at the Turner Dental School, University of Manchester, United Kingdom.

This fourth lecture dedicated to the memory of Eugene W Skinner was delivered on April 15, 1978 at Northwestern University Dental School, Chicago.

Given the rate of change of society, and in particular of science, there is a danger of our future, while we are projecting it, becoming the past. That indeed is the type of excitement that dental materials in general and amalgams in particular currently contain.

Early History of Amalgams

I should like to discuss "amalgams, past" in some detail, for there are many instructive lessons not only about amalgams but also about dentistry and life as a whole lying around awaiting discovery by a professor on study leave. In particular, the early controversy surrounding amalgams has many parallels to the attempts of modern dentistry to handle phenomena such as implantology, Sargenti endodontic treatment, and acid etch, to name but a few of our contemporary problems.

The etymology of the word amalgam is obscure (Baume, 1958). Perhaps it comes from the Greek *malagma,* meaning soft mass. Frequent mention is also made in the medieval alchemistic literature where the Arabic words *almagham* or *amalgam* are used to mean soft mass. We do know that mercury was indeed dearly beloved by the alchemist as a necessary ingredient to turn base metals into gold, as well as a component in various elixirs of love and eternal life. It seems only natural that the alchemists might have directed mercury toward treating one of man's oldest ailments, diseased dentition.

As early as 1601, a German "tooth doctor" of Luneburg, Tobias Dorn Kreilius, presents this prescription, taken directly from an old alchemist's incunabulum, for an amalgam filling (Guerini, 1909):

> Take vitriol (copper sulfide) and dissolve it with strong acids in a bowl. Add mercury. Boil it and you will have an amalgam. Pour it into the tooth cavity and it will become hard as stone and remain stable in the cavity.

However, the dentists of the 17th and 18th centuries did not have the benefits of educators in dental materials to tell them of the new or rediscovered wonders of dental therapeutics, and so amalgam was unknown. Instead, in the civilized world (which was France) a material called D'Arcets Mineral Cement was employed (Guerini, 1909). D'Arcets cement consisted of eight parts bismuth, five parts lead, three parts tin, and one part mercury to hasten fusing. This material became plastic at 212 °F (100 °C) and was poured directly into the cavity. However, in 1818 Regnart, again in France, perhaps out of some kindness for the long-suffering patient, suggested a lowering of the fusing temperature of D'Arcets cement by increasing the concentration of mercury. How the alchemists would have loved him! And so to Regnart we give the title Father of Amalgam. The final step in this French Connection occurred in 1826 when M Traveau advocated the use of *paté d'argent* (silver paste), a union of pure silver and mercury, for permanent fillings.

Amalgam became an American problem with the arrival on our shores of the Crawcour brothers in 1833 (Campbell, 1963). The Crawcours originally, according to Campbell, were "notorious empirics of Polish extraction," who, having acquired a superficial knowledge of dentistry in France, called themselves surgeon-dentists and as early as 1780 emigrated to England, where several generations practiced. The policy of the Crawcours was to advertise extensively, proclaiming the superior virtues of their Mineral Succedaneum. With this material (actually shaved French silver coins plus mercury) they claimed they could fill a tooth painlessly in about two minutes. Obviously, in those days before anesthesia, any technique removing only the barest minimum of diseased tissue for insertion of a filling was bound to be appreciated by the public. Enjoying financial success in Great Britain, two of the brothers decided to reap their financial harvest in New York. To pave the way for their advertising avalanche, they added the prefix "Royal" to Mineral Succedaneum and, using the technique of high-pressure advertising, claimed that with the Royal Mineral Succedaneum they would plug carious teeth in a few minutes without the least pain and thereby preserve the teeth.

The Crawcours had instant financial success, since the process had significant appeal to patients compared to the plugged gold fillings of the best US dentists like Parmly, Baker, and Greenwood. However, it soon became apparent that their painless technique consisted merely of placing mounds of amalgam on occlusal surfaces without any relation to dental anatomy, let alone excavating or working in a dry field. Salivation resulted, and when jaws were approximated, mercury was expelled from the filling and swallowed by the patient. Denounced by reputable dentists as "swindlers, villains and quacks," the Crawcours departed our shores in 1834, but the damage had been done!

In 1845, the American Society of Dental Surgeons passed a resolution "pronouncing the use of all amalgams as malpractice" and further demanded that each member sign a pledge not to use amalgams, use of which constituted prima facie evidence for expulsion from the society. But the lure of plastic filling material was too great.

The most serious drawback to the pure silver amalgams was obviously their expansion, but the clinicians of the times were more concerned with their blackening (a tarnish due to the formation of silver sulfide). Tin was added to improve the color. Tin also improved amalgamation and made the mass more plastic and easier to insert. The first alloy of note was four parts silver and five parts tin, and was used commercially until 1863.

In 1877 began the first organized movement on behalf of amalgam, the New Departure

Creed, which was spearheaded by some of the most forceful men in the profession. The New Departure Creed stressed the usefulness of the new plastic filling materials but its members, like many zealots, were carried into many indefensible positions on the successful therapeutic techniques of the day. For example, the New Departure people were anti-gold, anti-wedging, and anti-contouring, and not particularly concerned with leakage. They had to be unconcerned, considering the alloys available to them at the time.

One of the leaders of the New Departure was J Foster Flagg, professor of dental pathology and therapeutics in the Philadelphia Dental College. In 1855 Flagg came to believe that amalgam might have a future and worked with it clinically for a decade. He analyzed commercially available alloys, which were mainly 60% tin and 40% silver and altered the compositions to 60% silver and 40% tin as well as adding various minor constituents. Each alloy was tested by the laboratory methods of the time and by five-year clinical studies.

In 1881 he published the results of his experiments in a book, *Plastics and Plastic Fillings,* thus predating G V Black's work by some 15 years. Although ultimately not as successful as the work of Black, there can be no doubt that Flagg's work was the first scientific foray into amalgams.

The universal acceptance of amalgam as a restorative material resulted from the investigations of G V Black, founder, dean, and the first educator and researcher in dental materials at Northwestern University Dental School.

By combining the principles of cavity design, extension of the cavity into "immune" areas, and the development of an alloy composition that was easy to manufacture as well as having adequate and reproducible clinical properties of physical strength and dimensional stability, Black advanced amalgams into modern times. Black's work in these areas is contained in two monographs written in 1895-96, *Physical Characteristics of the Human Teeth in Relation to Their Diseases and to Practical Dental Operations* and *Physical Characteristics of Filling Materials.*

As we have seen, the early commercial alloys were rich in tin. A result of Black's pioneering work was the first commercial alloy rich in silver, True Dentalloy (1900) produced by S S White. This alloy was the first to show a slight expansion on hardening. The rest of the commercial alloys, worldwide, followed Black's lead and conventional amalgam was born. I would like to close the early history of amalgams with an anecdote that Brenner, in his interesting book *The Study of Dentistry,* related about Black (Brenner, 1964). The anecdote is taken to show Black's keen sense of intuition in recognizing important physical phenomena. I have another motive in its recollection, as you will soon see.

The problem that concerned Black was the "wildness" of his alloys; that is, after manufacture, when alloys were fresh, they behaved well, but after storage there was a variable decline in their ability to react with mercury and to attain optimal physical properties. Then, as now, the dental materials laboratory at Northwestern University Dental School was housed in less than luxurious quarters. The school was located in the former Tremont Hotel. Unlike the rest of the building, which was centrally heated, the dental materials laboratory was heated by a stove. Accidentally, Black stored amalgams on a shelf over the stove, and the rest is history. Black recognized that, as a result of the storage conditions, the fillings were annealed and reproducible properties were thenceforth obtained.

Thermodynamics and Setting Reaction

The existence of Black's "balanced" dental amalgam coincided with the availability to scientists of the developing tools of analytical chemistry, physics, and metallurgy. Naturally, the first questions to be asked are what and why, with the rationale that what we can understand, we can improve. An excellent review of the search for the mechanism of the setting of conventional dental amalgam has been presented by Ryge, Fairhurst & Fischer (1961) and is summarized below.

