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The views expressed in *Operative Dentistry* do not necessarily represent those of the Academies, or of the Editors.

EDITORIAL

On Dental School Reorganization

Reorganization of dental schools continues to be the "in thing" to do in today's dental school administrative environment. At least seven dental schools have undergone restructuring during the past 5-10 years; Kentucky, Minnesota, and Michigan within the past year. The question is: What is the driving force behind this need for reorganization, and is it truly justified? Dental schools exist to train dentists to practice quality dental services, both at the pre- and postdoctoral level. Dental schools also have other missions, such as service to the university, the community, and the nation at large, as well as to conduct scholarly activities, e g, research and publication.

If we consider reorganization as an alternative to the traditional structure, where there is a department for each specialty field as well as those divisions which are not recognized specialties, we should only do so if it will enhance the primary missions of the dental school. In the standard traditional structure many, if not most, schools have 10-12 departments, each with its own chairperson. Will reorganizing and reducing the number of departments facilitate the mission?

Is the primary moving force motivating dental schools to reorganize coming from within the dental school or from administrators such as university presidents or chancellors? Several of the recent reorganizations have occurred as a result of cost-cutting measures as directed by their universities' central administration. If schools are directed to consolidate departments to reduce the number of chairpersons in order to save money with no regard for the impact on the institution, I feel that to be very wrong. From my perspective the cost-saving factor is the only justification that those outside of the dental school environment could have.

If dental school reorganization occurs as a result of forces within the school, however, there could be many benefits, but they would not necessarily save money for the parent university. Combining several departments into a few megadepartments is not all bad. If it is done logically, from within, it could facilitate communication and cooperation and enhance the school's curriculum by allowing various specialty areas with common interests to work more closely together. It is my contention that we still need to retain in these new megadepartments the separateness of each entity that previously existed in the traditional setup. In this type of an arrangement, we would see chairpersons responsible for the megadepartments, but each of the old departments would be a division and chaired by the same individual who previously chaired it. Such an arrangement would more than likely enhance the mission, but would also create another administrative layer and therefore be more costly.

The matrix organization structure recently adopted by the University of Kentucky appears to be well-thought-out and does provide for restructuring yet retention of previous departments. Time will tell, but it appears to facilitate instruction, allows sharing of resources, and should enhance the mission.

When considering reorganization, let us not do so in a manner which will minimize our effectiveness, but instead look for a structure which will allow us to grow. Nothing less should be acceptable.

DAVID J BALES
Editor

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ORIGINAL ARTICLES

The Need for Operative Dentistry Services: Projecting the Effects of Changing Disease Patterns

JOHN W REINHARDT • CHESTER W DOUGLASS

Summary

The declining incidence of caries in children and adolescents has caused speculation that there will soon be a great reduction in need for restorative services among adults. This study used recent dental epidemiological data, population estimates, and numerous alternative assumptions to calculate the hours of adult operative dentistry treatment need in the US in 1972, 1990, and 2030. According to those calculations, the total hours of need were about 125 million in 1972. In 1990 and 2030, the projected hours of need were determined to be about 150 million and 192 million, respectively.

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Introduction

The most dramatic change in oral disease in this century has been the decline in caries among children and adolescents in the US (Brunelle & Carlos, 1982; Graves & Stamm, 1985; Burt, 1985). In fact, approximal caries in 5-17-year olds declined by about 50% between surveys taken in 1971-74 and 1979-80. Mean scores of decayed, missing, and filled surfaces for the group dropped from 7.06 to 4.77 during that same period. A more recent survey showed another significant decline in scores of 5-17-year olds, with an average of about three per individual (American Dental Association, 1988). Widespread fluoridation of water supplies and toothpastes, and an increasing awareness of the importance of dental health are believed to be largely responsible for the declining prevalence of caries.

In view of the changing caries experience of young people, one might assume that there will be considerably fewer operative dentistry treatment needs for adults in the future. Although general dentists currently spend about 35% of their treatment time doing operative procedures (American Dental Association, 1987) it seems logical to conclude that there will soon be a large reduction in that proportion. Some have suggested that dental schools should alter curricula as one solution to the "problem" of declining caries and the resulting decrease in need for operative dentistry (Reed & Mann, 1983). One proposed solution is to devote considerably less training time to restorative dentistry. It has been reported that a dentist to population ratio of about 1:20 000 might be adequate to provide the needed dental care by the year 2010 (Hein, 1986).

In contrast, Douglass and Gammon (1984) used epidemiological data to project hours of operative treatment needed up to the year 2000. Those calculations indicated that total operative treatment needs would not decline, largely due to greater restorative needs among older adults. Rather, treatment needs would increase by many millions of hours. One conclusion of the study was that dental school operative curricula may require additional new coursework. Those additions would be essential to develop skills and knowledge required by changes in carious lesion size and location, the aging of the population, and the necessity to make more uncertain clinical decisions.

The purpose of the present study is to re-examine several questions concerning the effects of changes in oral disease patterns on the practice of operative dentistry. Using the most recent data, new estimates of the need for operative dentistry services are calculated and then projected using population estimates into the twenty-first century.

Methods

The formula used for calculating hours of need for operative dentistry treatment is shown in Figure 1. This equation uses the number of teeth at risk, the proportion of carious teeth, and the proportion of filled teeth per age category. In addition, it assumes an average restorative treatment time of 0.5 hours per carious tooth. This estimate was based on a national study of general practitioners conducted by the Research Triangle Institute, Research Triangle Park, NC (Nash, Douglass & Wilson, 1979). The replacement rate for restorations used in the equation is one-tenth (0.1), assuming that the average life expectancy of a restoration is 10 years. This estimate was chosen upon reviewing numerous studies which have determined 50% survival times of dental amalgams to be widely varying (Paterson, 1984; Robbins & Summitt, 1988). Estimates of 50% survival times for other popular types of restorations, such as composite resins, are not clearly established. Those estimates are unlikely to be greater than 10 years.

The number of teeth at risk in the US adult population, per age category in 1972, is shown in Table 1. The figures in Table 1 are based upon population statistics for 1972 (Bureau of the Census, 1974) and estimates of number of teeth per individual derived from the 1971-74 National

$$\mathbf{TN} = \Sigma\,[t_i \cdot c_i \cdot 0.5] + \Sigma\,[t_i \cdot f_i \cdot 0.1 \cdot 0.5]$$

TN = total hours of treatment need
t_i = age-specific number of teeth
c_i = age-specific proportion of carious teeth
0.5 = one-half hour of service time needed per restoration
f_i = age-specific proportion of filled teeth
0.1 = the proportion of restorations needing replacement in a given year

FIG 1. *Formula for calculation of hours of treatment need for operative dentistry*

Table 1. US Adult Population and Number of Teeth at Risk, 1972

Age	Functional Teeth per Individual	Estimated 1972 Population	Teeth at Risk
18-24	30.1	25 901 000	779 620 100
25-34	26.6	27 397 000	728 760 200
35-44	20.8	22 853 000	475 342 400
45-64	15.5*	42 789 000	663 229 500
65-84	7.0**	19 324 000	135 268 000
85+	3.5**	1 559 000	5 456 500
	TOTAL	139 823 000	2 787 676 000

*mean of 45-54 and 55-64 categories
**estimate, based upon 9.2 for 65-74 age group

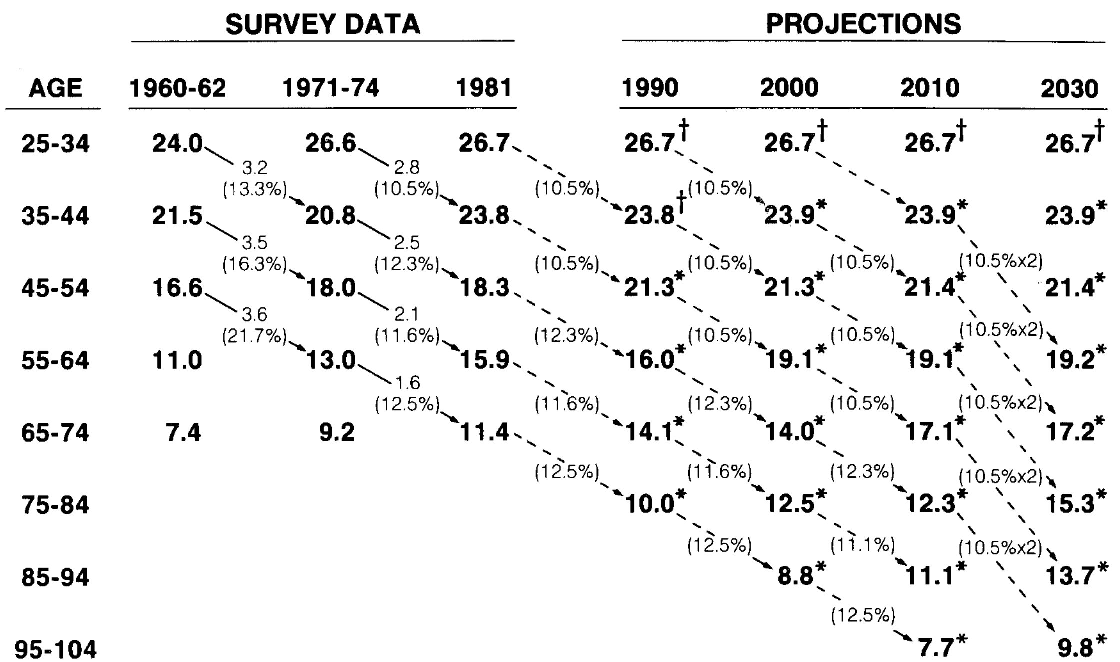
Center for Health Statistics national oral health survey (National Center for Health Statistics, 1981). The mean number of teeth per person shown in Table 2 are taken from three successive national oral health surveys, the 1960-62 (National Center for Health Statistics, 1965) and 1971-74 (National Center for Health Statistics, 1981) surveys and the 1981 survey (Brown, 1987) conducted by the Research Triangle Institute for the Health Resources and Services Administration.

Since the data in Table 2 are drawn from the same population and are separated by approximately 10-year intervals, it is possible to track specific age-group cohorts over time. The longitudinal trends in tooth loss of each cohort can be used to project the number of teeth at risk in future years. Figure 2 shows those projections in the 10-year age categories, beginning with the 25-34 group. The diagonal lines in Figure 2 trace the individual cohorts. The number and percentage of teeth lost between 1960-62, 1971-74, and 1981 are shown along the diagonals. Projections beyond 1981 are also shown in Figure 2.

It should be noted that a lower number and

Table 2. Mean Number of Teeth per Person by Age Category

	Survey		
Age	1960-62	1971-74	1981
18-24	26.8	30.1	28.4
25-34	24.0	26.6	26.7
35-44	21.5	20.8	23.8
45-54	16.6	18.0	18.3
55-64	11.0	13.0	15.9
65-74	7.4	9.2	11.4



*assumes % of teeth lost is no different than that which occurred between '71-74 and '81 surveys (no improvement)
†assumes initial count identical to 1981

FIG 2. *Actual and projected average number of teeth per age category in specific years* percentage of teeth were lost in the second 10-year survey span (1971-74 to 1981) than in the first (1960-62 to 1971-74). This finding is consistent with trends in declining rates of edentulism and partial tooth loss over that same time period. In order to project future tooth loss, it is necessary to make some assumptions about future trends. Those assumptions are:

1) The number of teeth retained by the 18-24 and 25-34 year old age groups will not improve any further. The number of teeth retained by persons in those age categories will remain the same as in 1981.

2) The rate of tooth loss for the 25-34-year age groups will continue to be what it was between 1971-74 and 1981 (10.5%).

3) The remaining cohorts will not improve their rates of tooth retention from the rates observed between 1971-74 and 1981 (even though each cohort demonstrated improvement in that decade over the previous decade). These assumptions necessarily imply that the current analysis will provide a conservative estimate of future operative needs.

Figure 2 shows the results of those projections for the years 1990, 2000, 2010, and 2030. Population estimates for 1990 and 2030 were then used to calculate the number of teeth at risk in each age group during those years. The population estimates are based upon the "middle series" assumptions of the US Census Bureau made in 1983, which are:

1) 1.9 lifetime births per woman;

2) a life expectancy increasing to 81 years for those born in the year 2080 (life expectancy is currently about 75 years in the US); and

3) an annual net immigration of 450 000 persons.

Table 3. Cohort-specific Projections of Adult Teeth at Risk in the US, 1990 (middle series population projections)

Age	Functional Teeth per Individual	Adult Population	Teeth at Risk
18-24	28.4	25 794 000	732 549 600
25-34	26.7	43 529 000	1 162 224 300
35-44	23.4	37 847 000	885 619 800
45-64	18.3*	46 453 000	850 089 900
65-84	12.1*	28 384 000	342 027 200
85+	8.2**	3 313 000	27 166 600
	TOTAL	185 320 000	3 999 677 400

*mean of adjacent categories

**assumed no different than projected for year 2000 (liberal estimate)

Table 4. Cohort-specific Projections of Adult Teeth at Risk in the US, 2030 (middle series population projections)

Age	Functional Teeth per Individual	Adult Population	Teeth at Risk
18-24	28.4	26 226 000	744 818 400
25-34	26.7	37 158 000	992 118 600
35-44	23.5	40 168 000	943 948 000
45-64	19.5*	70 810 000	1 380 795 000
65-84	15.0*	55 969 000	839 535 000
85+	10.9*	8 611 000	93 859 900
	TOTAL	238 942 000	4 995 074 900

*mean of adjacent categories

Results

Table 3 shows the data used and results of calculating the number of teeth at risk from the estimated population in 1990. Table 4 shows the results of similar calculations for 2030. There will be an increase of approximately one billion teeth at risk in US adults between 1990 and 2030. This increase is largely the result of lower rates of tooth loss and the "baby boom" generation (those born between 1946 and 1964) becoming older adults. Between 1990 and 2030 there will be a 73% increase in the number of people 45 and older and a 104% increase in those 65 and over. More importantly for operative dentistry, those 45 and older will have a total of 90% more teeth, and those 65 and over will have 153% more teeth in 2030 than in 1990.

The data for the number of teeth at risk from Tables 3 and 4 were used to calculate estimated hours of restorative treatment need in the future using the formula from Figure 1. Table 5 shows the resulting 124.9 million hours of restorative treatment needed in 1972, using 1972 population data and teeth at risk, percentage carious (c_i), and percentage filled (f_i) data from the 1971-74 survey. Table 6 shows that the projected treatment need in 1990 will be 149.6 million hours, which is a 20-million-hour increase over 1972. These calculations are based upon data from Table 3, population projections for 1990, and c_i and f_i data from the 1986 National Institute of Dental Research (NIDR) survey (National Institute of Dental Research, 1987). Likewise, Table 7 shows 192.1 million hours of treatment need in 2030, based upon population projections for 2030 and the 1986 NIDR c_i and f_i values.

Table 5. Hours of Adult Restorative Need by Age Category, 1972

Age	Teeth at Risk (millions)	% Carious Teeth (c_i)	% Restored Teeth (f_i)	Millions of Hours of Restorative Treatment Needed
18-24	779.6	6.6	22.9	37.4
25-34	728.8	6.4	33.1	35.3
35-44	475.3	5.2	39.4	21.6
45-64	663.2	4.5	39.4	27.9
65-84	135.3	3.8*	39.4[t]	5.2
85+	5.4	3.1*	39.4[t]	0.2
			TOTAL	124.9

*estimated decline in % (equal to mean % decline of younger groups)
[t]estimate (same % as previous two age groups)

Table 6. Projected Hours of Adult Restorative Need by Age Category, 1990

Age	Teeth at Risk (millions)	% Carious Teeth (c_i)	% Restored Teeth (f_i)	Millions of Hours of Restorative Treatment Needed
18-24	732.5	4.4	24.1	24.9
25-34	1162.2	3.8	31.9	40.7
35-44	885.6	2.9	44.5	32.8
45-64	850.1	2.9	55.3	35.7
65-84	342.0	2.9*	55.3[t]	14.4
85+	27.2	2.9*	55.3[t]	1.1
			TOTAL	149.6

*estimate (same as prior two age groups)
[t]estimate (same as prior age group)

Discussion

These projections of future operative dentistry need are dependent upon numerous assumptions. Changes in the assumptions could cause a marked effect on the results of the calculations. We believe that the assumptions used in this study are reasonably accurate, and rather conservative. The average replacement rate of 0.1 restorations per year (mean longevity of 10 years per restoration) is likely to be a reasonable estimate for amalgams; however, many clinicians believe the longevity of composite resins, which are used extensively, is less. Since the "middle series" population assumptions were made in 1983, the US birth rate has increased. The assumptions of tooth retention are based upon no improvement over current trends, and that represents a slightly pessimistic view of the future of oral health in the US. It may be just as likely that tooth retention rates will continue to improve. For all these reasons, the assumptions seem conservative.