The first attempt to propose a chemical reaction for the setting of dental amalgam was presented in 1912 by McBain and Joyner in *Dental Cosmos.* As a historical note it should be pointed out that, although a house publication of S S White and Company, *Dental Cosmos* was the leading dental scientific journal of its time, maintaining an excellent scientific reputation, until it merged with the *Journal of the*

American Dental Association. The equation postulated by McBain and Joyner was in dramatic error, but it did begin to point the way.

During the 1920s, Gray (1923) began to associate the product of the amalgamation reaction with the dimensional changes observed during setting, and Murphy used x-ray diffraction for the first time to characterize the phases of the product (Murphy, 1926; Murphy & Preston, 1931).

During the 1930s, Marie Gayler in England studied the setting reactions of dental amalgams extensively by using many types of analysis of metallurgical, chemical, x-ray, and physical properties on both commercial and experimental alloys (Gayler, 1937). She was able to postulate a mechanism in which alloys rich in silver produce expanding amalgams due to the predominance of the γ_1–phase (Ag–Hg) and alloys rich in tin produce contracting amalgams due to the effects of the γ_2–phase (Sn–Hg). Gayler also elucidated the metallurgical role of copper. Unfortunately, I believe she was misunderstood by her contemporaries.

Ryge and coworkers, particularly over the years 1952–60, have put together a fairly complete picture of the reaction mechanism of conventional dental amalgam as we know it today (Moffett, Ryge & Barkow, 1952; Ryge, Moffett & Barkow, 1953). It can be expressed as $Ag_3Sn \rightarrow \gamma_1\ (Ag_2Hg_3) + \gamma_2\ (Sn_7Hg) +$ unreacted Ag_3Sn. Since there is both copper and zinc in conventional amalgam alloys, one may expect to find reaction products of copper and zinc as well.

The First Study on Physical Properties

With the advent of Black's "balanced" alloy, many manufacturers were quick to copy it. The profession was then subjected to a diversity of alloys and to claims for their unique superiority. Among the large purchasers of amalgam alloy was the United States government, which had at the time in the National Bureau of Standards perhaps the only available resources of personnel, expertise, and equipment to begin to produce order out of chaos. In particular, the name of Wilmer Souder stands out. His contributions were so great that his colleagues named the annual prize for research in dental materials in his name. Eugene Skinner won the Souder Award in 1956. In 1920, Souder and his colleague, Chauncy Peters, published in *Dental Cosmos* a paper entitled, "An Investigation of the Physical Properties of Dental Materials." This investigation began at the behest of the United States government, which was interested in information on purchasing amalgam alloy. The results became the forerunner of the specifications of the American Dental Association, as well as the beginning of the long and fruitful involvement in research in dental materials by the National Bureau of Standards.

The contributions of Souder and Peters are, on the one hand, powerful in that they began an era of rigorous, well-defined testing culminating in appropriate specifications; but on the other hand, these developments perhaps held back research in dental materials by creating an environment where the measured property was all important and the association of these properties with either the microstructure of the material or its clinical implications was understressed. The impact of this work has been so great that it is only 50 to 55 years after its completion that these latter two concepts are finally coming into their own.

Souder and Peters codified the testing of mechanical properties of amalgam—particularly compressive strength and flow, setting and thermal expansion, as well as measurement of electrochemical potential. Specimen sizes were made uniform, that is, a ratio of length to diameter of two to one was used to overcome the disadvantages of the shorter sizes employed in the Black dynamometer, which gave artificially high readings. A dental interferometer was created, allowing both setting changes and thermal expansion to be measured to 0.1 μm. A test for flow was also specified, identifying the unique dependency of the physical properties of amalgam on strain rate. These well-described tests allowed the properties of dental amalgam to be measured over a wide variety of variables—composition, mercury/alloy ratio, trituration method, trituration time, condensation pressure, and so on, and thus set the tone of amalgam research for the next half century. The work of Souder and Peters culminated in Federal Specification Number 356 for dental amalgams, issued in 1925, and accepted generally.

Specification Number 1 of the American Dental Association for dental amalgam, based on Federal Specification Number 356, came about in 1929. Of 44 alloys on the market, only 18 passed.

In 1938 Skinner published a paper on amalgam flow that reveals the state of the art prior to the general acceptance of mechanical trituration in the early 1940s through the work of Sweeney and Romnes (Sweeney, 1940; Romnes, 1941).

> All specimens were triturated for one minute in the mortar with 170 revolutions of the pestle under light pressure after which they were palmed 100 times over a period of two minutes. Effect of trituration variables or mechanical properties were evaluated by varying the number of palming strokes or the time of mortar trituration. Also, the effect of palming was investigated using bare palms, surgical gloves and cellophane.

Skinner was aware of Gayler's work on metallography and attempted to relate his findings in physical properties to her work on microstructure and also related his opinion that homogeneity of amalgam is important to strength. Thus, Skinner displayed an early awareness of the importance of defect control of physical properties—another phenomenon about which I hope the dental materials students of today are cognizant.

One of the most important findings of this period, in terms of clinical success of an amalgam restoration and, certainly, the basis of the so-called dry technique generally taught today, has been the role of residual mercury on the determination of the amalgam's final properties. Although many workers have contributed to this area of study, the definitive work was a series of papers by Phillips and coworkers in the decade 1949–59 (Swartz & Phillips, 1953, 1956; Phillips & Swartz, 1949) culminating in the finding of a dramatic fall-off in physical properties with concentrations of residual mercury in excess of 55%.

The results of this investigation essentially paved the way for correlation of properties with the γ_2 reaction product, identification of high concentrations of γ_2 -phase at the margin of the restoration, and the acceptance of the dry, or minimal mercury, or Eames technique. The Eames technique, introduced in 1960, was presented to the profession in a series of papers by Eames and Skinner (Eames, Skinner & Mizera, 1961) while Eames was on the faculty of Northwestern University Dental School. The utility of the Eames technique was reinforced in the mid-1960s by the availability of preproportioned capsules, which eliminated handling of the bulk alloy and mercury by the dentist and produced uniform mercury/alloy ratios.

Modern Studies in Conventional Amalgam

In the mid-1940s mechanical trituration of amalgam became accepted (Taylor, 1929). As summarized by Phillips in 1944, "the effect of mechanical trituration on physical properties produced a more uniform mix, more thorough trituration as evidenced by higher strength values, greater flow and contraction." I think it important to note as well that Phillips, at this time, questioned the value of the free expansion test because alloys that contracted during mechanical trituration still produced successful restorations. Armed with mechanical trituration, control over mercury/alloy ratio, and the tests envisaged by ADA specifications, the 1950s and early 1960s aimed at increasing the one-hour strength of dental amalgam. This really was the only property that investigators of dental materials could change since they were restricted by specification to Black's "balanced" composition. Due to this restriction on composition, the physical properties of all certified amalgams reached the same values about two hours after trituration and attained maximum properties at about the same rate, that is, after 24 to 48 hours.

It was found that the kinetics of the initial reaction could be controlled by particle size and shape, mercury/alloy ratio, trituration energy, zinc and copper concentrations within prescribed limits, and so forth. With the emphasis placed upon one-hour strength, the profession moved to drier alloys, alloys with finer particles (micro), alloys with spherical particles, and zinc-free alloys. These changes, while increasing the one-hour strength by accelerating the wetting and the kinetics of the early reaction, did not really alter the rate of clinical success of the restoration.

One of the greatest disappointments of this era was the performance of the new alloys with particles of different sizes and shapes, such as Spheraloy and Velvalloy, which offered earlier strengths, yet did no better over the long term, the reason being that they were of the same composition as conventional alloy, and produced the same phases of product. The rationale for this was not hard to find. Thanks to classical work in the 1960s on the microstructure of set amalgam, as revealed by optical microscopy performed by Allan, Asgar & Peyton (1965) in the United States, and by Wing (1966) in Australia, the phases of set amalgam and their distribution could be visualized. Not surprisingly, the structure and distribution of the phases of the reaction products of all systems of amalgam proved nearly identical. The structural investigations confirmed the x-ray diffraction work of others and led the way to the electron microscopy and microprobe technology of today.

Dye Leakage Studies

In the decade of 1950–60, experiments to evaluate microleakage of direct filling materials were popular. The popularity was based on the relative ease with which the experiments could be performed and interpreted. Extracted teeth either containing restorations that had seen service in the mouth or that had been filled with a candidate material after extraction were immersed in a fluid containing an indicator such as a visible dye (for example, methylene blue) or a radioisotope (Ca^{45} or I^{131}), and the results reported photographically. If the margin was patent, some fluid would penetrate and if the margin was sealed, nothing passed. Leakage was often accelerated by cycling the temperature to induce percolation.

On the basis of work by Massler, Going and coworkers (Going, Massler & Dute, 1960a, 1960b), Phillips, Swartz and coworkers (Phillips & others, 1961), and others, the following picture of the marginal integrity of amalgam developed as elucidated by Wing (Wing & Lyell, 1966):

1) Amalgam restorations develop leakage.

2) A reduced rate of leakage is observed after a period of service in the mouth (this is inferred since dye and isotope leakage can never be evaluated directly in the mouth).

3) Corrosion products of amalgam may be deposited in the space between tooth and restoration.

4) Salivary constituents may be deposited in patent margins.

5) Copal resin varnish effectively seals the margins to ionic and molecular tracers.

Before blanket acceptance of this picture, however, we must remember that:

a) In studies on extracted teeth, the fluid exchange is probably completely different from that in vital teeth.

b) The detection of leakage requires a certain concentration of indicator in order to be discerned. The question of whether this concentration is related to the concentration of oral fluids and flora necessary to produce secondary decay must be addressed.

c) Although corrosion products of amalgam form and apparently seal, at least to dye and isotope, how does the margin function under occlusal stress?

Leakage experiments with dyes have, to some degree, become passé since scanning electron microscopy (SEM) has become the vogue. SEM is, if anything, an even easier technique and the pictures obtained are much more dramatic and more difficult to interpret, thus ensuring the continued gainful employment of dental materials scientists!

The Development of Contemporary Amalgam

The development and acceptance of present-day amalgams resulted from the confluence of four new ideas: (1) the patenting of a new composition, Dispersalloy (Innes & Youdelis, 1963); (2) an appreciation of the role of corrosion by saline and sulfide on the physical properties and microstructure of dental amalgam (Sarkar & Greener, 1974; Chen & Greener, 1976); (3) the elucidation of the theory of mercuroscopic expansion by Jørgensen (1965); and (4) the development of systematic clinical studies (Mahler & others, 1970; Larsen & others, 1979), the results of which can be transformed into parametric distributions capable of statistical treatment.

Shortly after succeeding Gene Skinner in the fall of 1964, I was made aware of the development, in Canada, of a dispersion-hardened dental amalgam. From all that I learned, I was highly skeptical. Dispersion hardening requires a coherent dispersion of a small concentration of very fine dispersant through the material but the dispersant system chosen by the inventors, Innes and Youdelis, was used incoherently in large concentrations (30–50%). Further, the hardness of the dispersant was only 10 DPH (diamond pyramid hardness) harder than that of dental amalgam itself. Dispersalloy did, however, display superior clinical performance. It was a case of serendipity of the highest order. The dispersant, gold-copper eutectic, approximately 72% gold and 28% copper, produced a dramatic change in the nature and distribution of the reaction products between alloy and mercury. We now know that the copper forms a reaction product, Cu_6Sn_5, during trituration, eliminating the Sn_7Hg (γ_2) reaction product ever present in all amalgams meeting the compositional requirement of ADA Specification No 1. We are in a position today to discuss the ramifications of this very fundamental change in amalgam.

By 1941 Schoonover and Souder (1941) were able to cite 26 authors who found that galvanism and electrochemical phenomena caused clinical abnormalities. Indeed, electrochemical activity of amalgam was widely appreciated. Schoonover and Souder began their own experimentation by placing a number of amalgams fabricated from amalgam alloys of different compositions against a gold disc in a 1% NaCl solution and analyzing the products of the resulting corrosion. They found that three of the alloys studied produced less corrosion of tin, by an order of magnitude, than amalgams of conventional composition. These alloys contained 15–20% copper and were very close to the composition of today's new high-copper amalgams. After Schoonover and Souder remarked on the excellent resistance of these three alloys to corrosion, they deleted them from the remainder of the experimental study and never mentioned them again.

One of the highlights of any retrospective scholarly effort is in finding a genuine mystery. Since these compositions predate today's amalgams by at least 25 years, we have to ask the following questions: One, where did Schoonover and Souder come upon three compositions of amalgam alloy that so closely mirror the newer amalgams of today? Nowhere in their classic paper do they tell if their alloys were obtained commercially or made by themselves. Two, if they found a superior resistance to saline corrosion, why did they eliminate these compositions from the remainder of their experimentation? The question gains further importance since they were able, qualitatively, to correlate the presence of corrosion of amalgam with loss of strength.

We can attempt to answer the first question by noting that there is an oral history of clinicians, certainly in the Midwest at the turn of the century, using a copper admixture amalgam of the type that John Anderson and Bernard Marker, for example, attempted to popularize in the 1960s. However, there is no mention of an admixture by Schoonover and Souder, so the mystery still exists.

At the recent midwinter meeting of the Chicago Dental Society, I discussed this matter with Nelson Rupp of the Bureau of Standards, who was intrigued enough to do some further research when he returned to Washington. He contacted Schoonover, now retired, who recalled that these compositions were, to his best recollection, experimental alloys supplied by Caulk or S S White. But Rupp also sent me an internal publication of the National Bureau of Standards of 1920, where Souder makes reference to these alloys (Souder & Peters, 1920b).

The ADA specification, placing an upper limit of 5% on copper concentration, was firmly supported by investigators of dental materials, citing Gayler's work as evidence that increasing the concentration of copper produced excessive expansion. Therefore, a copper concentration of 15–20% was not to be permitted. However, this is a misinterpretation of Gayler's work. What Gayler (1935) did say was that if copper was substituted for tin so that the concentration of tin dropped below 25% expansion could occur; but if copper was substituted for silver so that tin concentration was maintained at 27%, no excess expansion occurred. So theoretically a greater substitution of copper was possible without a consequent dramatic dimensional change if copper was substituted for silver. Unfortunately, the confusion surrounding the concentration of copper has resulted in a 25- to 30-year delay in producing amalgams resistant to corrosion.

Studies of corrosion of amalgam have, indeed, become more sophisticated. It is an area of research to which the Department of Biological Materials at Northwestern University Dental School has made significant contributions (Sarkar & others, 1975; Finkelstein & Greener, 1979). We can sum up the results of the saline corrosion of conventional amalgam by the now accepted process of the γ_2-phase being anodic to the γ- and γ_1-phases, according to the reaction:

$$Sn_7Hg + H_2O + Cl \rightarrow SnO + Hg + OH^- \text{ or } SnOH\,Cl + Hg$$

This reaction was anticipated by Jørgensen and carried one step further in his theory of mercuroscopic expansion. Basic to his proposal was the corrosion of the γ_2-phase at cavosurface margins with the production of mercury as a product of the corrosion reaction. This mercury could then react with unreacted alloy in the set mass to produce additional reaction product and dimensional change. The dimensional change produced an exfoliation of the amalgam at the margin in the form of "unsupported slits" which could then fracture easily in tension under occlusal loading.

The deleterious effects of corrosion upon mechanical properties can be measured as well in the laboratory (Chen & Greener, 1976). Corrosion of the γ_2-phase produces defects of the surface and defects within the set amalgam as the γ_2-phase is interconnected. These defects have been shown to lower the tensile strength of conventional amalgam by 25% or more (Chen & Greener, 1976).