There has been some criticism of the methodology used for the 1986 NIDR survey. Instead of using a randomly selected household population, that survey selected subjects who were employed. Since it is possible that the subjects chosen for the survey might have better dental health than a similar household sample, many researchers feel that the NIDR survey represents a picture of what the future dental health of the US population will resemble. With this in mind, the survey seems quite appropriate for making projections about future dental restorative needs. We used data from the NIDR survey to estimate

Table 7. Projected Hours of Adult Restorative Need by Age Category, 2030

Age	Teeth at Risk (millions)	% Carious Teeth (c_i)	% Restored Teeth (f_i)	Millions of Hours of Restorative Treatment Needed
18-24	744.8	4.4	24.1	25.3
25-34	992.1	3.8	31.9	34.7
35-44	944.0	2.9	44.5	34.9
45-64	1380.8	2.9	55.3	58.0
65-84	840.0	2.9*	55.3[t]	35.3
85+	93.9	2.9*	55.3[t]	3.9
			TOTAL	192.1

*estimate (same as prior two age groups)
[t]estimate (same as prior age group)

the proportion of carious teeth (c_i) and restored teeth (f_i) in the future.

Another consideration in determining hours of treatment need is that of effective demand. The mere presence of need does not always translate into demand for dental care, because only about 50% of US citizens have historically sought dental care on a routine basis. Effective demand does not enter in the equation upon which the comparisons in this study are based. However, there has been a general trend toward greater utilization of dental services as dental health and techniques improve. Today's society is growing increasingly health-conscious, and spending greater amounts of personal resources on dental care. The result of these factors should be an increasing demand when comparing past dental need to present and future need.

In addition to demand that is related to dental caries and replacement restorations, another demand factor for operative dentistry services has grown explosively over the past decade. That demand is for esthetic restorative services, unrelated to caries. Improvements in dental materials and techniques have dramatically affected the ability to produce esthetically pleasing dentition with conservative treatment via composite resins, porcelain veneers, and a variety of imaginative treatments. A recent survey of randomly selected dentists in the northeastern US found that they were generating about 10% of their gross practice revenues from esthetic treatment of noncarious teeth (Reinhardt, Capilouto & Padgett, 1988). That demand for esthetic treatment was virtually nonexistent in the early 1970s, and is most certainly here to stay.

The basic change of increasing numbers of older teeth at risk in the US will result in a different type of operative treatment. The older members of the "baby boom" generation (born between 1946 and 1955) did not benefit from the early application of topical fluorides, sealants, and fluoridated water supplies. Consequently, many in this large group now have complex restorations which require continuous monitoring for recurrent caries or material failures. Previously, a significant proportion of these teeth would have been extracted over time as periodontal disease or increasingly complex restorative treatment needs made extraction a reasonable alternative. Today, and in the future, preservation of many of these teeth is likely because of improved treatment modalities and patient dental health attitudes. The restorative dentist will be challenged to maintain older teeth through complex restorations, often in areas of difficult treatment access (i e, root-surface lesions).

The impact of these demographic, epidemiological, and technological changes on operative dentistry will be great. Adult patients (especially older adults) will present a volume and variety of restorative treatment needs unlike ever before seen in the US. The practice and teaching of operative dentistry will become more challenging, and will certainly require increasing time, effort, and skills. Research must continue to be directed toward improvement of materials and techniques for restoration of teeth in older adults.

Conclusions

There are many reasons, related both to

demographics of the US population and the epidemiology of dental diseases, to project an increase in operative dental needs over the next 40 years. The specific calculations in this study predict an increase of about 65 million hours of annual restorative treatment need in the year 2030, when compared to 1972. Those calculations indicate that in 1990, 20% more hours of need for operative dentistry treatment will exist for persons 18 years and older than existed in 1972. For the year 2030, calculations indicate there will be 54% more hours of need than in 1972.

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Editor's note:

This paper was felt to be of exceptional importance and was moved forward in the print-list to ensure early dissemination of this information.

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Retentive Pin Systems: a Laboratory Comparison of Effectiveness of Seating and Other Characteristics

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Summary

An evaluation in vitro of a number of currently available pin systems used for retaining direct restorative materials was made in this study. The criteria used for evaluation of the systems were completeness of pin seating in the prepared channels and overall effectiveness of the design of the shoulder-stop-style pins. There was a wide range of difference in the ability to seat pins completely, and the seating of the shoulder-stops on the dentin floor was quite inconsistent.

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Introduction

Several pin systems used to enhance retention of the various restorative materials have been evaluated by a number of investigators over the years. Methods of investigation and results have varied, but depth of penetration and damage to surrounding tooth structure have been some of the main issues.

Barkmeier, Frost and Cooley (1978) found that a TMS Minim single pin placed with a hand wrench reached the maximum depth, and backing it off slightly might create less stress on surrounding dentin. This was corroborated by Irvin and others (1985). In another study, Barkmeier and Cooley (1979) found a great amount of discrepancy in the length of the cutting portion of a 2-mm self-limiting twist drill. They noted that self-shearing pins often sheared off before reaching the bottom of the pin channel. Several pin systems were studied, and they noted that pins placed with the Auto Klutch contra angle were not consistent, possibly due to the pressure necessary in placement. Currens, Korostoff and von Fraunhofer (1980), on the other hand, suggested that mechanical placement was more effective than use of a hand wrench. They agreed that the nonshearing pins seated more completely than the self-shearing variety. The point was made that retention was directly proportional to the penetration depth. Webb, Straka and Phillips (1986) found that unthreading fully seated pins slightly did not reduce retention.

Some investigators calculated the depth of penetration by measuring the pin before placement, the length of the cutting portion of the twist drill, and the portion of pin protruding from the tooth (Barkmeier & others, 1978; Barkmeier & Cooley, 1979; Schaefer & Reisbeck, 1981; Van Nieuwenhuysen & Vreven, 1985a). Others sectioned the specimens vertically along the pin and measured the remaining space using a microscope (Currens & others, 1980; Garman & others, 1980; Collard & others, 1981; Kelsey, Blankenau & Cavel, 1983).

There is a lack of agreement as to whether there is an advantage to having pins reach the base of the pinhole (Perez, Schoeneck & Yanahara, 1971; Barkmeier & others, 1978; Barkmeier & Cooley, 1979; Schaefer & Reisbeck, 1981; Van Nieuwenhuysen & Vreven, 1985b). If 2 mm seems to afford the optimum retentive advantage (Barkmeier & Cooley, 1979), it may be best for pins to seat completely.

Manufacturers have more recently developed pins with shoulder-stops to afford a more positive seating on the dentin floor with a concurrent shearing of the pin. Marshall, Porter and Re (1986) showed that crazing occurred when pins reached the bottom consistently, with or without shoulder-stops, and stops were not as effective as advertised.

The purpose of this study was to evaluate several different pin systems relative to depth of penetration, adaptation to the channel wall, seating of the shoulder-stop, and possible deleterious effects caused during placement.

Materials and Methods

Sixty caries-free,,extracted human molars, stored in tap water prior to evaluation and kept wet when not in use, were used in this study.

Teeth were stained with silver-nitrate solution as per the method described by Durkowski and others (1982) in order to determine the existence of cracks or other defects prior to pin placement. Next, they were imbedded in blocks of tray acrylic resin, and crowns were reduced to within 2 mm of the cementoenamel junction using a 240-grit emery low-speed rotating wheel (Buehler Ltd, Evanston, IL 60204) under running water.

Four pin locations were developed on the flat dentin surface of each tooth, at the approximal angles, approximately 1-1.5 mm inside the dentinoenamel junction (Fig 1). A starting-point dimple was made with a #1/4 round bur, prior to drilling

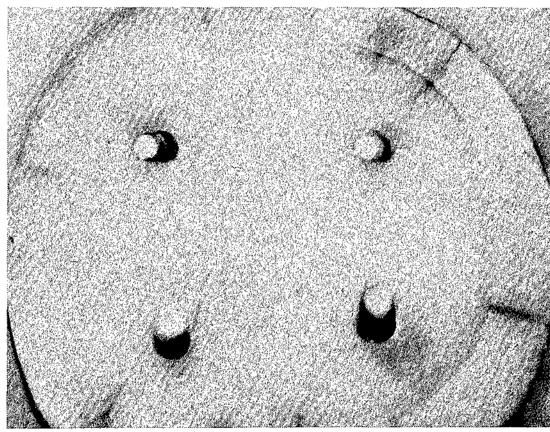

FIG 1. *Ground molar crown with pins placed at four line angles 1-1.5 mm inside DEJ (X2.5)*

holes. There were six groups of 10 teeth each, with four different pins to be placed in each tooth, for a total of 24 different pins. Each block was numbered, and a notch was cut in the edge to identify the starting pin of the group. Holes were drilled and pins placed in counterclockwise order, designated A, B, C, and D.

Specimens were hand held on a bench top, without regard to exact parallelism, to most closely resemble the clinical situation. Holes were drilled using a low-speed handpiece, according to manufacturers' instructions (Brasseler employs a specially designed small-head contra angle for drilling and pin placement). All holes were drilled by one operator, aligning the twist drill parallel to the external surface of the tooth.

The 24 different pins evaluated in this study are described in Table 1. The Brasseler (Brasseler, USA), Bondent (Whaledent), and TMS Link Plus series (Whaledent) all employ a shoulder-stop to prevent overseating of the pins. The various pins are depicted in Figure 2.

Due to inconsistency from drill breakage and pin placement of Brasseler's Regular series, 10 more teeth were prepared, using the Short series.

All pins were placed by one operator, using a hand wrench for the TMS nonshearing pins, the attached hand wrench for the Reten pins (Star Dental), the manufacturer's handpiece for the Brasseler pins, and the Whaledent 10:1 gear reduction handpiece for all others (Fig 3.)

Two weeks after pin placement, specimens were soaked for one minute in a 3% solution of phenol red dye containing 0.1% Triton X-100 (Fischer Scientific Co, Chemical Mfg Div, Fair Lawn, NJ 07410). Teeth were rinsed under running tap water to remove excess dye, and the surface dried with an air syringe. The surface was evaluated under an optical microscope (X20) to determine the existence of cracking or other modification of tooth structure. Damage was

Table 1. Pins Evaluated

PIN	TYPE	DIAMETER (inches)
Stabilok (Fairfax Dental, Inc, Coral Gables, FL 33134)	medium: stainless steel (SS), titanium (Ti)	0.030
	small: stainless steel (SS), titanium (Ti)	0.024
Brasseler Microdontic Pin System (Brasseler USA, Inc, Savannah, GA 31419)	#1	0.017
	#2	0.020
	#3	0.022
	#4	0.027
Reten (Star Dental-Syntex Corp, Valley Forge, PA 19482)		0.028
Thread Mate Systems (TMS) (Whaledent International, New York, NY 10001)	Bondent	0.021
	Minim: nonshear, Link single (S), Link double (D1 & D2), Link Plus single (S), Link Plus double (D1 & D2)	0.024
	Regular: nonshear, Link single (S), Link double (D1 & D2), Link Plus single (S), Link Plus double (D1 & D2)	0.031

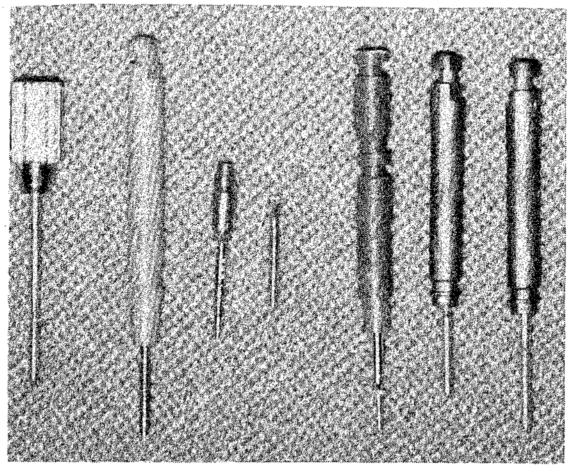

FIG 2. *Pins evaluated (left to right): Reten, Stabilok, Brasseler, TMS nonshearing, Bondent, TMS Link, TMS Link Plus (single shear)*

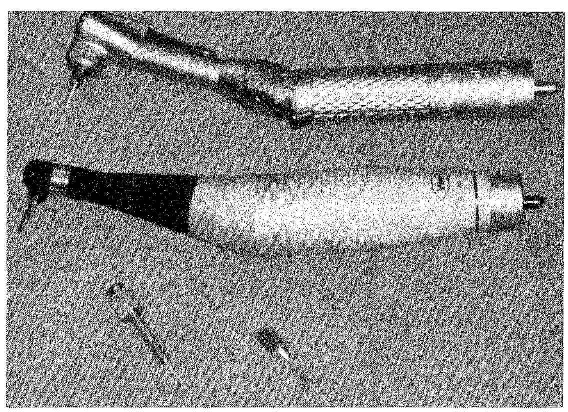

FIG 3. *Top: Auto-Klutch handpiece, Center: Brasseler handpiece, Lower left: TMS hand wrench, Lower right: Reten pin*

rated as none, slight, moderate, or extensive.

Next the resin blocks were removed and teeth were reduced parallel with the long axis of the pinhole, on a low-speed rotating wheel, using 240-grit emery abrasive (Buehler Ltd) with water.

Using a binocular microscope with a filar grid (American Optical, Buffalo, NY 14215), several measurements were made: the distance from the base of the shoulder to the dentin surface, the distance from the end of the pin to the base of the pinhole, the length of drills (self-limiting), and the length of pin extending below the shoulder stops. With a micrometer, a random sampling of each type of drill and pin were measured to determine the actual diameters.

Specimens were examined and representive photographs taken using a metallograph (Neophot 21, Leco Corp, St Joseph, MI 49085) with magnifications ranging from X20 to X32.

Results

The effect of pin-diameter mismatch with the corresponding drill and related damage to dentin is shown in Table 2. There was no cracking apparent, but a number of compressive or crushing defects appeared after staining.

The effectiveness of pin seating as related to the mismatch of pin and drill diameter is seen in Table 3. Pins were rated as being either fully seated, less than 0.5 mm short, or more than 0.5 mm short of the pin-channel base. Since many drills broke and pins sheared in the original group of Brasseler specimens, the values shown reflect the replacement shorter drills and pins, though diameters remained the same.

Differences in pin- versus drill-length, and discrepancies in reaching the bottom of the pinhole versus seating of shoulder-stops is shown in Table 4. As can be seen, drill lengths were consistently longer than the pin portion below the shoulder, yet there was a wide discrepancy in effectiveness of shoulder-stops.

A comparison of effective seating of shoulder-stop-type pins is shown in Table 5. Even those pins that seated fully in the pin channel did not consistently prove to rest on the shoulder-stops. Also, a number of the specimens' shoulder-stops were overseated.

It is obvious, as seen in Table 6, that a majority of the specimens could not have seated on shoulder-stops, as there was not adequate space remaining to the base of the pin channel to allow it.

Table 2. Mismatch of Pin Size Related to Tooth Damage

Type of Pin	Drill Diam*	Pin Diam*	Mismatch*	Damage**
Stabilok Med SS	.0265	.0290	.0025	1.3 ± 1.25
Stabilok Med Tit	.0268	.0304	.0036	1.1 ± 0.88
Stabilok Sm SS	.0215	.0240	.0025	0.7 ± 0.82
Stabilok Sm Tit	.0215	.0236	.0021	1.6 ± 1.17
Brasseler #1	.0150	.0174	.0024	0.7 ± 1.06
Brasseler #2	.0168	.0198	.0030	0.6 ± 1.07
Brasseler #3	.0190	.0223	.0033	0.67 ± 0.58
Brasseler #4	.0215	.0273	.0058	1.14 ± 0.90
Bondent	.0170	.0210	.0040	1.3 ± 1.25
Reten	.0230	.0280	.0050	1.6 ± 1.07
TMS Regular	.0270	.0305	.0035	1.1 ± 1.1
TMS Link Reg S	.0270	.0301	.0031	1.1 ± 1.1
D1	.0270	.0301	.0031	1.4 ± 0.84
D2	.0270	.0299	.0029	1.3 ± 0.95
TMS Link Plus Reg S	.0272	.0300	.0028	1.0 ± 0.47
D1	.0271	.0306	.0035	1.0 ± 0.00
D2	.027 1	.0306	.0035	1.0 ± 0.00
TMS Minim	.0208	.0230	.0022	1.4 ± 0.84
TMS Link Minim S	.0210	.0233	.0023	1.5 ± 0.85
D1	.0212	.0235	.0023	1.0 ± 0.94
D2	.0212	.0234	.0022	1.4 ± 1.17
TMS Link Plus Min S	.0210	.0240	.0030	1.3 ± 0.67
D1	.0211	.0241	.0030	1.7 ± 0.95
D2	.0211	.0240	.0029	1.3 ± 0.67

* Value in inches
** None = 0, slight = 1, moderate = 2, extensive = 3

Discussion

Specimens were drilled and pins placed without regard for exact parallelism, using a hand-held, contra angle handpiece. This is most closely related to pin placement as it is routinely done during clinical treatment.