One of the most striking differences in properties displayed by Dispersalloy and the newer high-copper amalgams is the absence of γ_2-phase (Greener, 1976). This same phenomenon was observed also with the copper admixture already mentioned. Electron probe microanalysis and scanning electron microscopy have shown that the high-copper amalgams contain little or no γ_2-phase and that the tin is associated with copper as Cu_6Sn_5. Obviously, with the tin bound in an inert phase, the corrosion reaction associated with the γ_2-phase could not occur. We must point with pride to the work of G W Marshall of our own department in this area of amalgam research (Marshall, Marshall & Greener, 1977). That Dispersalloy gave superior clinical behavior was proven conclusively over a four-year period by Mahler & coworkers in an effort that pioneered the use of statistical transformations to produce parametric data from intraoral photographs (Mahler & others, 1970).

Here at Northwestern University Dental School and at many other centers this technique has been used to study clinical tarnish (Larsen & others, 1979). These studies show that Dispersalloy, admixtures of copper, and many of the newer high-copper alloys possess superior clinical properties. There is some controversy among clinical researchers about the time needed to discriminate between the performances of restorative systems. However, in all cases the minimum time is at least several months.

All are agreed, however, that it would be desirable to find a laboratory test that would predict superior clinical performance. Based on correlation with the data on marginal integrity for several alloys, static creep has been proposed as such a property (Mahler & others, 1970), though no cause-and-effect relationship has been offered between creep and marginal integrity.

It is true, however, that the high-copper alloys have less than 1% creep whereas in conventional alloys the creep in general is greater than 2%, often differing by an order of magnitude or more. One can offer a few explanations of this phenomenon. Conventional amalgams contain a significant concentration of an interconnected soft γ_2-phase, the concentration of which can be altered by variations in technique. Effective high-copper alloys do not contain this concentration of γ_2-phase. Their matrix is almost entirely γ_1 (Ag_2Hg_3). In fact, such Cu_6Sn_5 that does exist in these systems may act to key the boundary area of large grains presented by the γ_1-phase and thus prevent "grain boundary sliding," which is probably the major mechanism of creep (Okabe & others, 1977). I think, therefore, that we can explain the superior performance of the margins of high-copper amalgams by the absence of the γ_2-phase, the improved resistance to saline corrosion, and the maintenance of tensile strength.

The success of Dispersalloy has, of course, brought competing alloys into the marketplace. In general, however, they are all close to the compositions found corrosion-resistant 37 years ago by Schoonover and Souder, and all use copper to combine with tin. As a result of differences in fabrication, alloys with wide differences in clinical handling are possible.

As the use of the new alloys increases, their idiosyncrasies become appreciated. They apparently are drier, faster setting, and more sensitive to trituration time than are conventional alloys. The high-copper amalgams appear to tarnish more severely in a sulfide environment than do conventional amalgams. The tarnish layer is thought to be Ag_2S. While unesthetic, it does not appear to affect the marginal integrity of the amalgam. Some of the tarnish may be severe enough, however, to cause surface pitting. Alloys that fail in the marketplace will be replaced by second-generation alloys. The conventional amalgam may become one with 15–20% copper.

There can be no doubt that the development of high-copper amalgam has created additional excitement in the field of dental restoratives. Many of us dental researchers were set to bury amalgam a decade ago when composites were brought forth. The combination of the development of amalgam and perhaps a lack of similar progress in composite leaves amalgam clearly in the lead today as the direct restorative material of choice for posterior applications. But we must ask as we did a decade ago, "What of its future?"

Future of Dental Amalgam

There exists, like the tip of an iceberg, the ever-present question of the biocompatibility of amalgam. Every generation, it seems, must tackle this question. We are, perhaps, the first to do so with concern of legislation on a national and international level. Legislation has determined that the environment of dental offices, like other segments of our society, must be safe. In terms of mercury hygiene, they are more specific. A threshold limit value (TLV) of .05 mg/m^3 has been established, with health hazard being defined as exposure to a concentration of inorganic mercury greater than 40% of TLV in the work place. Recent surveys have shown that, nationally, at least 10% of dental offices have mercury vapor in excess of TLV (Mantyla & Wright, 1976; Gordon, Tsujii & Breysse, 1977). Last year, the result of a survey of 85 operatories in Seattle revealed 10–15% had ambient mercury over TLV, with signs of mercury poisoning in clinicians; and, perhaps more frightening, 70% of the operatories had ambient mercury levels above 40% TLV. Recently, the British Broadcasting Corporation on prime time television reported similar statistics for England, so we must believe that the problem is universal. There are many reasons for the lack of mercury hygiene, some of them traceable to the operatory personnel, perhaps some even to the amalgam system itself, for example, capsule design. I wish only to pose the problem and indicate that it is one present after 100 years of the routine use of amalgam.

Another cloud has arisen recently since we have developed the refined analytical tools to attack problems which, heretofore, have been ignored for want of appropriate technology. We have seen that conventional amalgams suffer saline corrosion in the oral environment. The concentration of chloride ion in saliva is 0.1 N. What is the corrosion of amalgam like in extracellular fluid at a 1 N concentration of chloride ion? We have some idea of the magnitude from our corrosion studies, where corrosion rates are increased several times. In a series of histochemical studies of amalgam tattoos and implants in soft tissue, Harrison and coworkers in England (Eley, Garrett & Harrison, 1976; Harrison, Rowley & Peters, 1977) and Hembree and coworkers in the United States (McGinnis, Hembree & Lewis, 1977) have found, by both conventional analysis and electron microprobe analysis, that silver is almost universally identified in the particulate matter contained within the tissues, tin infrequently, and mercury never. Harrison has further postulated a mechanism whereby corrosion products are ingested by macrophages, producing Ag_2S which is found in many varieties of biological tissue; tin is occasionally surrounded by macrophages, and the biological fate of mercury is unknown. Not enough to get excited about, considering the successful history of amalgam extending over 100 years? Perhaps, but need I remind you that saccharin also had a long record of clinical use. Fortunately, the resistance of high-copper amalgams to saline corrosion may narrow the extent of this problem.

At the recent meeting of the British Division of the International Association for Dental Research, an entire half day was devoted to the problems of mercury possibly associated with poor standards of amalgam hygiene. One of the most dramatic findings was presented by Dale and coworkers, of the University of Glasgow, who found six times higher concentration of methylated mercury in the dental population and who have hypothesized that methylated mercury may be synthesized from mercury vapor by microorganisms in the gut (Goolvard, Dale & Ferguson, 1979).

I introduce the following ideas to indicate the direction in which I think the future of amalgam research will proceed, at least in the Department of Biological Materials at Northwestern University Dental School, where some people have to listen to me.

First, just as mechanical amalgamation was an idea whose time had come, I think that we will see an adaptation of the design of amalgamators to ensure greater mercury hygiene. I have seen one such device, the Dentomat, employed as the triturator of choice in several dental schools in the United Kingdom for the express purpose of mercury control. However, the BBC study, already mentioned, revealed that it was merely a concentrator of mercury vapor.

Second, now that the acceptance of high-copper amalgams has essentially made the compositional part of ADA Specification No 1 obsolete, it is open season on new compositions. One direction must be to use our knowledge of metallurgy and intuition to design novel alloys that can be triturated with significantly less mercury than can present alloys. The less mercury used, the less is the hazard to operators, auxiliaries, and patients. With that in mind we are now experimenting in our department with alloys containing nickel.

Finally, if we reject the alchemists' position that mercury is good and necessary, we are faced with the problem of developing a system completely free of mercury. Obviously, the composites and the polyelectrolytes hold promise for the future.