While drilling holes for the Brasseler Regular system, the drill would break before the completion of 10 pinholes. The larger diameter drills would not allow more than two or three holes to be made without breakage. The length of these drills and pins was thought to be excessive prior

Table 3. Seating Effectiveness Compared to Drill/Pin Mismatch

Type of Pin	Mismatch*	% Mismatch	# of specimens and discrepancy: Flush	<.5 mm	>.5 mm
Stabilok Med SS	.0025	9.43	1	--	9
Stablilok Med Tit	.0036	13.43	1	2	7
Stabilok Sm SS	.0025	11.63	--	4	6
Stabilok Sm Tit	.0021	9.77	8	2	--
Brasseler #1	.0024	16.00	6	4	--
Brasseler #2	.0030	17.86	6	4	--
Brasseler #3	.0033	17.37	8	2	--
Brasseler #4	.0058	26.98	2	5	3
Bondent	.0040	23.53	--	4	6
Reten	.0050	21.74	2	4	4
TMS Regular	.0035	12.96	7+	2	--
TMD Link Reg S	.0031	11.48	8	2	--
D1	.0031	11.48	9+	--	--
D2	.0029	10.74	9+	--	--
TMS Link Plus Reg S	.0028	10.29	10	--	--
D1	.0035	12.92	10	--	--
D2	.0035	12.92	10	--	--
TMS Minim	.0022	10.58	10	--	--
TMS Link Minim S	.0023	10.95	10	--	--
D1	.0023	10.85	9	1	--
D2	.0022	10.38	8	2	--
TMS link Plus Min S	.0030	14.29	10	--	--
D1	.0030	14.22	8	2	--
D2	.0029	13.74	10	--	--

* Values in inches, ** Values in mm, + = Pulp perforation

Table 4. Shoulder Pins

Type of Pin	Drill Length*	Pin Length*	Difference*	Pinhole Discrep*	Shoulder Discrep*
Brasseler #1	1.73	1.46	0.27	6 = 0 4 = <.5	0.21 ~ .09
Brasseler #2	2.32	2.03	0.29	6 = 0 4 = <.5	0.66 ~ .24
Brasseler #3	2.60	2.32	0.28	8 = 0 2 = <.5	0.36 ~ .17
Brasseler #4	2.93	2.55	0.28	2 = 0 5 = <.5 3 = >.5	0.71 ~ .40
Bondent	1.88	1.54	0.34	4 = <.5 6 = >.5	0.58 ~ .21
Link Plus Reg S	2.24	2.17	0.07	10 = 0	0.18 ~ .09
Link Plus Reg D1	2.28	2.19	0.09	10 = 0	0.43 ~ .15
Link Plus Reg D2	2.28	2.12	0.16	10 = 0	0.18 ~ .11
Link Plus Min S	2.32	2.12	0.20	10 = 0	0.10 ~ .00
Link Plus Min D1	2.34	2.20	0.14	8 = 0 2 = <.5	0.16 ~ .05
Link Plus Min D2	2.34	2.18	0.16	10 = 0	0.20 ~ .00

* Values in mm

Table 5. Shoulder Seating Discrepancy

Type of Pin	Flush	Discrepancy #	Discrepancy Mean* & SD	Buried
Brasseler #1	4	4	0.21 ~ 0.09	2
Brasseler #2	2	8	0.66 ~ 0.24	--
Brasseler #3	1	9	0.36 ~ 0.17	--
Brasseler #4	--	10	0.71 ~ 0.40	--
Bondent	--	10	0.58 ~ 0.21	--
Link Plus Reg S	2	8	0.18 ~ 0.09	--
Link Plus Reg D1	6	4	0.43 ~ 0.1	--
Link Plus Reg D2	2	5	0.18 ~ 0.11	3
Link Plus Min S	3	2	0.10 ~ 0.00	5
Link Plus Min D1	5	5	0.16 ~ 0.05	--
Link Plus Min D2	4	2	0.20 ~ 0.00	4

* Values in mm

Table 6. Comparison of Shoulder Discrepancy and Touching Bottom

Type of Pin	Shoulder Mean Discrepancy	Effect*	Bottom Mean Discrepancy
Brasseler #1	0.21mm	-	0.4
Brasseler #2	0.66	+	0.4
Brasseler #3	0.36	+	0.2
Brasseler #4	0.71	+	0.5
Bondent	0.58	-	1.6
Link Plus Reg S	0.18	+	0.0
D1	0.43	+	0.0
D2	0.18	+	0.0
Link Plus Minim S	0.10	+	0.0
D1	0.16	-	0.2
D2	0.20	+	0.0

*Effect: - = shoulder could have seated, + = shoulder couldn't seat to their placement--the shortest is 2.25 mm long and the longest is 3.90 mm long. Since the accepted optimum length for retention has been placed at 2 mm, these lengths seemed excessive. The length, coupled with the mismatch in diameter with respect to drill and pin, doomed this group to failure. Also, the excessive length of the manufacturer's miniature handpiece was somewhat unwieldy and may have contributed to the lack of success in placement. Changing to the "Improved" drill, which was shorter, pin channels could be completed, allowing placement of pins.

The results of the present study agree with the findings of others that many pins do not reach the bottom of the pinhole (Barkmeier & Cooley, 1979; Currens & others, 1980; Garman & others, 1980; Schaefer & Reisbeck, 1981; Van Nieuwenhuysen & Vreven, 1985b). In cases of slight discrepancy, this probably does not affect retention to any degree, but when this discrepancy amounts to one fourth or more of the total length, the effectiveness is questioned. It seems likely that there is probably some stress at the base of the pinhole when pins are fully seated, but also it is possible that in time there may be a relaxation of the resultant strain on the dentin and the subsequent formation of secondary dentin. Backing the pin off slightly may reduce the stress at the base of the hole, but this may be complicated when using pins that shear, or are placed with a handpiece.

Placement method did not seem to matter as much as the type of pin. In most cases, as the percentage mismatch in drill and pin increased beyond 15%, the effectiveness of seating decreased. When the difference was over 20%, seating was very inconsistent. In the case of Stabilok pins, the titanium variety was more effective than the stainless steel, but as the pin diameter increased, the consistency of seating decreased.

With the shoulder-stop pins, length of drill was always adequate to allow the shoulder to touch the dentin, without having the pin bottom out, but as is seen in Table 6, this was not consistent. This would indicate that pinholes were not always drilled to the full length of the limiting drill. If this occurs in a laboratory situation with direct vision, it is also likely to occur in the clinical situation. As can be seen in Figure 4, some shoulders would not have been able to reach the dentin surface. In comparison, the pin in Figure 5 is not seated completely, with the shoulder in proper position. The pin in Figure 6, on the other hand, has not reached the base of the channel, but the shoulder has gone beyond the surface of the dentin.

There is a considerable variation in the adaptation of pin to pinhole. Some threads barely touch the walls of the channel (Fig 7), while others seem to engage the dentin securely (Fig 8). The shape of the pin tip as related to the drill tip varies considerably. This means that a flat-bottomed pin could not fully reach the bottom of a tapered or pointed pinhole. The optimum would appear to resemble a closer match with both (Fig 9).

An interesting point was noted in regard to pulp communication. Even with an experienced operator using a careful touch to place the pinholes, greater than 5% exhibited some degree of pulp exposure. In most cases, this was a lateral communication, and did not involve the obvious feel of "sinking" into the pulp while drilling or placing the pin (Fig 10). This raises the question regarding the frequency of pulp exposures which go unnoticed on a regular basis.

Conclusions

Several available pin systems have been evaluated for effectiveness in design relative to seating in the pinhole and shoulder-stops to prevent overseating.

1. Many pins do not seat fully in the pinhole, but TMS pins, including the Link and Link Plus series, are the most consistent, the second half of the two-in-one variety seating as well as the first.
2. In this study, it seemed to make little difference whether pins were placed by hand or mechanical means.
3. When the diameter mismatch between pin and drill exceeds 15%, pins are not likely to seat fully.
4. Pins with shoulder-stops do not consistently accomplish their intended purpose, so may be of questionable value.

Pins serve a real purpose, and should be used with discretion where indicated. One should consider the advantages of the various pin systems available and employ the type which most effectively solves the restorative problem.

(Received 17 February 1988)

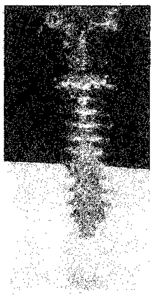

FIG 4. *Typical Bondent pin, incompletely seated with shoulder-stop outside of possible seating range (X12)*

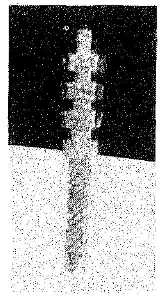

FIG 5. *Brasseler #1 pin seated securely with shoulder-stop on dentin surface (X8)*

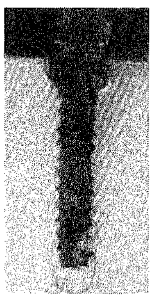

FIG 6. *Brasseler #1 pin with shoulder-stop buried in dentin, short of channel base (X12)*

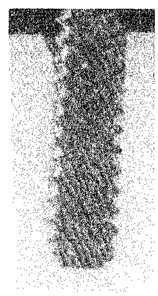

FIG 7. *TMS Link regular pin demonstrating mismatch in channel and pin diameters (X12)*

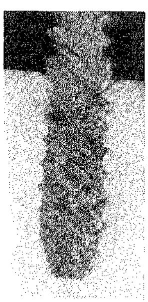

FIG 8. *TMS Link Plus regular pin closely fit and fully seated, with shoulder-stop resting on dentin (X12)*

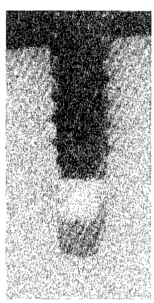

FIG 9. *Stabilok medium stainless-steel pin short of channel depth (X12)*

FIG 10. *Example of a lateral perforation, though pin was seated securely in channel (X12)*

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Repair Bond Strength of Glass-ionomer Restoratives

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Summary

The repair bond strength of three different brands of glass-ionomer restorative was tested over time. In this laboratory study, immediate repair of glass ionomer was possible with all three brands; however, over time the repair bond strengths decreased at different rates for the different materials.

Introduction

Since Wilson and Kent introduced glass-ionomer cement in 1971, the use of this material has increased dramatically (Matson, 1986). Due to its ability to chemically bond to dentin (Craig, 1985; Council on Dental Materials, 1987), glass ionomer has been advocated as a direct restorative material, especially in class 5 preparations (McLean, 1984, 1986; Mount, 1986). As with other direct restorative materials, it is sometimes necessary to repair glass-ionomer restorations due to inadequate placement, overfinishing, or fracture. Therefore, the question of whether glass ionomer can be repaired is of major clinical significance. The purpose of this study was to examine the repairability of glass-ionomer restorative materials over time.

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Materials and Methods

The following three materials were evaluated for repairability: Ketac-Fil and Ketac-Silver (ESPE/Premier, Norristown, PA 19404) and Fuji II (G-C International Corp, Scottsdale, AZ 85260). The glass-ionomer cements were mixed according to the manufacturers' instructions and inserted into aluminum blocks which contained "wells" 8 mm in diameter and 4 mm deep. Glass plates were placed over the cement and removed after the initial set. The specimens were coated with Ketac Varnish (ESPE/Premier) and stored at 37 °C in distilled water. The materials were then examined for repairability at 30 minutes, 24 hours, seven days, one month, two months, and three months. Five specimens of each material for each time period were prepared. After aging for the specified time period, new material of the same brand was added to the original material

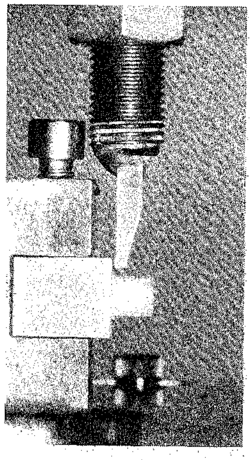

FIG 1. *Shear blade and repaired specimen*

using cylindrical teflon molds 5 mm (inside diameter) by 8 mm in height. Prior to the repair procedure, the surface of the glass-ionomer specimens was dressed with 600-grit silicon carbide paper under a continuous flow of water. The teflon mold with the repair material was placed perpendicular to the original glass-ionomer surface and allowed to set. All exposed glass-ionomer material was coated with Ketac Varnish. The repaired specimens were then stored at 37 °C in distilled water for 24 hours. Following the storage period, the shear bond strengths of the repaired specimens were determined using an Instron Universal Testing Machine (Instron Corporation, Canton, MA 02021). A shear blade was placed flush with the surface of the repaired specimen (Fig 1) and a crosshead speed of 0.5 mm/minute was used to shear off the cylinder of repaired cement. Data were analyzed using a two-way analysis of variance followed by a Student-Newman-Keuls test.

Results

The results of the five shear bond tests in each group were averaged. The mean shear bond strengths are shown in Figure 2. Initially, the materials were tested at 30 minutes, 24 hours, seven days, and three months. Since there was

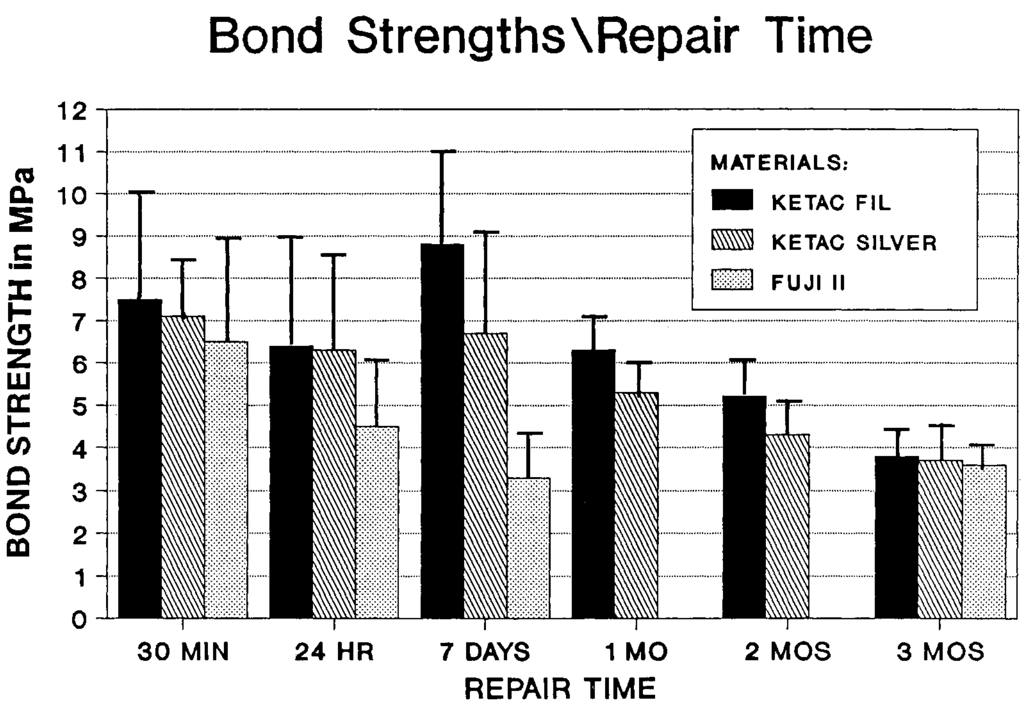

FIG 2. *Mean shear bond strengths*

no change in the values for the seven-day and three-month Fuji II samples, the Fuji II was omitted in the one-month and two-month test periods. Significant differences ($P < .05$) between time periods are illustrated in the table.

Differences between Time Periods

KETAC-FIL		KETAC-SILVER		FUJI II	
Group 3	8.8	Group 1	7.1	Group 1	6.5
1	7.5	3	6.7	2	4.5
2	6.4	2	6.3	3	3.3
4	6.3	4	5.3	6	3.6
5	5.2	5	4.3		
6	3.8	6	3.7		

Brackets illustrate similar values ($P < .05$)
Group 1 - 30-minute repair
Group 2 - 24-hour repair
Group 3 - seven-day repair
Group 4 - one-month repair
Group 5 - two-month repair
Group 6 - three-month repair

Discussion

In the Ketac-Fil and Ketac-Silver specimens, bond failures at 30 minutes, 24 hours, and seven days were cohesive with failure occurring in the original cement (Fig 3). The Ketac-Fil also demonstrated cohesive failure at one month, while the Ketac-Silver demonstrated a mixed cohesive/adhesive pattern of failure. The two-month and three-month specimens of both Ketac products demonstrated mixed cohesive/adhesive fractures (Fig 4). With Fuji II, a cohesive failure was found at 30 minutes. At 24 hours, seven days, and three months, combination cohesive/adhesive failure occurred.

The repair strength of all three materials at each repair time was greater than or equal to the tensile bond strength of these materials to dentin. Aboush and Jenkins (1986) reported a bond strength to dentin of 2.77 MPa for Ketac-Fil and 3.11 MPa for Fuji Type II. Their reported bond strength to enamel for Ketac-Fil was 6.1 MPa, which was less than the repair bond strengths of the 30-minute, one-day, seven-day, and one-month groups in this study. For Fuji Type II, Aboush and Jenkins (1986) reported an enamel bond strength of 4.2 MPa, which was less than the 30-minute and one-day repair strengths in this study.

In the Ketac-Fil, the repair bond strength compared to the 30-minute repair strength decreased 15% at 24 hours, increased 17% at seven days, and progressively decreased to 51% at three months. In the Ketac-Silver, the repair bond strength compared to the 30-minute repair strength decreased 11% at 24 hours, 6% at seven days, and progressively decreased to 52% at three months. In the Fuji II, the repair bond strength compared to the 30-minute repair strength decreased 31% at 24 hours and 49% at seven days. The repair bond strength was approximately the same at seven days and three months.

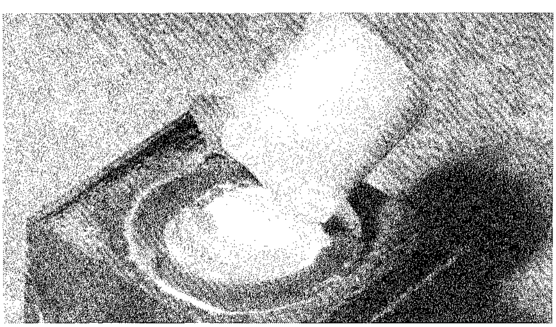

FIG 3. *Cohesive failure of Ketac-Fil at seven days*

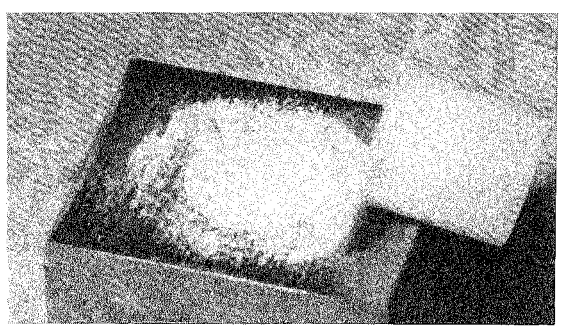

FIG 4. *Predominantly adhesive failure of Ketac-Silver at two months*

Conclusion

Based on the results of this study, it appears that the repair of glass-ionomer restorative materials, in vitro, is possible; however, the success of this procedure may vary between different commercial brands of glass ionomer used. At one month the repaired Ketac-Fil demonstrated cohesive failure in the original specimen, indicating that the bond strength of the repair was as strong as the original material. In the Ketac-Silver repair, failure was cohesive at seven days but became mixed cohesive/adhesive at one month. With Fuji II, a cohesive failure was only observed at the 30-minute repair.

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Surface Characteristics of Glass-ionomer Cements when Treated with Cavity Varnish

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TRAVIS J TAYLOR

Summary

Two glass-ionomer cements were evaluated. Sixty molds were prepared, 20 with a lining cement, 20 with a base cement, and 20 with a control cement. The samples were tested for hardness; the glass-ionomer materials proved to be significantly harder than the control.

Introduction

Although there is no consensus in their use, insulating bases and cavity varnishes are often recommended for use under amalgam in certain clinical conditions (Sturdevant & others, 1985; Yates, Murray & Hembree, 1980). ZnOE (zinc oxide and eugenol) and CaOH (calcium hydroxide) materials are being used for insulating purposes with cavity varnish despite the fact that studies show this combination increases microleakage in the completed amalgam restoration (Larson & others, 1979); however, the value of cavity varnish beneath dental amalgams in the reduction of microleakage and postoperative sensitivity has been well documented (Andrews & Hembree, 1975; Council on Dental Materials, 1972). Some authors have suggested that varnish should not be applied to ZnOE and CaOH bases when varnishing adjacent dentinal and enamel walls in a cavity preparation (Silva & others, 1985; Ben-Amar & others, 1985). Practically, this is difficult if not impossible to do, considering the small size of a cavity preparation and the low viscosity of cavity varnish.

Recently a number of glass-ionomer cements have become available in the forms of liners and bases. Glass-ionomer cements have properties that would seem to recommend them as good base materials: they are biocompatible with the pulp, they have the ability to bond to dentin, they leach fluoride ions, and they have a reasonably short setting time with some formulations. Unfortunately, product information pamphlets accompanying these materials do not address the use of cavity varnishes. Instead, they describe how these materials may be acid-etched and their compatibility with composite resins. Studies by Larson and by Silva, cited above, support the proposition that there is a relation between the surface softening of base materials by cavity varnish and microleakage in the completed

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amalgam restoration.

The purpose of this paper is to examine the surface changes of a glass-ionomer liner and a glass-ionomer base when treated with cavity varnish. A reinforced ZnOE-cement material frequently used as an insulating base under amalgam restorations is used as a control in this study.

Materials and Methods

Two glass-ionomer cements were evaluated in this study, G-C Lining Cement (G-C International Corp, Scottsdale, AZ 85260) and GlasIonomer Base Cement (Shofu Dental Corp, Menlo Park, CA 94025). The control material was a reinforced ZnOE cement, IRM (L D Caulk Co, Milford, DE 19963). The varnish used was Copalite (Harry J Bosworth Co, Skokie, IL 60076), a widely used copal varnish. Sixty samples were prepared in cylindrical stainless-steel molds, 1 mm thick by 5 mm in diameter. Twenty molds were filled with glass-ionomer lining cement, 20 with the glass-ionomer base cement and 20 with the reinforced ZnOE. The cements were mixed according to the manufacturers' instructions. A smooth surface for testing was obtained by compressing the material in the molds between two glass slabs. The samples were removed from the slabs upon setting per the manufacturers' instructions. The materials were allowed to set for one hour. Ten samples from each group were painted with two coats of cavity varnish in the manner recommended for clinical use.

The samples were tested using a microhardness tester (Model DMH-2, Clark Instruments, Ann Arbor, MI 48103). The Knoop hardness test was applied with a diamond indenter set at 10 grams of force for 15 seconds, and each specimen was tested at three different surface sites. The three readings were averaged to give a hardness value for each sample subset.

Results

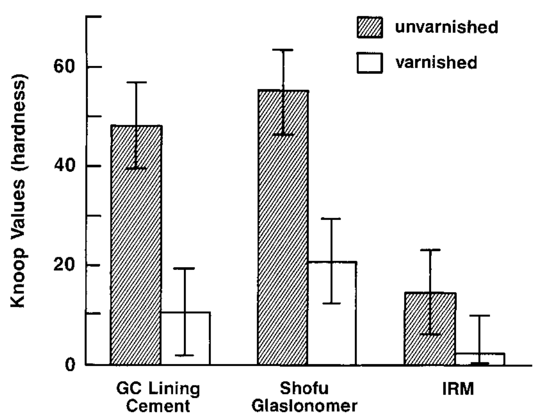
Knoop values for the three materials in their varnished and unvarnished conditions were compared using a two-way analysis of variance (ANOVA) with replication. Results show that differences in hardness among the materials are highly significant ($P < .001$), as are differences among the varnished samples (table). The interaction between bases and varnish also reveals significant differences ($P < .01$). Further analysis was carried out using comparison intervals based on the T-method (Sokal & Rohlf, 1981) for multiple comparisons among pairs of means from populations with equal sample sizes (figure). By

Two-way ANOVA with Replication Comparing Bases, Varnished Bases, and the Interaction between These Two Groups

Source of Variation	SS	DF	MS	F
A (varnish)	12101.52	1	12010.51	71.42***
B (base)	9244.34	2	4622.17	27.48***
A x B	1892.85	2	946.43	5.63**
ERROR	9081.39	54	168.17	
TOTAL	32229.11	59		

***A $P < .001$
***B $P < .001$
**A x B $P = .006$

SS = sum of squares, DF = degrees of freedom, MS = mean square, F = F distribution value



Comparison intervals by the T-method for the hardness (Knoop value) means of varnished and unvarnished base materials. Means whose intervals do not overlap are significantly different (P < 0.05).

using the T-method, it can be determined which of the sample means are different from the rest. Accordingly, results show that there are no differences in hardness between unvarnished G-C Lining Cement and Shofu GlasIonomer Base samples, but the hardness of IRM is significantly less. Comparison intervals of the varnished bases show a hardness continuum with Shofu GlasIonomer Base the hardest, G-C Lining Cement next, and IRM last. The glass-ionomer materials are significantly harder than the IRM, but the G-C Lining Cement interval overlaps the other two groups.

In each case, the application of varnish to the bases reduced the mean surface hardness; however, only the G-C Lining Cement and the Shofu GlasIonomer Base showed a significant difference when the varnish was added. This was not true for the IRM where comparison intervals overlapped between varnished and unvarnished sample populations.

Discussion

Two other base materials were considered for use as a control in this experiment, zinc-phosphate cement and CaOH liner. Zinc-phosphate cement was widely used in the past as an insulating base under amalgam restorations. It presented a problem for use in this experiment because a smooth surface sample could not be obtained with a base consistency mix of the material. CaOH liners such as Dycal (L D Caulk Co) and Life (Kerr-Sybron Co, Romulus, MI 48174) were not used because the sticky surface presented a testing problem with the microhardness penetrator.

The surface hardness of both glass-ionomer materials was harder than the ZnOE cement. When cavity varnish is applied, there is a significant reduction in surface hardness in both of the glass-ionomer materials. The surface hardness of the ZnOE cement before and after treatment with cavity varnish was less affected than the other two materials and not significantly changed.

Conclusions

From the results of this experiment, the following conclusions may be drawn:

1. The glass-ionomer liner and bases tested showed significantly greater surface hardness than the reinforced ZnOE cement.
2. The glass-ionomer liner and base showed a significant reduction in hardness when cavity varnish was applied.
3. The treatment of the reinforced ZnOE cement did not result in a significant reduction in surface hardness.
4. Microleakage studies in glass-ionomer-based amalgam restorations treated with cavity varnish should be conducted to determine their suitability as an insulating base.

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The Retention of Titanium Pins in High-copper Amalgam and Their Influence on Its Fracture Resistance

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Summary

In this study, the influence of titanium pins on the fracture resistance of amalgam and the retention of amalgam by titanium pins were compared to that of stainless-steel pins. The retention of stainless-steel pins embedded in amalgam to various depths was also evaluated.

None of the pins had a significant influence on the compressive fracture resistance of amalgam. All pins embedded to standard depth in amalgam failed in tension, with titanium pins demonstrating the lowest resistance to tensile forces. Stainless-steel pins embedded 1.75 or 1.5 mm and loaded in tension caused failure in the amalgam, but at forces comparable to the retention of such pins in dentin.

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INTRODUCTION

Stainless-steel pins are widely used to enhance the retention and resistance of extensive amalgam restorations. Recently, new pin designs and titanium pins have been introduced. In this study, the retention of these new pins in amalgam, and their influence on its fracture resistance, were compared to that of stainless-steel pins.

Pins must mechanically stabilize restorations, but present minimal risk of pulp perforation or tooth fracture. Durkowski and others (1982) have shown that pins 0.6 mm in diameter probably provide the best balance of these requirements.

Moffa, Razzano, and Doyle (1969) reported that threading a 0.6-mm stainless-steel pin 2 mm into dentin provides optimum retention. This retention reportedly ranges from 12 to 25 kg (Moffa & others 1969; Butchart, 1987; Van Nieuwenhuysen & Vreven, 1985; Eames & Solly, 1980; Dilts, Welk & Stovall, 1968). It is probable that this range of force also represents the optimum retention of pins in amalgam. Retention beyond this range is presumably unimportant, while retentive failure or fracture of the pin below this range would indicate inadequate resistance to masticatory forces. Studies of pin retention in amalgam (Moffa & others, 1969; Welk & Dilts, 1969; Butchart & Lloyd, 1986) have generally been limited to conventional amalgams and stainless-steel pins.

Studies examining the effect of pins on the strength of amalgam are similarly limited. The only demonstrated effects of pins within conventional amalgam are a reduction in transverse strength (Welk & Dilts, 1969), reduced diametral tensile strength when pins are oriented perpendicular or oblique to the tensile forces (Going & others, 1968), and decreased compressive fracture resistance in amalgam cylinders of equal height and diameter (Welk & Dilts, 1969).

MATERIALS AND METHODS

Six types of pin, two of stainless steel and four of titanium (Table 1), were evaluated in this study. A representative high-copper amalgam (Valiant PhD, LD Caulk Co, Milford, DE 19963) was used. Because of the mechanical/biological considerations previously discussed, only threaded pins 0.6 mm in diameter on the apical end were evaluated.

The length of each type of pin embedded in amalgam is given in Table 1. This was the length obtained using the manufacturer's twist drill and self-shearing pin.

Two types of titanium pin had retentive cleats on their coronal end (Fig 1). One of the titanium pins was pure titanium, while the others were alloys (Table 1.) All but two of the types of pin evaluated had depth-limiting shoulders (Fig 1).

Cylindrical specimens of similar height and diameter were used to evaluate the influence of the various pins on fracture resistance of amalgam because of their resemblance to pin-retained restorations, as cited by Welk and Dilts (1969). These were 6 mm in height and 5 mm in diameter and were tested in compression.

Retention of the pins in amalgam was evaluated using cylinders similar to the compressive specimens, but tapered 15 degrees. Standard Minim stainless-steel pins, which had no depth-limiting shoulder, were used to examine retention of pins embedded to progressively shorter lengths. These could be conveniently obtained by shortening the apical end of the pin.

A sample size of 10 per group was used for the retention test, and 20 specimens per group were used for the fracture-resistance test. Specimens

Table 1. Pin Types and Manufacturers

Pin type	Brand name	Manufacturer	Manufacturer
Stainless steel	Minim, standard	Whaledent International New York, NY 10001	Whaledent International New York, NY 10001
Stainless steel*	Minim, Link Plus	Whaledent	Whaledent
Titanium alloy*	Minim, Link Plus	Whaledent	Whaledent
Titanium	Filpin, universal	Vivadent USA, Inc Tonawanda, NY 14151	Vivadent USA, Inc Tonawanda, NY 14151
Titanium alloy*	MPS, size 3 short**	Brasseler USA, Inc Savannah, GA 31419	Brasseler USA, Inc Savannah, GA 31419
Titanium alloy*	MPS, size 3**	Brasseler	Brasseler

All pins 0.6 mm on apical end
*Depth-limiting collar
**Retentive cleats, coronal end; 0.83 mm diameter

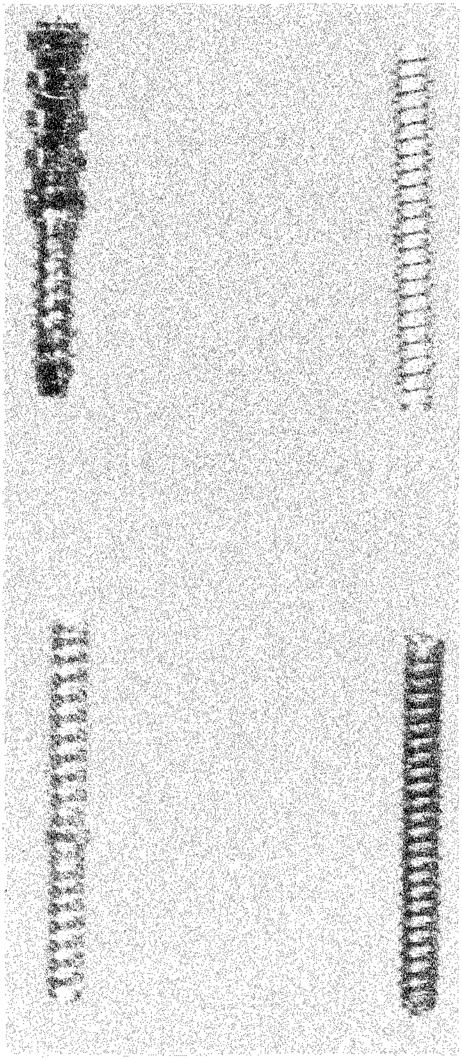

FIG 1. *Design of pins. Retentive cleats (top left), uniform threads with depth-limiting shoulder (bottom left), uniform threads (top and bottom right). Pin materials: top left, titanium alloy; bottom right, titanium; top right and bottom left, stainless steel. (Magnification = X2)*

without pins served as controls for fracture resistance.

Pins were positioned for condensation of amalgam in a slightly oversized pin channel prepared in a plexiglass block. The block was indexed such that pins could be uniformly positioned in the center of an aluminum mold. The amalgam was hand-condensed in six increments into this mold. The resulting cylinders contained one pin located in the center of one end, oriented parallel to the long axis.

All specimens were stored at room temperature for one week. To evaluate retention, the tapered cylindrical specimens were placed in a similarly tapered sleeve and the pins secured in a custom holding device (Fig 2). Tensile force was applied to the pins with a universal testing machine (MTS Systems, Inc, Minneapolis, MN 55424) at a crosshead speed of 0.25 mm/min.