As part of my year abroad, I have been working with the Dental Materials Unit and Turner Dental School on the new polyelectrolyte cements, in particular, ASPA and FUJI glass ionomers. Since the mechanism of setting involves chain locking of polyacrylic acid by ionic charge, that is, Ca^{++}, we have thought of substituting cations such as those found in amalgam alloy or tin and zinc metal. Using strictly commercial components, we have fabricated setting systems of amalgam/glass ionomer, tin polyacrylate, and zinc polyacrylate. Whereas the physical properties of these systems are not clinically acceptable yet, they possess, I feel, exciting potential.

Of equally exciting import has been the work reported at the most recent IADR meeting in Washington by Moffa and Jenkins (1978) who presented clinical results (4 years) of an experimental composite used in posterior teeth (Profile, S S White, Philadelphia, PA 19102, USA). The major difference is that experimental strontium glasses were used. This composite behaved as well as or better than amalgam on all clinical indices evaluated, that is, 92% were free of occlusal wear, compared to 36% of conventional composite controls. These composites have been recently offered to the profession.

Conclusion

The amalgam that Gene Skinner knew and with which he worked appears to be on its way to obsolescence, just as the amalgams of Flagg, Crawcours and D'Arcet. We will have a new system, probably based on the current high-copper alloys, to be worked upon, studied, and improved. This, in turn, will eventually be replaced with another system of direct restorative material offering improved care for patients. As a betting man I opt for change coming sooner rather than later. Certainly, we will not have to wait for a century.

Amalgam research in 1979 is where the action is!

The interaction of scientist and clinician, the degree of international cooperation, and the considerations of the marketplace, all contribute to an ambience of excitement and enthusiasm in research. The vision of Gene Skinner in these areas persists and has contributed in no small measure to the accomplishments the field has made to date. We who toil at Northwestern University Dental School owe our own special thanks to Dr Skinner for the creation of an understanding of the science of dental materials by all segments of our University.

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POINT OF VIEW

Influencing the Dental Curriculum

HAROLD R LASWELL • NEAL D BELLANTI

All of us concerned about an apparent loss of emphasis on restorative dentistry in our dental schools should be aware of the influences currently determining the dental curricula in this nation. Although a comprehensive review is beyond the intent of this commentary, a list of a few of the major contingencies with only a single example from the many that can be cited may serve to awaken us to the need for study and planning by anyone (particularly clinicians) striving to influence the dental curriculum.

Tradition

The survey of dental education, if the means, medians, and ranges are cited as standards, may tend to maintain the status quo. Will the results of this survey lead to well-documented mediocrity?

Antitradition

Rejection of unit requirements as an approach to the clinical curriculum in favor of comprehensive care for patients has a profound influence on the types of experience encountered by students. Unlike the medical curriculum, the dental curriculum must prepare a student for practice upon graduation. In assigning patients, can we afford "luck of the draw" to provide the breadth and depth of clinical experience that general practice demands?

The American Dental Association

The Commission on Accreditation of the Council on Dental Education exerts a strong influence on curricula. The composition of this committee and its leadership is important to us. Are their priorities in the right order, or do certain programs receive more attention than they deserve?

The Federal Government

The increased enrollment and shortened curricula that resulted from the capitation approach selected by the federal government, as well as its emphasis on increasing the respon-

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sibility of auxiliaries and extramural experiences, have been directed at an increased quantity of dental care. How can we influence the government to turn its attention to quality?

State Government

Altering the process of admitting students to dental schools to correct real or supposed maldistributions of dentists influences the level of the ability of the entering student. In one state a legislative bill has been proposed to enumerate medical and dental school admissions by congressional district. Can we influence our legislators to help us encourage highly qualified individuals to seek careers in dentistry?

Granting Agencies

An acknowledged shift of funding to research on the delivery of health care can ultimately affect our curriculum by determining the profile of faculty hired and by the knowledge which such research reveals. Is the college of dentistry an appropriate arena in which to perform such research?

Dental Insurance

Among the many influences of the increased availability of payment by third parties is a diminished availability of patients with certain categories of dental need. Although this change has been most profound in prosthodontics and pediatric dentistry, we must recognize that the clinical curriculum is largely determined by the clinical textbook that we have chosen, that is, the living patient. Will we be able to cope with the ever-increasing availability of third-party support for fees by making the services of a college of dentistry as attractive as those provided by the private practitioner?

Education Theory

Theories of education are, of course, continually subject to change and modification. The self-paced, self-instructed approach, the need for relevance, recognition of individual differences, and many other current trends pressure the curriculum to adapt. Can we sort out the differences between fad and timeless principle?

Faculty

Faculties of the college of dentistry are brought more and more into accountability to the academic game. Achieving the requirements for promotion leads to a narrowing of fields of interest and the development of academic specialists. G V Black was capable of being dean of the faculty, a dental practitioner of high quality, an excellent teacher, and a leader in meaningful research on a broad base. Was he the last "Man for All Seasons"?

The General Practitioner

To the extent that the dental colleges have participated in the experimentation and modeling advocated by consumer groups and the federal government, rifts have been created between the colleges and their colleagues in private practice. Many general practitioners, formerly supportive, have come to view the college of dentistry as an opponent rather than as an ally. Can we heal these wounds and regain the confidence and much needed support from this important source of input in determining a relevant clinical curriculum?

Students

The modern student, by his involvement in the academic process through both formal and informal evaluation, as well as by participation in the academic process, exerts pressure for curricular change. His input can be very shallow and self-serving or it can be invaluable in apprising us of strengths and weaknesses in our program. Are we able to discriminate the difference?

The Consumer

The shifting demand of the dental consumer from that of episodic care to that of oral health care on a broader base is in only the early stages of development. Can the current curriculum accommodate this shift in emphasis while retaining excellence? Can oral health care be provided in the absence of excellence?

Academic Governance

The shift from an autocratic to a democratic system of academic governance may have lasting influence on the curriculum. An individual effort to influence the curriculum by force of persuasion on the administration is highly unlikely to succeed. How do we negotiate the democratic process to achieve our aims?

Specialties

We must recognize that, among a faculty devoted to the goal of educating a generalist, the specialist is dominant. Perusal of the *Directory of Dental Educators* will confirm this overwhelming disproportion. Can nonspecialists retain and build upon the curriculum base they now control?

Basic Sciences

Proliferation of knowledge has been most evident in the basic sciences. Every clinician who has been remote from such subjects as biological chemistry or microbiology should devote a few moments of his busy life to a cursory review of these subjects and compare the material with that to which he was exposed during his dental education. Can we provide the necessary support to our basic scientists as they strive to sift through their subject matter to provide a relevant biologic orientation for our students without "watering down" the content of their courses?

Development of Other Dental Disciplines

Development of greater knowledge of the etiology, progress, and treatment of periodontal disease demands increased time in the curriculum. How do we support this need for revision to accommodate this and many other developing disciplines such as orthodontics, occlusion, and practice administration, while retaining an emphasis on restorative excellence in our curriculum?

New Disciplines

An expanding influence of the behavioral sciences demands that a student not only know what to do for his patients but also be able to relate to his patients so that they will be receptive to his recommendations. Can we deny that this is important and can we deny our students an opportunity to master these skills?

These simple illustrations should make it obvious that to effect changes that we desire for the modern dental curriculum we must achieve a level of sophistication far greater than that which was necessary in a previous era. We must understand and appreciate the views of groups with other interests. We must face the reality that, should all interests achieve their goals, the resulting dental curriculum would be broadened and deepened beyond manageability in time and resources and beyond the capacity of our students. Our goals must be clearly stated, documented, and justified. We need to do our homework, establish an effective lobby, and be willing to serve at any level, including administration. Ours is not a lost cause suitable for martyrs only; but "voices crying in the wilderness" will not prevail.

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PRODUCT REPORT

Mercury Leakage during Trituration: An Evaluation of Capsules

The design of capsules for triturating amalgam should be improved to prevent leakage of mercury.

CAMILLE B CAPDEBOSQ, JR • WILLIAM N VON DER LEHR

Summary

Seven brands of reusable capsules and five brands of disposable capsules were tested for mercury leakage. All but one leaked. The disposable capsules as a group leaked less than the reusable capsules as a group.