Compressive fracture resistance was meas-

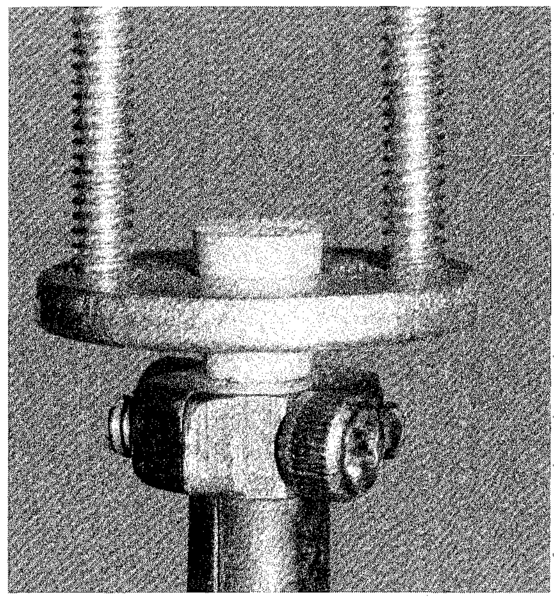

FIG 2. *Tapered cylindrical specimen in tapered sleeve, with pin secured in custom holding device. (Magnification = X0.6)*

ured using the same testing machine and crosshead speed. Prior to testing for fracture resistance, the protruding ends of the pins were removed and the ends of the cylinders finished perpendicular to their long axes.

RESULTS

Retention

Failure forces for all pins embedded to standard length in the amalgam are presented in Table 2, and failure forces for progressively shorter lengths of Minim pins are given in Table 3. In all cases where pins were fully embedded, the pin

Table 2. Retention of pins in amalgam, standard depths

Pin type	Failure force, kg (SD)
Stainless steel, 0.6 mm (Link Plus)	33.6 (3.9)
Titanium alloy, 0.6 mm (Link Plus)	27.8 (3.4)
Stainless steel, 0.6 mm (Minim, standard)	25.7 (1.3)
Titanium alloy, 0.83/0.6 mm* (MPS, short)	19.8 (0.9)
Titanium, 0.6 mm Filpin)	12.6 (0.3)

(n = 10)
*All failures occurred in 0.6-mm section of pin.
Means connected by vertical lines are not significantly different.
ANOVA, Tukey's method of multiple comparisons, $P < 0.05$.

Table 3. Retention of Standard Minim Pins in Amalgam at Various Depths

Pin length	Failure force, kg (SD)
Minim, 2.5 mm*	25.7 (1.3)
Minim, 2.25 mm*	24.5 (1.0)
Minim, 2.0 mm*	24.0 (1.0)
Minim, 1.75 mm**	21.3 (1.9)
Minim, 1.5 mm**	20.1 (1.4)
Minim, 1.25 mm**	15.6 (1.2)

(n = 10)
*Pin failed in tension.
**Alloy failed at level of end of pin.
Means connected by vertical lines are not signifcantly different.
ANOVA, Tukey's method of multiple comparisons, $P < 0.05$.

fractured before pulling out of the specimen. Stainless-steel pins embedded 1.75 mm or less caused the end of the amalgam cylinder to separate at the level of the pin end (Fig 3).

All pins with retentive cleats failed in the 0.6-mm end. Because the shorter pin of this design failed in tension, no retention test was performed on the longer pin, which was the same diameter.

As shown in Tables 2 and 3 and in Figures 4 and 5 these results formed several statistically distinct groups (ANOVA, Tukey's method of multiple comparisons, $P < 0.05$). The pure-titanium pins failed at the lowest force, which was less than 50% of the force required to fracture stainless-steel pins.

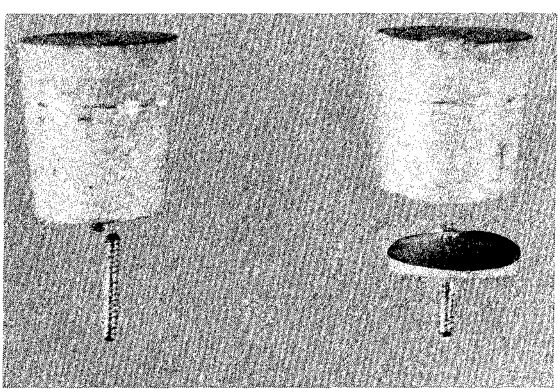

FIG 3. *Modes of failure, retention: failure of pin (left) and failure of amalgam (right). (Magnification = X0.6)*

Fracture Resistance

Compressive fracture resistance values are presented in Table 4. Although specimens containing the largest pins failed at the lowest force, no significant difference was observed between the means of any of the experimental groups or the control group (ANOVA, $P > 0.05$).

DISCUSSION

All of the pins and lengths of pin, except the pure-titanium and the 1.25-mm stainless-steel pins failed at forces greater than 19.8 kg. These values compare favorably with the previously cited range of 12 - 25 kg (Figs 4, 5). Since stainless-steel pins 1.5 mm in length give retention of 20 kg, the 2.5 - 3.3-mm length obtained with self-shearing pins may be excessive.

Failure of the pure titanium and the 1.25-mm stainless-steel pins at 12 - 15 kg suggests that

Table 4. Compressive Fracture Resistance of Amalgam Cylinders with and without Pins

Pin type	Fracture force, kg (SD)
Control (no pins)	729 (96)*
Titanium, 0.6 mm (Filpin)	712 (51)*
Stainless steel, 0.6 mm (Standard Minim)	711 (111)*
Titanium alloy, 0.6/0.83 mm (MPS short)	706 (98)*
Titanium alloy, 0.6 mm (Link Plus)	694 (100)*
Stainless steel, 0.6 mm (Link Plus)	693 (51)*
Titanium alloy, 0.6/0.83 mm (MPS)	676 (69)*

(n = 20)
*No significant differences, ANOVA, $P > 0.05$

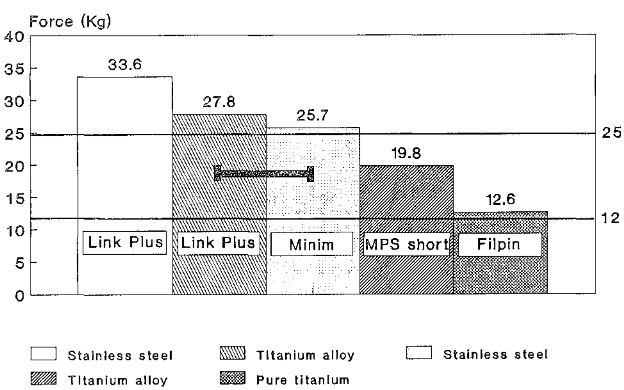

FIG 4. *Failure forces for retention of various pin materials and types. All failures occurred in pin. Means connected by the horizontal bar are not significantly different (P < 0.05, Tukey test). The reported range of retention of 0.6-mm pins in dentin is represented by broken horizontal lines.*

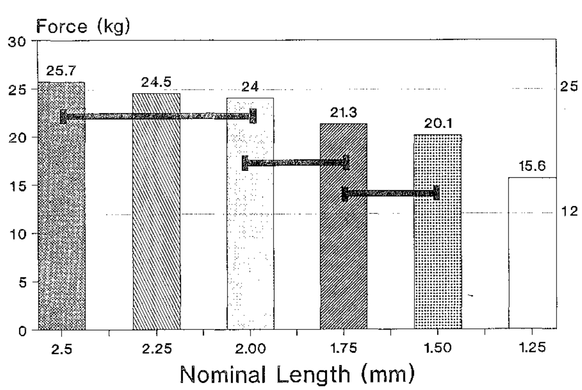

FIG 5. *Failure forces for retention of various lengths of Minim pin. The three shortest lengths failed in amalgam, others in the pin. Means connected by broken horizontal bars are not significantly different, (P < 0.05, Tukey test). The reported range of retention of 0.6-mm pins in dentin is represented by broken horizontal lines.*

these may not provide sufficient retention or fracture resistance. Since the retention of uniformly threaded pins in amalgam is greater than the tensile fracture resistance of titanium alloy, the retentive cleats on the MPS pins appear to have no beneficial effect on retention in amalgam.

The values observed for compressive fracture resistance suggest that high-copper amalgams are not particularly weakened by the presence of one pin, but supporting clinical data is needed.

CONCLUSIONS

The compressive fracture resistance of the amalgam specimens used in this study is not significantly affected by any of the pins evaluated.

A stainless-steel pin had the greatest resistance to tensile forces of the pins tested.

Embedding a stainless-steel pin 1.5 mm in amalgam provided retention approximately equal to the retention of like pins in dentin.

Pure titanium pins fail in tension at relatively low forces; stainless-steel or titanium-alloy pins may be preferred.

The retentive cleats of the MPS pins produced no positive effect on the retention of amalgam.

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Inhibition in Vitro of Caries around Amalgam Restorations by Bonding Amalgam to Tooth Structure

Y TORII • M STANINEC • M KAWAKAMI
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Summary

Class 5 preparations in human molars were restored with amalgam. In half of the restorations, an experimental resin liner capable of bonding amalgam to tooth structure was used. The restored teeth were incubated in a bacterial medium containing sucrose and a culture of *Streptococcus mutans*. Artificial carious lesions were produced around all restorations. The experimental liner inhibited penetration of the lesions along the cavity wall. This inhibition was more effective at the occlusal side.

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Introduction

The interface between a restorative material and the cavity wall is susceptible to leakage, which can lead to recurrent caries. Microleakage has been studied mostly by penetration of various tracers around restorations. Clinical recommendations are sometimes made on the basis of these studies, although it has not been established that such studies can predict the clinical success of filling materials. The results of leakage in vivo can be marginal staining, pulpal irritation, or recurrent caries. In a survey of restorations done in private practice, Mjör (1981) concluded that 71% of amalgam restorations are replacements, and 58% of these are due to recurrent caries. This figure was very close to the percentages reported in five comparable studies.

Artificial caries can be produced in vitro around restorations which are histopathologically indistinguishable from secondary lesions in vivo (Hals & Simonsen, 1972). Such studies can also predict the success of restorative techniques in rendering the restoration more resistant to recurrent caries in vivo (Shimizu & Kawagoe, 1976).

In amalgam restorations, resistance to recurrent caries has been shown to be increased by addition of fluoride to the amalgam (Heintze & Mornstad, 1980), or by placing a self-curing diethyleneglycol dimethacrylateo-monomethacryloxyethyl phtalate sealant on the margins of the restoration (Fukuda, 1978). Recently a study by Staninec and Holt (1988) demonstrated that amalgam can be bonded to etched enamel or etched dentin by an adhesive resin liner, resulting in tensile bond strengths of 1404 PSI and 469 PSI respectively. This is the same order of magnitude as bond strengths of composite resins to tooth structure. Adhesive techniques have been used with composite resins since the 1960s and have a number of well-documented advantages, including increased resistance to recurrent caries (Staninec & others, 1985). The present study was carried out to test the resistance to recurrent caries of amalgam restorations bonded to the cavity walls with the adhesive liner and to compare them to unlined controls.

Materials and Methods

Fourteen freshly extracted human molars, free of restorations, caries, or other defects, were used for the study. The teeth were cleaned of all debris by scaling, the roots were cut off with a water-cooled bur and the pulp tissue was curetted out. In each tooth, two oval-shaped class 5 preparations were cut with a #58 carbide bur in a high-speed handpiece cooled with water spray. The preparations were 1.5-2.0 mm wide occlusogingivally, 2.0-2.5 mm deep pulpally and the gingival margin was located approximately 1.0 mm occlusal to the cementoenamel junction. The teeth were marked randomly to identify one side as experimental and the other as control. The code was revealed after evaluation of the radiographs.

The experimental cavities were etched for 30 seconds with 37% phosphoric acid, coating all the walls. The cavities were then rinsed with a water stream for 20 seconds and dried with an air stream for 30 seconds. A thin coat of freshly mixed Panavia EX, (Kuraray Co, Ltd, Osaka, Japan) mixed according to the manufacturer's instructions, was painted on the cavity walls using a fine brush. A fresh mix of amalgam (Tytin, Sybron/Kerr, Romulus, MI 48174) which had been triturated in a HIMIX VS-II triturator (G-C Dental Industrial Corp, Tokyo, Japan) for 10 seconds, was condensed immediately into the cavity using vertical and lateral pressure. The condensed amalgam was carved to anatomical contour using a Half-Hollenback carver. Next, a coating of Oxyguard was placed over the margins of the restorations for five minutes.

(Panavia EX is an adhesive resin cement containing a phosphate ester adhesive promoter which is capable of adhesion to sandblasted metal surfaces and freshly mixed amalgam as well as etched tooth surfaces. When used as a luting cement, the film thickness is reported by the manufacturer to be 19 μm. The setting reaction of the cement is inhibited by oxygen, so the margins of restorations must be protected from oxygen for about six minutes during the setting process. For this purpose, a viscous polyvinyl alcohol gel (Oxyguard) is provided in the kit. After wiping off excess cement, this gel is placed over the margins of the restoration, left in place for six minutes, then rinsed off with water spray.)

The control cavities were then washed with water for 20 seconds, dried with an air stream for 30 seconds and filled with amalgam, condensing and carving in the same manner as for the experimental restorations. The teeth were stored in water for 24 hours at 37 °C, then both experimental and control restorations were highly polished with discs. This removed any traces of resin which might have remained on the exposed surface of the experimental restorations.

Next, all teeth were thermocycled between 4 °C and 60 °C in water baths for 100 cycles, two minutes in each bath. The restored teeth were painted with nail varnish, leaving only the restoration and a 0.5-mm peripheral area exposed. The teeth were mounted on plastic tubes and set into an artificial caries chamber, as shown in Figure 1. The assembly was sterilized with

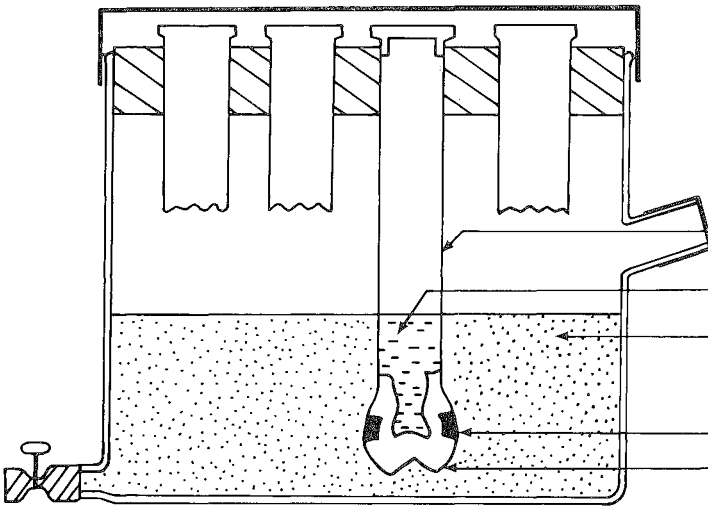

FIG 1. *The artifical caries chamber*

ethylene-oxide gas, and brain-heart infusion broth containing 3% sucrose was added to the chamber under sterile conditions. The chamber was incubated for three days at 37 °C and when no bacterial growth was noticed, the broth was replaced and inoculated with *Streptococcus mutans* OMZ 176. The incubation was continued for five weeks, changing the medium every four days. After incubation, the teeth were imbedded in epoxy resin, sectioned through the middle of both restorations, and ground sections 80-100 μm thick were prepared. Contact microradiographs were made in a soft x-ray unit (Softex TV-PBO-C, Nippon Softex Co, Ltd, Tokyo, Japan) by exposure for 30 minutes at 15 KV and 3 mA. The microradiographs were evaluated in a microscope equipped with a calibrated eyepiece at X40 power. The lesions were measured for depth of penetration along the cavity walls as shown in Figure 2. The depth of penetration as well as the morphology of each lesion was recorded.

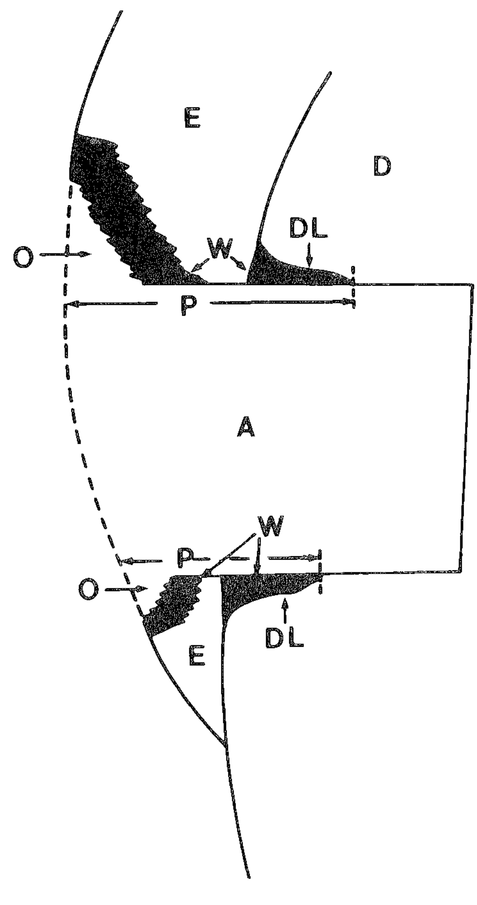

FIG 2. *Measurement of the lesions. A–amalgam space, E–enamel, D–dentin, O–outer lesion, DL–dentin lesion, W–wall lesion, P–depth of penetration of lesion along cavity wall*

		Average Depth of Penetration (mm)	Standard Deviation	*P* Value
Occlusal side	Experimental (with liner)	0.81	0.34	≥0.005
N = 14	Control (unlined)	1.20	0.29	
Gingival side	Experimental (with liner)	0.75	0.21	≥0.05
N = 14	Control (unlined)	0.93	0.20	

Results

The results are presented as the average depths of penetration of the carious lesions along the cavity wall (table). The difference is significant in both occlusal and gingival side lesions, but is greater in the occlusal side lesions. The *P*-values were calculated using a paired Student's *t*-test. The lesions reached dentin on the occlusal side in three out of a total of 14 cases in the experimental group and 10 of 14 cases in the control group. On the gingival side, where the enamel was thinner, 13 of 14 experimental side lesions and 14 of 14 control lesions reached dentin. The typical morphology of the lesions can be seen in the microradiographs in Figure 3 and Figure 4. The amalgam is not seen in the microradiographs as it was lost during the preparation of the thin sections. Note the penetration of the lesions along cavity walls (wall lesion) in the control specimens. These results indicate that the experimental adhesive liner had a significant inhibiting effect on the progress of the carious lesion along the tooth-resin-amalgam interface. This effect was smaller on the gingival side where less enamel was present and the lesion reached dentin in most cases.