INTRODUCTION

Choosing a capsule for the mechanical trituration of alloy and mercury is complicated by several things, such as leakage of mercury, ease of use, and acceptable trituration. The complexity is increased by the availability of disposable capsules containing premeasured amounts of alloy and mercury. The problem is of as much concern to the instrument committee of a school as to a private practitioner. This study was undertaken to see if there is a superior method of mechanical trituration that can be recommended.

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MATERIALS

Seven brands of reusable capsules and five brands of disposable capsules were tested. They are listed in Table 1, along with the type of lid on the capsule and the presence or absence of a pestle.

METHODS

Reusable Capsules

Three capsules of each brand were used and each capsule was tested three times, making a total of nine trials for each brand. Each cap-

Table 1. Brands and Types of Capsule Tested

Brand	Lid	Pestle
Reusable		
Baker Dental (Carteret, NJ 07008, USA)	Friction	No
L D Caulk Co (Milford, DE 19963, USA)	Friction	Yes
Crescent Dental Mfg Co (Lyons, IL 60534, USA)	Screw	Yes
Johnson & Johnson Dental Products Co (East Windsor, NJ 08520, USA)	Friction	Yes
Kerr Mfg Co (Romulus, MI 48174, USA)	Screw	Yes
S S White (Philadelphia, PA 19102, USA)	Friction	Yes
Shofu Dental Corp (Menlo Park, CA 94025, USA)	Screw	Yes
Disposable		
Aristaloy (Baker Dental)	Friction	Yes
Fine Cut (L D Caulk Co)	Friction	Yes
Indiloy (Shofu Dental Corp)	Friction	Yes
Sybraloy (Kerr Mfg Co)	Friction	Yes
Tytin (S S White)	Friction	Yes

sule was marked and then weighed on an analytical balance accurate to 0.1 mg (August Sauter Amerika, Inc, New York, NY 10036, USA). Each capsule was loaded with a six-grain pellet of Velvalloy (S S White, Philadelphia, PA 19102, USA) and a drop of mercury from a Caulk dispenser with an E rod in place (L D Caulk Co, Milford, DE 19963, USA). Each loaded capsule was weighed, triturated, and then weighed again before the capsule was opened. All mixes were triturated for 15 seconds on a Caulk Vari-Mix II set on M-2 (L D Caulk Co, Milford, DE 19963, USA). The Baker capsule was used without a pestle. All mixes were well triturated.

Disposable Capsules

Disposable capsules can be used only once, so six of each brand were tested. Each was weighed before and after trituration. The time of trituration recommended by the manufacturer was used with all the alloys except Tytin. The two seconds recommended did not give a proper mix, so the trituration time for this alloy was extended to four seconds. At this time interval the mixes of Tytin were excellent.

RESULTS

Reusable Capsules

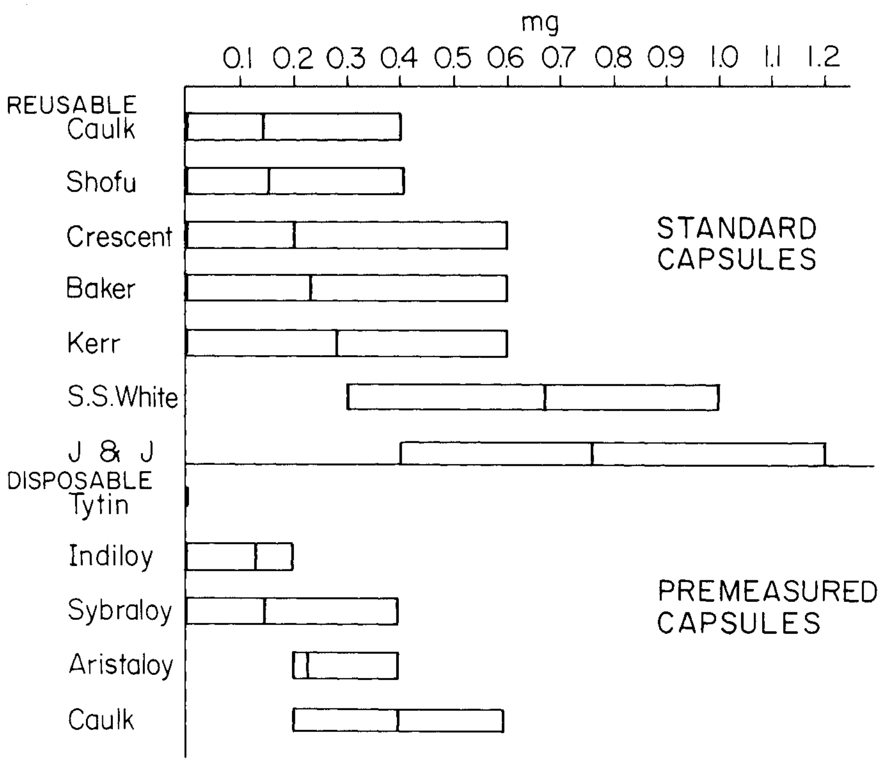
The results of each test are shown in Table 2 and the average loss of mercury from each brand of capsule is depicted by the graph (see figure). All capsules leaked. Though we exercised great care to fit the lids tightly to place, whether of friction or of screw type, most times they leaked when triturated. Occasionally they did not leak, but there was no pattern of when a particular brand of capsule would or would not leak. Two capsules, Caulk and Crescent, each survived five trials out of nine without leaking; one capsule had a screw lid, the other did not. Two capsules, Johnson & Johnson and S S White, leaked on every trial; one had a screw lid, the other did not. The other three brands withstood leaking on one or more trials. The Shofu capsule had an elastic O ring, which is supposed to eliminate leakage of mercury. These capsules leaked also but ranked second in the final rating. The average leakage of the reusable capsules was 0.38 mg.

Disposable Capsules

The results of each test are shown in Table 3 and the average loss of mercury from each brand of capsule is depicted by the graph. The disposable capsules as a group leaked less

Table 2. Mercury Leakage of Reusable Capsules for Each Trial

Capsule \ Trial	Leakage of Mercury mg 1	2	3	4	5	6	7	8	9	Total	Mean
Baker	0.4	0.2	0.3	0.2	0.6	0.2	0.2	0	0	2.1	0.23
Caulk	0.4	0.3	0	0.3	0	0	0.3	0	0	1.3	0.14
Crescent	0	0.3	0	0	0.5	0	0.6	0.4	0	1.8	0.20
J & J	0.8	0.9	1.0	0.9	1.2	0.4	0.9	0.4	0.4	6.9	0.76
Kerr	0.3	0.2	0.2	0.4	0.2	0.5	0	0.2	0.6	2.6	0.28
S S White	0.5	1.0	0.7	0.3	0.9	0.8	0.7	0.5	0.7	6.1	0.67
Shofu & O-Ring	0	0	0.3	0	0.4	0.3	0.2	0.2	0	1.4	0.15



Mercury leakage of capsules during trituration. Open bars show range of leakage. The line indicates the average.

Table 3. Mercury Leakage of Disposable Capsules for Each Trial

Capsule \ Trial	Trituration s	Leakage of Mercury mg 1	2	3	4	5	6	Total	Mean
Aristaloy	12	0.2	0.2	0.2	0.4	0.2	0.2	1.4	0.23
Caulk Fine Cut	12	0.4	0.2	0.2	0.5	0.6	0.5	2.4	0.40
Indiloy	11	0.2	0.2	0	0.1	0.1	0.2	0.8	0.13
Sybraloy	6	0	0.4	0.2	0.2	0.1	0	0.9	0.15
Tytin	4	0	0	0	0	0	0	0	0

than the reusable capsules. Aristaloy and Fine Cut leaked on every trial but Tytin survived six trials without leaking. The average leakage of the disposable capsules was 0.18 mg.

DISCUSSION

These results are at best discouraging for the practitioner. Attention needs to be directed to the design and construction of capsules. Newly designed covers for triturating arms of mechanical amalgamators, as recommended by the Council on Dental Materials and Devices of the American Dental Association, will help contain this spillage of mercury, but it would be better to design a capsule that does not leak. Although screw-type lids might be expected to prevent leakage, they did not. The addition of an O ring to seal the capsule is an improvement but did not solve the problem entirely.

Leakage from disposable capsules was affected by triturating time. The two capsules with the longest triturating time, Aristaloy and Fine Cut, leaked the most. Tytin had the least triturating time and no leakage. When Tytin was mixed for 12 seconds (not recommended by the manufacturer) it too began to leak. Indiloy was the exception; it was triturated for 11 seconds and had next to the least leakage of the five brands tested.

CONCLUSION

Unfortunately, no clear answer is forthcoming. The disposable capsules reduce leakage but cost more. Some new sealing mechanism should be devised for the reusable capsules.

DEPARTMENTS

Press Digest

Allergy to partial denture casting: case report. Fenton, A H & Jeffrey, J D (1978) *Journal of the Canadian Dental Association* (44) 466–467.

A 38-year-old patient with an acrylic maxillary denture and a mandibular partial denture with a Nobilium framework exhibited signs of allergy to the partial denture. The patient reported a history of reactions to stainless steel sutures and difficulty in wearing watches, rings, or earrings unless made of gold over 14 carat. Replacing the partial denture with one of acrylic with gold clasps did not solve the problem. On the suspicion the allergy might be caused by a trace element in the gold, two brands of gold were embedded in the buccal flanges of the maxillary denture to test for reactions. Within 24 hours the first brand had caused a reaction orally; the other had caused no reaction at the end of two weeks. A partial denture with a framework of the second brand of gold has been well tolerated by the patient.

Allergy to silver amalgams. Catsakis, L H & Sulica, V I (1978) *Oral Surgery, Oral Medicine and Oral Pathology* (46) 317–375.

A 52-year-old patient with persistent periodontal disease, which resisted cure by periodontal treatment including surgery, was found to be allergic to silver. Removal of restorations of silver amalgam and their replacement with gold castings has allowed the periodontium to regain its health.

Human pulp response to a new composite system. Dalleske, R L, Stanley, H R & Heyde, J B (1978) *Oral Surgery, Oral Medicine and Oral Pathology* (46) 418–426.

The response of the pulp to Vytol has been found to be similar to that of other composites, that is, a greatly increased response compared with zinc oxide and eugenol. A layer of calcium hydroxide over the dentin reduces or eliminates the adverse response.

Pulpal and periodontal effects of electrosurgery involving cervical metallic restorations. Robertson, P B, Lüscher, B, Spangberg, L S & Levy, B M (1978) *Oral Surgery, Oral Medicine and Oral Pathology* (46) 702–710.

When silver amalgams in cervical cavities in monkeys were touched for no longer than one second with the tip of a single wire electrode adjusted for cutting, coagulation necrosis of the pulp and resorption of cementum, dentin, and interradicular bone resulted consistently. When enamel was touched there was no adverse reaction in the pulp or periodontium.

Book Review

HANDBOOK OF MEDICAL EMERGENCIES IN THE DENTAL OFFICE

by Stanley F Malamed

Published by C V Mosby Co, St Louis, 1978.
359 pages. $14.50

This handbook is a very comprehensive review of medical emergencies that could occur in the dental office. It deviates from the traditional systems-oriented approach to medical emergencies. Instead it focuses attention on the signs and symptoms through which medical emergencies usually manifest themselves clinically.

The *Handbook* is divided into eight sections dealing with prevention, unconsciousness, respiratory difficulty, altered consciousness, convulsions, drug-related emergencies, chest pain, and cardiac arrest. In addition there is an excellent appendix/quick reference section to life-threatening situations which diagrammatically summarizes the management of unconsciousness, respiratory difficulties, altered consciousness, convulsions, local anesthetic reactions, and chest pain.

Section I includes a chapter on medical-legal considerations written by Gerald A Sheppard, BA, LLD. Chapter 2, "Prevention," deals with the importance of physical evaluation and the medical history. It emphasizes "never treat a stranger." The medical history questionnaire format used was developed by the anesthesia faculty of the University of Southern California and has been adopted by the American Dental Association. All of the health history questions are listed and the significance of positive responses is discussed. These same questions are repeated in subsequent chapters such as "Respiratory Difficulties" and "Drug-Related Emergencies." The significance of positive responses related to these problems is explained in much greater detail in these later chapters.

The book is the most comprehensive discussion of medical emergencies in the dental office that is currently available. The emphasis on signs and symptoms as opposed to the traditional systems-oriented approach is an excellent departure and is especially valuable for readers who only rarely encounter emergency situations. It is impossible for most dentists to act with composure during an emergency situation because they have not acquired the skill of recognizing the signs and symptoms of developing emergency situations. The book emphasizes that it is not always necessary to recognize the specific condition as long as the dentist is capable of managing the various signs and symptoms such as the allergic symptoms and chest pain.

The *Handbook* goes well beyond the discussion of the management of medical emergencies. It is in fact a comprehensive review of internal medicine which is related to the management of emergency situations. This is an essential strength of the book, and it is suggested that the reader may consider the book on those merits alone. Of course its main value is that of an excellent presentation of the management of medical emergencies.

The book is intended for a general audience and it should be of equal value to dental students, general practitioners, and specialists.

James R Hooley, DDS
Professor and Chairman
Department of Oral and Maxillofacial Surgery
University of Washington

Letters

Dear Sir:

On the whole I agree with the observation of Dr Harmon Adams (Point of View, Autumn 1978) about silver amalgams. There are some points on which I differ.

When I'm making a diagnosis, money is not an element. My concern is that the patient has enough information to make a sound decision about the treatment he is to receive. I do not have a financial interest in the decision. Even if the patient decided to accept only emergency treatment, that is all right with me.

After we have decided on the level of treatment, we talk about the expense. There are two components to cost—one is money, the other is time. Either or both of these components influences the final treatment plan. The patient may decide he doesn't have the time for the bridges or crowns, or that he would rather have amalgams or composites placed one more time. Here again I have no financial interest in the patient's decision. Whatever he decides after being informed is all right with me.

The reason I can be comfortable with the decision my patient makes is that I feel my fee schedule is appropriate. My net hourly income from an amalgam, a crown, a bridge, or a denture is the same. Therefore, I think it inappropriate to use mean fees in discussing philosophical positions of readers of *Operative Dentistry.* We are not addressing average operators.

There is an allusion, that I sense, to "The Fee" for a particular service and the "disparity of fees" and that these fees are set by "them." I don't recall anyone telling me that my fee should be this or that, except for the Department of Social Health Services (DSHS) and the Veterans Administration (VA). I do not deal with DSHS because of fees and other reasons. I do interact with the VA for personal reasons, even though I must accept a fee schedule that I find unsatisfactory.

To restate simply, I am curious about the fees of others and interested in mean fees. But my fees are my responsibility. I find that my fee schedule is acceptable to most of my patients and appropriate to the service performed.

I thank Dr Adams for opening a discussion of what I view as the second most important component of quality. I believe that appropriate fees are second only to integrity in contributing to the quality of dental service.

Sincerely,
Lawrence O Owens
508 West 6th
Spokane, WA 99204

Dear Sir:

I would like both to disagree and agree with Harmon Adams.

Fees should reflect the difficulty of the work being done. Amalgams are simply not *as* difficult. Porcelain-fused-to-metal crowns require a greater investment in physical plant, your own laboratory time, aggravation with your technician, and more postgraduate courses. Displacement of soft tissue is necessary for the ceramoveneers. This lessens predictability. Amalgams are difficult; crowns are even more difficult.

In the market place, cosmetic anything is always worth more to the buyer. To expect dental fees not to reflect that is silly. It is natural that esthetic crowns and composites have higher fees.