Discussion

The results of this study in vitro indicate that, in the laboratory, the amalgam bonding technique is effective in sealing the interface of cavities with enamel margins and thus inhibiting recurrent caries. Since most amalgam preparations are entirely above the cementoenamel junction, this result has potential clinical usefulness. The effect of the bonding technique on cavities extended below the cementoenamel junction was not investigated in this study, but the smaller difference between lesions around control and experimental restorations at the gingival side suggests that bonding to dentin is less effective than bonding to enamel. Numerous microleakage studies have shown that gingival margins of restorations, especially those extended below the cementoenamel junction, are notoriously difficult to seal, even when using the newer dentin bonding agents (Council on Dental Materials, Instruments and Equipment, 1987). A previous study by Staninec and others (1985) indicated that etching and bonding is not effective in inhibiting recurrent caries around the gingival margins of composite resin restorations extended below the

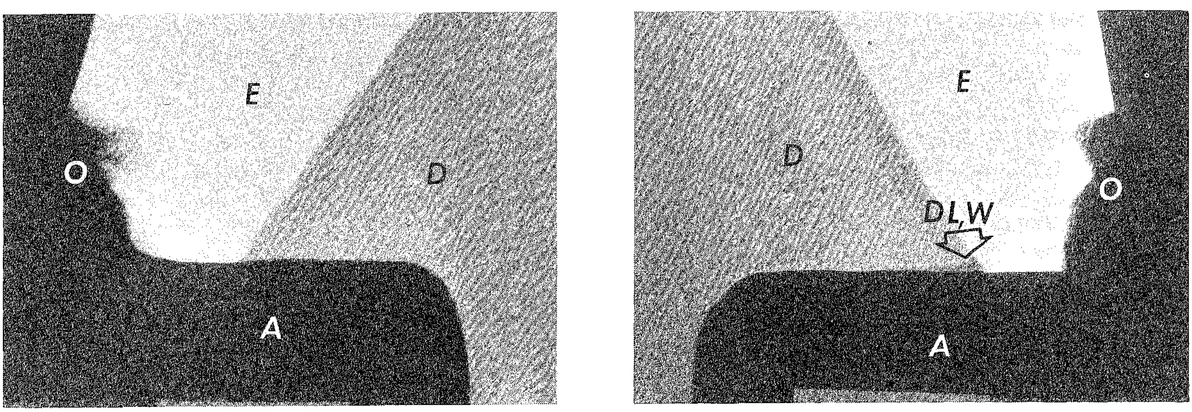

FIG 3. *Microradiographs of occlusal-side lesions. Magnification X10 A. Experimental, resin-lined B. Control, unlined*

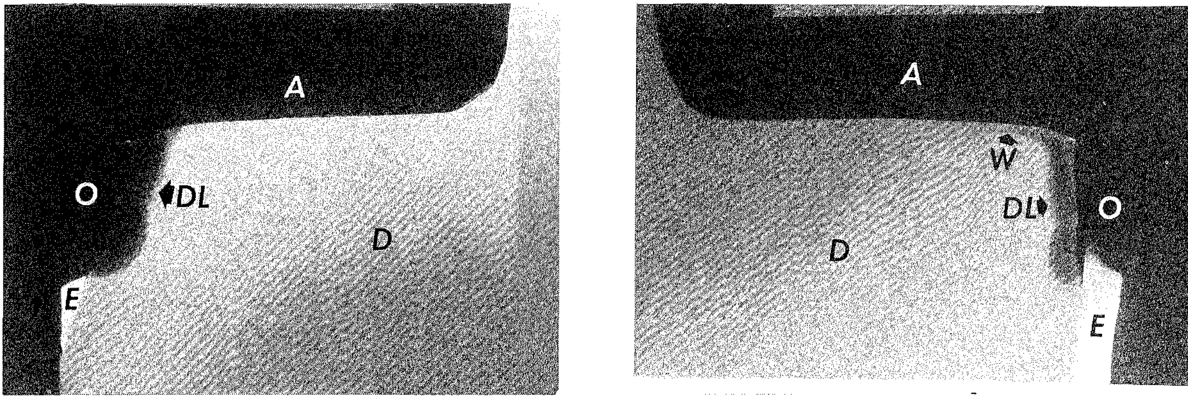

FIG 4. *Microradiographs of gingival-side lesions. Magnification X10. A. Experimental, resin-lined B. Control, unlined*

cementoenamel junction, but is quite effective at the enamel margins.

Etching and bonding dentin to obtain a seal may be not only ineffective, but also undesirable in a clinical situation because of possible pulpal irritation; however, etching and bonding of the entire cavity in the experimental restorations in the present study was done because we did not wish to introduce other variables into the experiment. In a clinical situation, exposed dentin could be lined with a glass-ionomer lining cement prior to etching and bonding. This would not only prevent possible pulpal irritation, but should also help inhibit recurrent caries reaching dentin. The caries-inhibiting effect of glass ionomers has been demonstrated in cavities with dentin and cementum walls (Derand & Johansson, 1984).

Traditionally, leakage around amalgam restorations has been reduced by varnishes which inhibit early leakage and though they may wash out in time, they are replaced by corrosion products of the amalgam which help seal the interface. However, these conclusions are based on dye and isotope penetration studies, and neither varnish nor corrosion has been shown to inhibit recurrent caries.

Another technique for sealing amalgam margins, reported by Fukuda (1978), consists of placing a resin based on diethyleneglycol dimethacrylate o-methacryloxyethyl phtalate on the margins of the restoration after carving. This resin self-cures under anaerobic conditions in the presence of metals. This method is effective in inhibiting recurrent caries around amalgam; however, it is not able to seal enamel fissures not directly bordered by amalgam.

Panavia EX, the adhesive resin used in the present study, is based on Bis-GMA, so it should be able to seal enamel fissures away from the restoration as well, although this was not investigated in the present study. However, the sealing of enamel pits and fissures by other Bis-GMA-based resins is a well-documented and effective method of preventing caries on occlusal surfaces (Mertz-Fairhurst, 1984).

Panavia EX contains an adhesive monomer which is capable of bonding to metal and also enhances the bond to tooth structure beyond simple micromechanical interlocking with etched surfaces. A previous experiment, using a Bis-GMA resin of a different formulation without adhesive monomers, found it to be ineffective for inhibition of recurrent caries around amalgam, possibly due to incomplete curing or lack of adhesion to amalgam (Staninec & others, 1988).

If enamel fissures can be sealed as well as the tooth-amalgam interface, this adhesive technique could be used in place of extension for prevention, thus saving unnecessary removal of tooth structure. Such a technique has been described for composite-resin restorations, the so-called preventive resin restoration, combining composite resin and sealant (Simonsen, 1980). Composite resins have not yet attained universal acceptance as suitable direct-filling materials for posterior teeth (Bales, 1987; Gilbert, 1987); however, avoiding unnecessary removal of healthy tooth structure should certainly be the goal of a conscientious operator.

Tytin, the high-copper spherical alloy used in the present study, appears to be more prone to leakage, resulting in reports of postoperative sensitivity (Mahler & Nelson, 1984). This may be due partly to a slightly inferior adaptation to cavity walls on a microscopic level and also to decreased corrosion (Fayyad & Ball, 1984). However, Tytin and similar formulations continue to be a popular choice, because of good physical properties and good performance in clinical controlled studies (Doglia & others, 1986). The adhesive technique has the potential of taking advantage of both the good physical properties of high-copper spherical alloys and the sealing ability of the metal and tooth-bonding resin. When compared to bonded composite-resin restorations, the bonded amalgam restoration exhibits less leakage above the cementoenamel junction, presumably because shrinkage on setting is much less than the polymerization shrinkage of composite resins (Staninec, Wada & Watanabe, 1988).

The results of this study agree with a previous study by Shibatani and others (1984) where Panavia EX was used as a luting medium for inlays and had the same inhibiting effect on recurrent caries when compared to zinc phosphate. This particular resin formulation is not unique in its ability to bond amalgam to tooth structure. Varga and others (1986) reported similar bonding using a resin containing 4-META. Shimizu and others (1986) have also reported shear bond strengths of amalgam bonded to enamel and dentin by Panavia EX or Super-Bond using various surface pretreatments. The same group of investigators later reported reduction in microleakage as measured by dye penetration by using the amalgam bonding technique (Shimizu & others, 1987).

One important limitation of this study is the short duration of the experiment. Any effect of long-term weathering of the bond or corrosion of the amalgam cannot be observed. Clinical implications, however, are possible, as this technique in vitro has been used to predict the clinical usefulness of a recurrent-caries-inhibiting agent (Shimizu, 1976). Ultimately, of course, this technique must be validated by long-term clinical studies, which this is not. To check the caries-inhibiting effect clinically, the technique should be tested in a population with high caries activity, which may be difficult in controlled clinical trials (Petersson & others, 1985).

Conclusion

The adhesive amalgam technique using a metal and tooth-bonding resin liner was effective in inhibiting the progress of a carious lesion along the cavity wall as tested in vitro when the preparations are above the cementoenamel junction. The effect was greater at the occlusal side of the restorations than at the gingival side.

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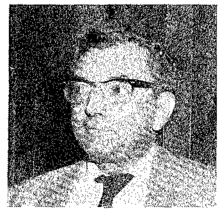
BUONOCORE MEMORIAL LECTURE



Michael Buonocore

Caries Diagnosis within Restored Teeth

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Presented on 16 February 1989 at the annual meeting of the Academy of Operative Dentistry in Chicago

INTRODUCTION

Dentists spend a great deal of time replacing restorations. Clinical studies show that secondary caries is often the single most important factor given by dentists for these replacements (Healey & Phillips, 1949; Richardson & Boyd, 1973; Lavelle, 1976; Dahl & Eriksen, 1978; Mjör, 1981; 1985; Qvist, Thylstrup & Mjör 1986a,b). It would appear, therefore, that dentists diagnose caries within restored teeth frequently and with confidence.

This confidence has been shaken in recent years, however, by papers demonstrating that dentists vary widely in their treatment planning decisions (Mileman, Purdell-Lewis & van der Weele, 1982; Elderton & Nuttal, 1983). In many ways the results of this work have disturbed the profession, but present a fascinating challenge for the future. This challenge was addressed in an international symposium, "Criteria for Placement and Replacement of Dental Restorations," which was held in Florida in October 1987 (Anusavice, 1989). This paper aims to define some of the problems in the diagnosis of caries within restored teeth and presents some recent research on the subject.

SECONDARY OR RECURRENT CARIES

Histological examination of the early

secondary carious lesion gives some indication of how such a lesion is formed (Kidd, 1981). When a filling is placed, the adjacent enamel may be considered in two planes (Fig 1). These are the surface enamel and the enamel of the cavity wall. For this reason a secondary carious lesion has been described as occurring in two parts: an "outer lesion" formed on the surface of the tooth as a result of primary attack and a "wall lesion" which will only be seen if there is leakage of bacteria, fluids, molecules, or hydrogen ions between the restoration and the cavity wall (Hals, Andreassan & Bie, 1974). This clinically indetectable leakage around restorations is referred to as "microleakage" (Kidd, 1976a).

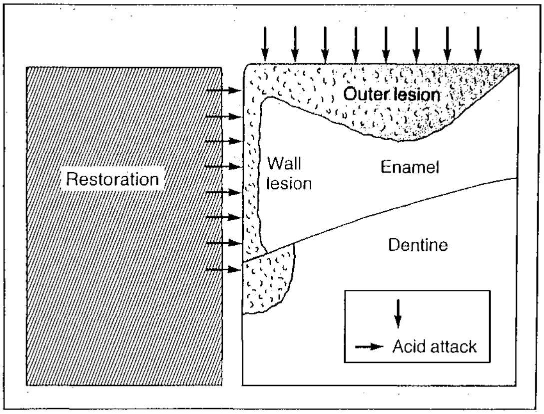

FIG 1. *A diagrammatic representation of secondary caries showing that the secondary carious lesion may occur in two parts: an "outer lesion" formed on the surface of the tooth as a result of primary attack and a "wall lesion" formed as a result of leakage between the filling and the cavity wall*

Many techniques have been devised over the last 25 years to test the cavity-sealing properties of restorations both in the laboratory and in the mouth. These include the use of dyes, radioactive isotopes, air pressure, bacteria, neutron activation analysis, scanning electron microscopy, and artificial caries. Artificial caries experiments have a particular interest because they link microleakage with one of its consequences, namely the development of the secondary carious lesion.

These experiments (Hals & Nernaes, 1971) have been conducted on caries-free human premolars extracted for orthodontic reasons. Rectangular cavities were prepared on buccal surfaces and filled with the material under test. The teeth were then varnished to expose a window of sound enamel around the restoration and the specimens placed in a gelatin gel acidified with lactic acid to produce artificial, caries-like lesions. After a number of weeks specimens were removed and longitudinal ground sections prepared which were examined in polarized light.

Amalgam, composite, glass-ionomer cement, and cemented inlays have all been tested in this way. As expected from dye and isotope work (Kidd, 1976a) the freshly packed amalgam restoration leaked, but this leakage could be drastically reduced by the use of a cavity varnish (Hals & Nernaes, 1971; Kidd, 1976b).

Composite restorations were a better seal (Hals & Kvinnsland, 1974; Kidd, 1976b), especially when placed against acid-etched enamel walls. In recent years, however, the relevance of polymerization shrinkage of composites has become apparent, particularly in the class 2 cavity (Jensen & Chan, 1985; Kidd, 1985). The danger area is the junction between the thin enamel or dentin at the cervical margin and the restorative material. The bond to the thick enamel of the cavity walls will be stronger than the bond to the thin enamel or dentin at the cervical margin. A restorative material which shrinks as it sets will move towards the stronger bond, leaving a gap at the cervical margin.

Glass-ionomer cements, with their available fluoride, showed interesting pictures after exposure to the artificial caries system (Kidd, 1978). The outer lesion was now some distance away from the cavity wall, presumably because the available fluoride in the material exerted a cariostatic effect. Similarly the wall lesion was less pronounced, but there was still evidence of leakage, seen histologically as a fine line of demineralization running adjacent to the cavity wall. This is important because although glass-ionomer cement is chemically adhesive to enamel and dentine, it will still allow leakage. Thus chemical adhesion, The Holy Grail of the materials scientist, will not necessarily eliminate the problem of recurrent caries.

Examination of artificial lesions around inlay restorations cemented with glass-ionomer cement gave further proof of this (Kidd & McLean, 1979). Clear wall lesions were seen. In the same experiment there was evidence of leakage around inlays cemented with zinc-phosphate cement.

The salient point in this experimental work is that all these filling materials leak and therefore, in a caries-prone mouth, all restorations may potentially fail because of recurrent caries, although some will fail more quickly than others. Thus, although the materials scientist has an important role to play in the prevention of dental caries, in the final analysis, restorations cannot be regarded as a treatment for dental caries. Fillings merely replace missing tissue with a poor substitute for unblemished enamel and dentin. The management of dental caries, be it primary or secondary, rests with assessing risk and reducing the rate of caries progression by dietary control, judicious use of fluorides, and plaque control. These preventive measures, which seek to reduce caries progression, are just as much active treatment of the disease as restorative treatment and should be recognized and rewarded as such.

SPECIFIC DIAGNOSTIC PROBLEMS

Four specific problems in the diagnosis of caries in restored teeth will be discussed. These are:

1. the difficulty of seeing the wall lesion,
2. whether the filling with a defective margin is synonymous with recurrent caries,
3. distinguishing recurrent from residual caries, and
4. distinguishing active from arrested caries.