Most importantly, no other segment of our society works with such mental and physical intensity, for so long, under such consistently difficult circumstances, for so little money. (And that's just chairside.) There is no mystery in why lots of dentists are suicidal. Maybe we are not tops, but dentists number among the best at committing suicide. We have got to change our attitudes. What dentists do for people is offer them care unequaled in time or place. We are intellectual artisans, an unusual and difficult combination. We restore terrible defects (mechanical and esthetic) with wonderful ease and facility for the patient, at terrible expense to us.

Of course, the fee for a three-surface amalgam of good quality should be increased to where it provides adequate monetary incentive to do it right. Fees for *all* services should reflect that philosophy. To paraphrase what LD Pankey, Sr, has said: Dentists should not compete with one another, for they are competing with General Motors.

Do not look over your shoulder at the other guy's fees. As a matter of fact, that is illegal today. Charge your patient for your care, skill, and judgment. Be thorough in your care, extend your skills, and help improve the quality of your patient's life.

Sincerely,
Steven N Green
8740 North Kendall Drive
Miami, FL 33176

Dear Sir:

Your editorial, "Are Specialists Spoiling Dental Education?" in the Summer 1978 *Operative Dentistry* is a most provocative one. I heartily agree with your succinct conclusion: "Is it not time for the specialists to recognize their limitations and relinquish the control of dental education to those more conversant with treating the patient as a whole?"

In my opinion, dental educators and, in particular, those responsible for the curricula in our schools, are leading us, however unwittingly, toward increasing specialization in the predoctoral programs. This seems to be occurring at the expense of the highly qualified dental educator in the area of general dentistry.

As witness to this unhappy trend, please note the copy of an advertisement for a full-time position as an educator in operative dentistry. It appeared in the classified section of the *Journal of Dental Education,* November 1978, Vol. 42, No. 11:

> **MICHIGAN—Operative dentistry.** Full-time, 12-month assistant professorship available after January 1979. M.S. in restorative dentistry beyond dental degree required. Teaching and practice experience desirable. Must be licensed in Michigan or eligible for next licensing exam. Non-discriminatory, Affirmative Action employer. Applications must be received before December 15, 1978. Send brief resumé and request for application to Operative Dentistry Search Committee, Office of the Dean, The University of Michigan School of Dentistry, Ann Arbor, MI 48109.

This advertisement is merely an example of many that appear regularly in our dental journals and that preclude the persons who are trained and qualified from occupying faculty positions in operative dentistry education. It seems to presage a trend toward further specialization in dental education.

I am acquainted with a large number of highly qualified and expert dental educators currently engaged in teaching operative dentistry who would not qualify to apply for this position because of the lack of a postdoctoral degree in "Restorative Dentistry." There are only a few schools with postdoctoral programs in restorative dentistry, so the supply of candidates that could qualify for this position must be scarce. When schools insist on candidates with higher degrees, some educators with good skills in operative dentistry are being excluded.

Another example I can cite occurred at the March 1978 business meeting of the Academy for Operative Dentistry. A movement to investigate the possibility of starting a specialty program in operative dentistry was initiated—in my opinion, another step in the fragmentation process of our profession.

Much as I abhor federal intervention in our professional lives, I must admit that pressures from the Department of Health, Education, and Welfare on dental education to provide more general practice residency programs may be a meaningful step in solving this vexing problem.

I believe that a sounder solution is to be found in the careful assessment of the dental school curriculum with a view toward reinstituting emphasis on general practice training with special attention given to operative dentistry.

However, the most reliable answer to the problems appears to be a significant effort to encourage dental educators to obtain advanced training in educational skills. This approach would be a means of efficiently educating students in all phases of comprehensive dental care, with emphasis on increased competence in operative dentistry. The result should be *better* teachers rather than specialized teachers.

Sincerely,

Bernard L Abrams
Assistant Professor and Chairman
Department of Comprehensive Dental Care
Case Western Reserve University
Cleveland, OH 44106

Announcements

NOTICE OF MEETINGS

American Academy of Gold Foil Operators

Annual Meeting: October 18 and 19, 1979
Baylor College of Dentistry
Dallas, Texas

Academy of Operative Dentistry

Annual Meeting: February 14 and 15, 1980
Hyatt Regency Hotel
Chicago, Illinois

Emory Dental Professor Named 1978 "Man in Dentistry" Recipient

Dr Wilmer B Eames, director of the division of applied dental materials and professor of operative dentistry at Emory University School of Dentistry, has received the 1978 Northern District Dental Society "Man in Dentistry" award.

Dr Eames is best known in the dental profession for developing an improved technique for preparing dental amalgam that is now widely accepted and taught throughout the world.

The "Man in Dentistry" award was created by the Northern District Dental Society in 1971 to recognize a member who has contributed significantly to the progress of dental health and the dental profession and who has demonstrated good citizenship by participation and effectiveness in worthwhile community affairs.

Wilmer Eames (center) receives the "Man in Dentistry" award from William H Callahan, Jr, president of the Northern District Dental Society for 1978, and Joseph W Looper (right).

CORRECTION

The editor regrets that the acknowledgment, "This study was supported in part by the National Institutes of Health, National Institute of Dental Research, Research Grant No 5–RO–1–DE–03504–08 and by the Fifth District Dental Society of Atlanta," was omitted from the following articles:

1. EAMES, W B, EDWARDS, C R & BUCK, W H (1978) Scraping resistance of dental die materials: a comparison of brands, **3**, 66–72.
2. EAMES, W B, ROGERS, L B, WALLACE, S W & SUWAY, N B (1978) Compatibility of gypsum products with hydrocolloid impression materials, **3**, 108–112.
3. EAMES, W B & MacNAMARA, J F (1978) Evaluation of casting machines for ability to cast sharp margins, **3**, 137–141.

NEWS OF THE ACADEMIES

American Academy of Gold Foil Operators

The 28th annual meeting was held 18–20 October 1978 at Barbers Point Naval Air Station and the Sheraton Waikiki Hotel in Honolulu, Hawaii. Clinical operations were demonstrated during the morning of 19 October. The president's reception and banquet featuring Oriental cuisine and Hawaiian music were held in the evening. Essays were given the following morning and the meeting concluded with a eulogy for David Grainger, past secretary-treasurer, delivered by D Alan Hays, a graduate in the first dental class at the University of Florida.

Harold and Sally Sondheim operating a tooth for a class 3 foil. Photograph courtesy of W H Gyllenberg.

On behalf of the Academy of Operative Dentistry and the American Academy of Gold Foil Operators, Dr Jose E Medina (left) presented a plaque in memory of Dr David A Grainger to Dr Don L Allen, Dean, College of Dentistry, University of Florida. Mrs Mary Grainger was present during the ceremony.

Perry and Addie Dungey preparing a cavity for a class 3 foil

Ted and Doreen Ramage condensing a class 5 foil

Alan and Hazel Osborn preparing a cavity for a class 2 foil

INSTRUCTIONS TO CONTRIBUTORS

Correspondence

Send manuscripts and correspondence about manuscripts to the Editor, Professor A. Ian Hamilton, at the editorial office: OPERATIVE DENTISTRY, University of Washington, School of Dentistry SM-57, Seattle, Washington 98195, U.S.A.

Exclusive Publication

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

Manuscripts

Submit the original manuscript and one copy; authors should keep another copy for reference. Type double spaced, including references, and leave margins of at least 3 cm (one inch). Supply a short title for running headlines. Spelling should conform to *Webster's Third New International Dictionary,* unabridged edition, 1971. Nomenclature used in descriptive human anatomy should conform to *Nomina Anatomica,* 4th ed., 1977; the terms 'canine', 'premolar', and 'facial' are preferred but 'cuspid', 'bicuspid', and 'labial' and 'buccal' are acceptable. SI (Système International) units are preferred for scientific measurement but traditional units are acceptable. Proprietary names of equipment, instruments, and materials should be followed in parentheses by the name and address of the source or manufacturer. The editor reserves the right to make literary corrections.

Tables

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

Illustrations

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

References

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

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