Seeing the wall lesion

Although secondary caries is essentially similar to the primary disease, its histological features cause certain specific diagnostic problems. For instance the wall lesion cannot be seen until it is so advanced that the tooth tissue over it becomes grossly discolored, or the overlying tissue collapses to reveal a large hole. This is analagous to the problems in the diagnosis of fissure caries (Kidd, 1984) where histologically the white spot lesion forms on the walls of the fissure, and the fissure, which looks clinically caries-free, may histologically show signs of early lesion formation.

The filling with a defective margin

The filling with a defective margin also presents diagnostic difficulties. The ditched amalgam restoration is a good example of this. It would seem that such restorations are plaque traps and in this respect they may be similar to fissures. Perhaps this explains the widely held view that recurrent caries is largely the result of marginal failure of restorations (Goldberg & others, 1981). It may also explain why it is common dental practice and teaching to replace such defective restorations as a preventive procedure; but is the ditched amalgam restoration actually more prone to caries than the well-adapted restoration? To attempt to answer this question a small study was carried out where sections through amalgam restorations were examined histologically to see if there was a difference in caries prevalence beneath ditched as compared to nonditched margins.

Thirty extracted molar and premolar teeth, with old occlusal amalgam restorations which had been placed some years earlier when the teeth were in vivo, were used in this study.

Figure 2 is typical of the specimens. Part of the margin of the restoration is obviously ditched, while in another part of the same restoration the filling is better adapted. Each tooth was now sectioned so that the cut passed through a ditched margin and a better margin. The first ground section was prepared from this cut face and examined in polarized light for outer and wall lesions. Using this protocol, the histological features beneath ditched and intact margins could be compared on a tooth from the same oral environment.

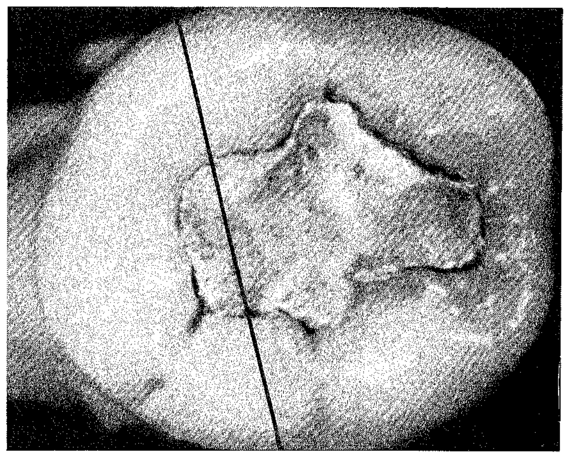

FIG 2. *This amalgam restoration has been in service for a number of years but the tooth has now been extracted. Part of the margin of the restoration is obviously ditched while in other places the filling is better adapted. The black line shows where the tooth was sectioned so that the cut passed through a ditched and a nonditched margin.*

Figure 3 shows a section through the ditched side of one of these restorations. The ground section is in quinoline and viewed in polarized light. The amalgam has remained in place and the ditch is obvious (D). An outer lesion (O) has formed adjacent to this plaque stagnation area and a wall lesion (W) is also present. Figure 4 shows a section through the nonditched side of a restoration but this time the amalgam has been lost during section preparation. There is no outer lesion in this specimen, but a wall lesion is obvious.

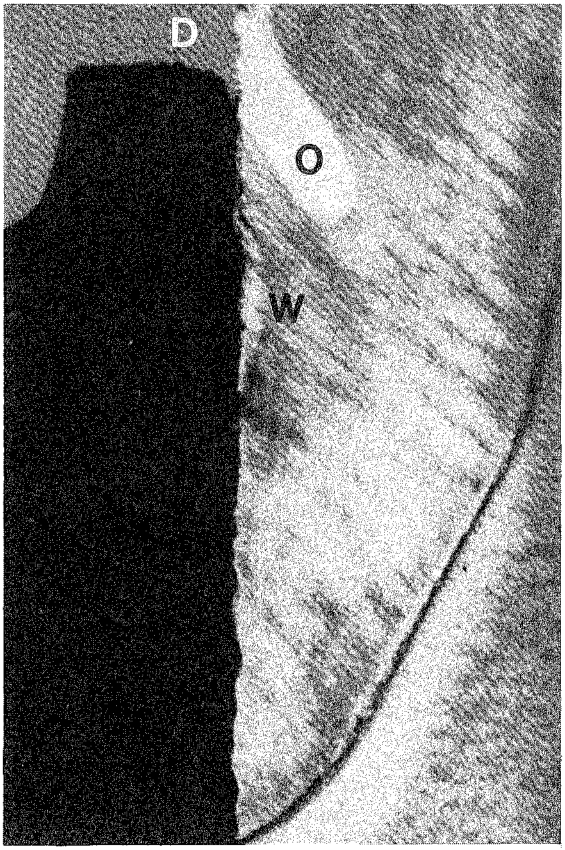

FIG 3. *A longitudinal ground section showing the ditched side of an amalgam restoration. The ground section is in quinoline and viewed in polarized light. The amalgam has remained in place and the ditch is obvious (D). An outer lesion has formed (O) adjacent to this plaque stagnation area and a wall lesion (W) is also present.*

The 30 teeth in this study should have yielded histological pictures of 30 ditched and 30 nonditched cavity aspects. Section damage reduced this number to 28 ditched aspects and 24 nonditched aspects. Very few outer lesions were found: only four adjacent to ditched amalgams and one adjacent to the nonditched amalgams. This is presumably because plaque control was good on the occlusal aspect of these teeth. It is reassuring that the ditches were not acting as obvious plaque traps. With respect to wall lesions, there were 15 adjacent to the ditched side of the restorations, which is 54% of the total; however, there were 13 wall lesions adjacent to the nonditched side of the restorations, which is also 54% of the total. It is important to point out that all these wall lesions, although detectable on histological examination in polarized light, represent a very early stage of lesion formation. None of these lesions was cavitated. A reasonable hypothesis might be that the wall lesions in enamel might have formed soon after placement of the amalgam restorations while the freshly packed restoration allowed leakage, and then arrested once corrosion products blocked the

FIG 4. *A longitudinal ground section through the nonditched side of a restoration. The ground section is in quinoline and viewed in polarized light. The amalgam has been lost during section preparation. There is no outer lesion in this specimen but a wall lesion is obvious.*

microspace between the amalgam and the cavity wall.

Thus, this experiment did not reveal any difference in caries prevalence in ditched and non-ditched aspects of the same amalgam restorations. If these results are representative of all ditched restorations, ditching per se is not a reason to replace a restoration, and indeed this was one of the conclusions of the Florida symposium on "Criteria for Placement and Replacement of Dental Restorations" (Anusavice, 1989). Again the situation of the ditched restoration is analagous to the fissure. Both the marginal defect and the fissure are stagnation areas; but just as not all fissures develop clinically detectable lesions, not all defective restorations will develop new caries. The prerequisites for caries are a cariogenic plaque of specific microorganisms, together with a suitable dietary substrate. If either the plaque or the substrate are not present, caries will not develop, irrespective of tooth morphology.

Distinguishing recurrent from residual caries

It is also relevant to consider whether the dentist can distinguish new, recurrent caries around a restoration from residual caries that the dentist left during cavity preparation. Recent work using the caries-detector dye (Fusayama & Terachima, 1972) indicates that faculty members frequently pass cavities prepared by students where the use of the dye subsequently shows caries to be present at the enamel-dentin junction (Anderson & Charbeneau, 1985; Anderson, Loesche & Charbeneau, 1985; Kidd & Joyston-Bechal, 1989). In these clinical studies carried out at an American (Anderson & Charbeneau, 1985) and a British (Kidd & Joyston-Bechal, 1988) dental school, the conventional visual and tactile method of detecting carious dentin, using a mirror and probe, was compared with a visual method enhanced by a dye.

In each study 100 cavities were prepared by the students under the supervision of five teachers, each teacher supervising the preparation of 20 cavities. When the teacher was satisfied that caries removal was satisfactory using a mirror and probe (Fig 5) the caries detector dye was applied to the dried cavity. The dye used in the American study was basic fuchsin, while in the British work it was 1% acid red. The cavity was then thoroughly washed and dried and re-examined for any dentin stained by the dye (Fig 6). The American study found dye stain at some point on the enamel-dentin junction in 59% of the teeth, whereas in the British study dye stain was found in the same position in 57% of

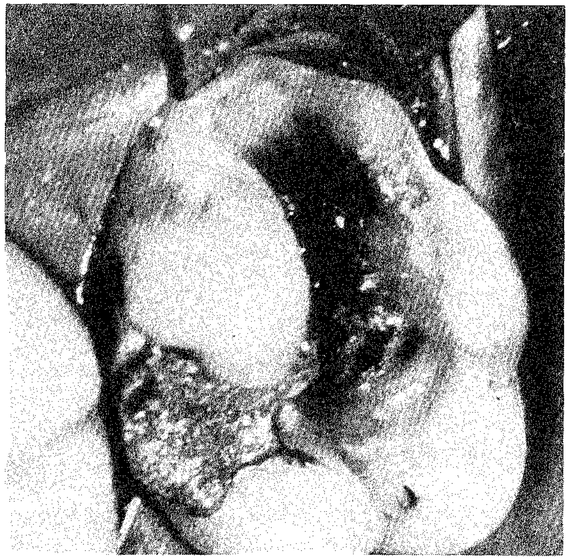

FIG 5. *A cavity judged as caries-free at the enamel-dentin junction*

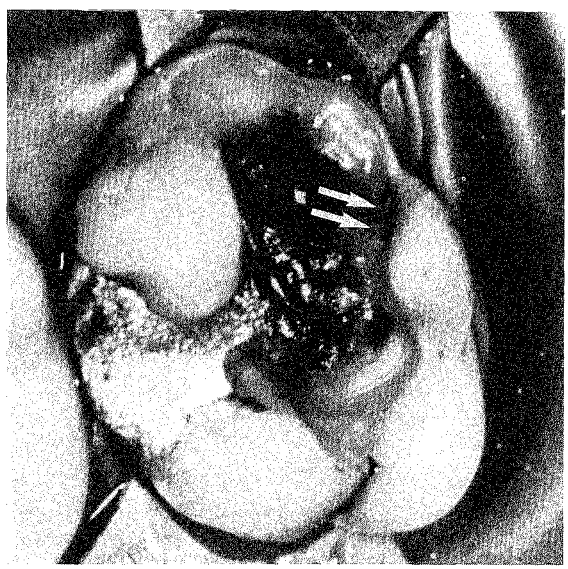

FIG 6. *A caries-detector dye (1% acid red) has now been applied to the cavity shown in Figure 5 and the cavity washed and dried. Dye stain at the enamel-dentin junction (arrows) shows that the original clinical decision was incorrect.*

the teeth. To judge from these studies the incidence of residual caries is high, and it is certainly thought-provoking that dentists cannot diagnose caries when they can look directly at it and use explorers!

Will this residual caries progress? Currently teachers insist that the enamel-dentin should be made clinically caries-free since it is argued that residual caries in this area may flourish beneath a leaking restoration. Logic suggests, however, that the relevant factor is what happens in the plaque at the tooth surface. It would seem likely that recurrent caries is inevitable, irrespective of whether caries has been left in the cavity, if a restoration leaks and a cariogenic plaque with a suitable dietary substrate remain.

Distinguishing active from arrested caries

The last problem to be considered is whether the clinician can distinguish active caries that is likely to progress from chronic, static lesions that are already arrested. In many ways this problem is intimately linked with the preceding one. If caries is left in the cavity it may arrest, but there are no clinical criteria on which to base this judgment when the tooth is re-opened. Indeed, as will be discussed, the residual caries may later be diagnosed, incorrectly, as new disease, causing the operator to replace the restoration.

CLINICAL METHODS TO DIAGNOSE CARIES IN RESTORED TEETH

To diagnose caries, be it primary or secondary, the clinician needs good lighting; dry, clean teeth; sharp eyes, with magnification if necessary; and good bitewing radiographs (Kidd, 1984). Recurrent disease occurs more frequently at cervical and approximal margins, thus particular care must be taken in these areas (Mjör, 1985).

Vision

A freshly cavitated lesion adjacent to a restoration may be obvious clinically, but sharp eyes may also pick up the gray or brown appearance of enamel undermined by caries (Fig 7). Color is particularly difficult to interpret adjacent to amalgam restorations because a gray or blue discoloration may be caused by the presence of the amalgam itself, corrosion products, or caries.

FIG 7. *An amalgam restoration with obvious stain around it. The clinician judged this to indicate recurrent caries and replaced the restoration.*

Unfortunately in the case of caries, it will not be obvious whether such staining represents residual or recurrent disease. In addition it will not be obvious whether the caries is active or arrested. It is relevant here to discuss why carious dentin is colored brown. Part of the explanation seems to be that the collagen in demineralized dentin is altered and changes color (Deakins, 1941; Dreizen & others, 1957); however, it is well known that arrested or slowly progressing dentin lesions are darkly staining (Miller & Massler, 1962) and that such stain is probably picked up from exogenous dietary sources such as tea and coffee. If lesions around restorations pick up stain in a similar way, those lesions that are most obvious clinically because of their color may be the ones that are inactive, arrested or slowly progressing!

It is also possible that this stained appearance could be caused by residual caries which has subsequently taken up exogenous stain from the mouth.

A laboratory experiment has recently been carried out to test the hypothesis that residual caries beneath freshly packed amalgam restorations could take up stain from tea. Cavity preparation was carried out on 20 freshly extracted, carious teeth. All stained caries was removed from the enamel-dentin junction, but some stain-free, residual carious dentin was left in some areas (Fig 8). Half of the specimens were then placed in a beaker of hot, strong tea for two minutes. In order to intensify the stain, the specimens were then placed in a beaker of chlorhexidine for five minutes before being returned to the hot tea. Finally the beaker was placed in a thermos flask surrounded by ice and refrigerated overnight.

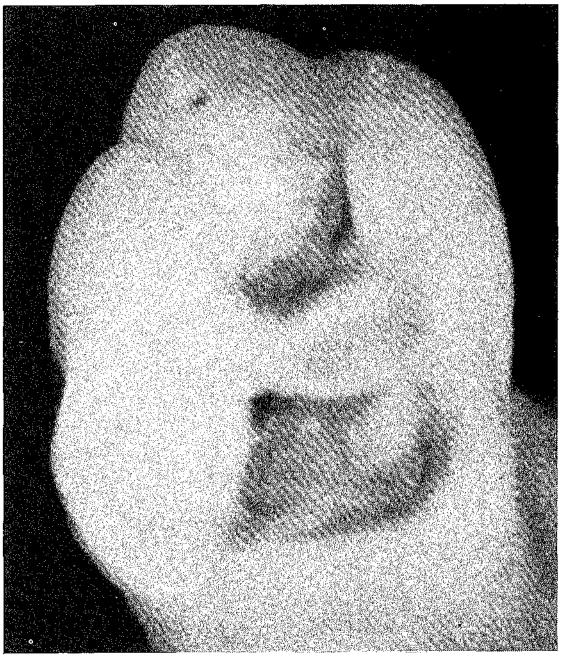

FIG 8. *Gross caries and stain have been removed from this extracted molar. Note that the enamel-dentin junction is stain-free; however, it is not entirely caries-free as judged by the usual tactile and visual criteria.*

The idea of this was that the metal fillings would contract more than the teeth, thus allowing the staining solution to pass beneath the fillings. This cycling regime was repeated daily for five days. The remaining 10 specimens were cycled in tea alone without the use of chlorhexidine.

After five days all specimens were obviously stained and this surface stain was removed with pumice, water, and a rotating brush. Figure 9 shows a specimen that was cycled in tea and chlorhexidine where pumice has already been used to clean off the surface stain. The tooth is obviously discolored in one part and this appearance in vivo could well make a clinician suspect recurrent caries. Removal of the restoration (Fig 10) shows gross staining of the enamel-dentin junction. Again this appearance in vivo could well be interpreted as recurrent caries, whereas in this experiment the caries is residual.

Subsequently, ground sections were cut from these specimens from both stained and unstained parts of the enamel-dentin junction. Microradiographs were taken of these sections to determine whether the stained enamel-dentin junction corresponded with an area of carious

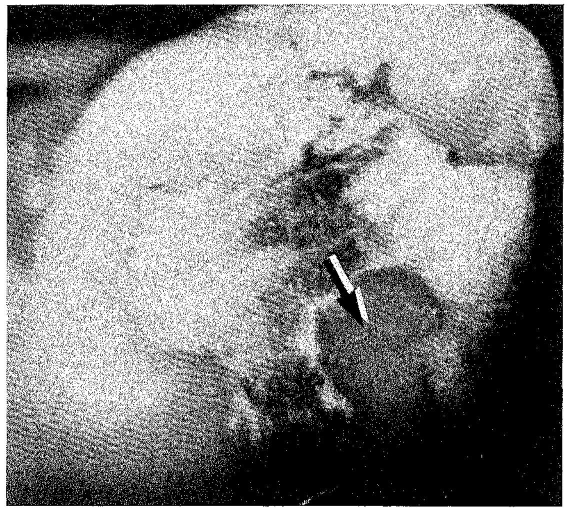

FIG 9. *This tooth was prepared as in Figure 8 and then filled with amalgam. It has been temperature-cycled in tea and chlorhexidine solution for five days. The gross surface stain has been removed with pumice, water, and rotating brush. Note the discolored appearance (arrow), which a clinician might interpret as recurrent disease. (Compare with Figure 7.)*

dentin. Of 21 sections through stained parts of the enamel-dentin junction, 18 showed demineralization, whereas of 15 sections through nonstained areas, none showed demineralization.

Thus, this experiment showed that in the laboratory residual caries beneath freshly packed

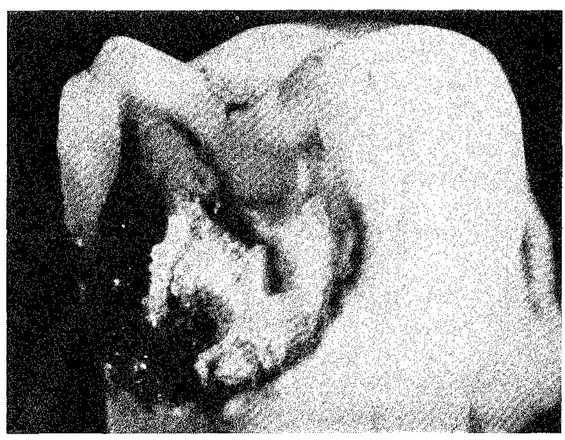

FIG 10. *The restoration has now been removed from the tooth seen in Figure 9. Note gross staining of caries at the enamel-dentin junction. This area was stain-free before the restoration was placed as shown in Figure 8.*

amalgam restorations could pick up stain from tea and chlorhexidine solutions as well as from tea alone. If the same can happen in vivo this would underline the importance of removing caries from the enamel-dentin junction during cavity preparation since residual caries may pick up stain and mimic recurrent disease. Alternatively, the dentist faced with stain around an amalgam restoration should consider the possibility that this is residual disease which does not require treatment rather than active recurrent disease in need of operative management. Unfortunately it is currently impossible for the clinician to distinguish between the two.

The use of sharp explorers

For many years sharp explorers have been advocated for use in the diagnosis of primary and recurrent caries. In recent years, however, it has been shown that a sharp explorer is potentially damaging because it may cause cavitation of a demineralized area (Bergman & Linden, 1969; Ekstrand, Qvist & Thylstrup, 1987) and could force cariogenic bacteria into the depth of the lesion. Certainly this approach seems unwise with respect to secondary caries. A sharp explorer could cause cavitation of an outer lesion, could damage the margin of a restoration, or could become impacted in a marginal discrepancy which might then be misinterpreted as caries. For all these reasons it is suggested that this technique should no longer be advocated and this tactile test should be omitted from the Ryge criteria (Ryge, 1980), which are commonly used in clinical trials of restorations. Despite these reservations, a curved probe is helpful cervically where bitewing radiographs are difficult to interpret. However, the probe should be used gently.

The value of bitewing radiographs

Bitewing radiographs are very important to the diagnosis of caries within restored posterior teeth. For this reason restorative materials should be radiopaque although the optimum radiopacity has yet to be determined. Unfortunately radiographic shadows are open to misinterpretation and the clinician should probably emulate the epidemiologist and use film holders to help to produce reproducible films. There is considerable variation in radiographic caries diagnosis and treatment decisions (Mileman & others, 1982) and it is therefore tempting to suggest that clinicians should undergo training and calibration programs in an attempt to reduce this. Unfortunately this calibration was not successful when tried on school dentists (Poulsen, Bille & Rugg-Gunn, 1980).

There is an urgent need to improve our criteria for the diagnosis of caries within restored teeth and the future may lie in a much more accurate assessment of caries risk on an individual patient basis (Krasse, 1985). The dentist already relies heavily on dental history and clinical examination, but since caries is a sugar-dependent, infectious disease involving specific microorganisms, it seems logical to extend the diagnostic net by the use of diet analysis, salivary flow rate, buffer capacity, and specific microbiological tests. Unfortunately before the latter can be put on a sound scientific footing, research is needed into the microbiology of recurrent caries. Although it would seem likely that *Streptococcus mutans* and lactobacillae are important, as with primary disease, there is very little experimental proof of this.

THE CONSEQUENCE OF IGNORANCE

Thus far this paper has been a catalog of ignorance, and such ignorance has its consequences. There has already been a laboratory study showing that dentists are not capable of reliably diagnosing caries in restored teeth (Merrett & Elderton, 1984), which is very understandable in view of the difficulties. Nevertheless the dentists proposed to treat operatively 95% of the teeth in which they thought they diagnosed caries. Thus caries is seen as a good reason to replace restorations.

One important consequence of this depressing situation is that clinicians, and those who fund them, must currently accept that fillings may be done unnecessarily or that caries may be missed and therefore the appropriate preventive and operative measures are not taken. It is currently inevitable that dentists will not agree on diagnosis. The epidemiologist will have enormous difficulties when attempting to include recurrent caries in clinical trials. Teachers must discuss these diagnostic difficulties with their students, and practitioners could investigate the problem in the surgery. Each restoration replaced could become its own little clinical trial. A decision may be made that caries is present, and then the diagnosis is checked on removing the restoration. Unfortunately the practitioner will still not know whether the caries is active or arrested, recurrent or residual.

As usual there is a compensation for the academic who is paid to investigate these problems. In the meantime, there is no reason to alter all concepts of when and how to restore teeth. Indeed to do so would be the height of folly. The academic may question current concepts, but without sound scientific evidence has no mandate to reject the working philosophy of generations of practitioners and possibly put patients at risk.

Acknowledgment

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DEPARTMENTS

Press Digest

The editor wishes to thank the General Dentistry Residents, Wilford Hall USAF Medical Center, for their assistance in the preparation of the following abstracts.

The use of ultrasound for the removal of the smear layer. The effect of sodium hypochlorite concentration; SEM study. *Cameron, J A (1988) ***Australian Dental Journal*** **33 193-200.**

(*PO Box 101, Charlestown, New South Wales, Australia 2290)

The purpose of this study was to evaluate the optimum concentration of sodium hypochlorite for use with ultrasonic irrigation in an effort to remove the smear layer from root canal preparations. Concentrations of 4, 2, 1, and 1/2% solutions of sodium hypochlorite were evaluated after three minutes of irrigation using an ultrasonically activated endodontic broach, the tip of which was placed at approximately half the length of the canal. The results suggested that a 2% solution was the minimum concentration needed to remove all traces of the smear layer as judged from scanning electron micrographs.

Efficacy of dentin-bonding agents in relation to application technique. *Hansen, E K & Asmussen, E (1989) ***Acta Odontologica Scandinavica*** **47 117-120.**

(*Helsingorsgade 7, DK-3400 Hillerod, Denmark)

This study was designed to evaluate the effect created on the tooth/bonding-agent interface by the withdrawal of an unpolymerized, light-activated resin from a cavity wall coated with one of two dentin-bonding agents, reapplying the agent, and following this with polymerization. The two bonding agents evaluated were Scotchbond Dual Cure and GLUMA; Silux was used as the resin. The study demonstrated that resin may stick to a syringe or instrument tip during application, which can cause it to be pulled away from the bonding-agent-coated wall. This can cause a significantly larger gap upon polymerization compared to resin that had not been pulled away and reapplied. This paper tends to reinforce the technique sensitivity of dentin-bonding agents. GLUMA did perform better than Scotchbond on this one parameter.

The effect of latex gloves on setting time of vinyl polysiloxane putty impression material. *Rosen, M, Touyz, L Z G & Becker, P J (1989) ***British Dental Journal*** **166 374-375.**

(*Department of Conservative Dentistry, University of Witwaterstrand, Johannesburg, South Africa)

The setting time of vinyl polysiloxane putty impression material (VPPIM) can be extended when mixed with some forms of latex gloves. This study evaluated synthetic versus natural latex gloves in their effect upon Exaflex, Reprosil, and Express VPPIMs. All synthetic latex gloves produced mixing times comparable to those of ungloved hands, but the natural latex gloves extended the setting time up to 20 minutes. The authors suggested that dentists should consider these findings when purchasing gloves.

The effects of GLUMA and GLUMA/Scotchbond on in vivo marginal adaptation of a composite resin to dentin. *van Dijken, J W V & Horstedt, P (1989) ***Dental Materials*** **5 165-167.**

(*Department of Cariology, Faculty of Odontology, University of Umeå, S-901 87 Umeå, Sweden)

This study was designed to test in vivo if GLUMA, alone or in combination with another dentin-bonding agent, can decrease marginal discrepancies in class 5 resin restorations filled by one- or two-step application techniques. Silux was used as the restorative resin. All 32 restorations demonstrated some marginal gaps, but the smallest gaps were seen with the GLUMA/Scotchbond combination in which Silux was applied in a two-step process. Gaps were determined with scanning electron microscopy. The widest gap for the GLUMA/Scotchbond combination was one-third that of the GLUMA-only samples. This may precipitate a new avenue of research.

A bond strength study of luted capable ceramic restorations. *McInnes-Ledoux, P M, Ledoux, W R & Weinberg, R (1989) *Journal of Dental Research* 68 823-825.

(*Department of Orthodontics, Louisiana State University School of Dentistry, 1100 Florida Avenue, New Orleans, LA 70119)

The increasing use of castable ceramic restorations prompted these authors to evaluate the bond strengths of three glass-ionomer luting cements and one resin cement to treated and untreated DICOR™, enamel, and dentin surfaces. The three glass-ionomer cements were: Shofu I, Fuji I, and Ketac-Cem; the resin cement was DICOR™ LA Cement. The DICOR™ light-activated cement was clearly superior to the glass-ionomer cements in its adhesion to DICOR™ (which had been etched and silane-coated) and also superior to the other cements in adhesion to etched enamel and untreated dentin--in several areas by a factor of 10. Selected surface treatment of DICOR™, enamel, and dentin prior to luting should be clinically useful.

A comparison of Flex-R files and K-type files for enlargement of severely curved molar root canals. Sepic, A O, *Pantera, E A Jr, Neaverth, E J & Anderson, R W (1989) *Journal of Endodontics* 15 240-24

(*Assistant Professor, Department of Endodontics, Medical College of Georgia, Augusta, GA 30912)

In this study 80 extracted human molar teeth with curvatures on mesial buccal roots ranging from 30-73° were cleaned and shaped with either a balanced-force technique, using Flex-R files, or a step-back technique using K-type files. With a unique radiographic technique and computer digitization of the views, the authors reported significantly less apical transportation with the use of the balanced-force technique when compared with a step-back protocol in canals exhibiting both more and less than 45° of curvature.

The effects of variable wash times and techniques on enamel-composite resin bond strength. *Mixson, J M, Eick, J D, Tira, D E & Moore, D L (1988) *Quintessence International* 19 279-285.

(*University of Missouri-Kansas City School of Dentistry, 650 E 25th St, Kansas City, MO 64108)

The effects of different rinse times using water only or water/air spray on the shear bond strength of resin to enamel was investigated. Resin buttons were bonded to enamel following a 60-second etch with rinsing according to duration and technique. Bond strengths were not found to be significantly different beyond 10 seconds for either rinse technique; however, a weaker bond for the water/air spray group was present at 60 seconds. SEM evaluation revealed a damaged etched enamel surface at this rinse time. Shorter rinse times of 10 seconds to 30 seconds with water/air spray were effective.

Research Abstracts

The following research abstracts are unpublished research results from the two-year General Dentistry Residency, Dental Directorate, USAF Medical Center, Keesler AFB, MS. For further information on any of these abstracts please contact:

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The editor wishes to thank the General Dentistry Resident and Graduates, USAF Medical Center, Keesler AFB, MS, for their assistance in the preparation of these research abstracts.

Scanning electron microscope comparison of the effects of various irrigants in root canal debridement. Clarke, D A (1988).

This scanning electron microscope study used a rank-ordered scoring system to statistically compare the amount of debris and smear layer remaining on the canal wall following root canal preparation. The four irrigating regimes used were: (1) 0.9% saline, (2) 5.25% NaOCl, (3) 5.25% NaOCl used alternately with 50% citric acid, and (4) 3% H_2O_2 used alternately with 5.25% NaOCl. The NaOCl/citric acid combination had the lowest (best) cumulative scores for both residual debris and smear layer; however, statistical analysis using the Mann-Whitney U test revealed that the regimen using citric acid was not significantly better than NaOCl used alone.

Effect of chlorine dioxide on color stability and hardness of pink denture-base acrylic. Chamberlain, L B (1987).

The purpose of this study was to determine if repeated soakings in chlorine dioxide (Alcide LD™) caused any visible color change or hardness change in denture-base acrylic. Samples of pink denture-base acrylic were soaked in Alcide LD™, Hibiclens™, or distilled water five times over a period of three weeks. No visible color change in any sample was detected. The hardness of all three groups was checked before and after soakings, using Knoop hardness values. The results showed no significant difference in the hardness of the disks soaked in either disinfectant.

A scanning electron microscope study of the effects of tetracycline HCL on periodontally involved root surface. Feeley, J (1989).

A SEM comparison of the effects of citric acid or tetracycline HCL on periodontally diseased, root-planed teeth showed that tetracycline HCL solution consistently gave smoother root surfaces. Citric acid solutions were adjusted to the same pH as tetracycline concentrations of 10, 50, 100,and 250 mg/ml (pH 2.4, 1.9, 1.6, 1.3 respectively). The collagen fibrils characteristically seen following citric acid treatment were absent from the tetracycline-treated roots. The difference in the two acids' effect on dentin does not appear related to the pH.

The effect of the Prophy-Jet™ on blood pH, electrolyte concentrations. McVay, J T & Synder, J A (1988).

In this canine study, prophylaxes performed with the Prophy-Jet™ showed no significant change in blood-electrolyte pH or sodium levels up to two hours following prophylaxis. These results would not support the warning that the device not be used on patients on a sodium-restricted diet. A human study is planned to further evaluate these questions.

The clinical effect of a stannous fluoride cavity wash on post-operative sensitivity of amalgam restorations. Peterzen, R M (1989).

A double-blind study on 10 patients with matched bilateral amalgam restorations showed that a 60-second toileting of the cavity preparation with an 8% stannous fluoride solution resulted in a statistically sigificant reduction of patient-reported thermal sensitivity ($P < 0.0112$) during the three-month post-operative period.

Methods to reduce bacterial levels on dental-alginate impressions. Bussone, R (1989).

This study on the effect of chlorhexadine rinse in alginate impressions showed a 30-second rinse with plain water reduced bacterial count in the impressions by 50.8%. Adding chlorhexadine (Hibiclens™) for 15 seconds reduced bacteria by 95.6%. A 60-second exposure to the chlorhexadine gave a 99.8% reduction in bacteria. This was a very simple chairside process.

Periodontal dressings: Do they support the growth of periodontal pathogens? Eckles, R L (1984).

Twenty-one patients treated surgically for periodontitis by flap procedures received Coe-Pack™ dressings. In five to seven days the dressings were removed and the tissue side of the dressings and the oral-environment side were cultured under aerobic and anaerobic conditions. There was no significant difference in the types of bacteria found on either side of the dressing. The bacteria found were typical of bacteria found in the formation of plaque.

Book Reviews

DENTAL OFFICE HAZARD COMMUNICATION KIT
Second Edition

Diane Miller, Bud Miller, Peter Harnack

Published by HASCOM, INC, Lake Oswego, OR, 1988. 85 pages. $95.00.

Making sure that your office complies with federal, state, and local regulations concerning sterilization, hazardous chemicals, waste disposal, and employee training is very difficult. This publication can help significantly.

This edition is expanded and improved. Some of the changes result from the fact that the authors have continued to work on the manual, adding useful forms and including new information as it has become available. This is significant, since new regulations continue to be issued and existing ones continue to be expanded. Equally significant is the fact that a year's worth of "updates" are included with the purchase of the manual.

As one example of the improvements in this edition, there is an expanded section designed to organize, explain, and hold Material Safety Data Sheets (MSDS). The explanations of the MSDSs, advice on what to look for, and directions for labeling containers are very clear and helpful. HASCOM now includes a few of the required labels and will sell more at reasonable prices.

The manual will save your office a lot of time; it continues to be a very good value. Highly recommended.

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GLASS-IONOMER CEMENT

Alan D Wilson and John W McLean

Published by Quintessence Publishing Co, Inc, Chicago, 1988. 280 pages, indexed. 338 illustrations (252 in color). $88.00.

This is an excellent, well-prepared text covering all aspects of glass-ionomers. The authors are well-recognized for their leadership in this area of dental materials.

There are 16 chapters in the book. The first eight chapters deal primarily with the development, physical properties, durability, and longevity of glass ionomers. The remainder of the book deals primarily with their clinical usage.

The photographs and the illustrations in the clinical section of the book are mainly in color and well-done.

For the dentist interested in being well-versed in the background and materials science of glass-ionomers as well those whose interests are chiefly in the clinical applications of glass-ionomers, this book will be a handy reference and is recommended to all.

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DIFFERENTIAL DIAGNOSIS OF DISEASES OF THE ORAL MUCOSA

Bengel, W, Dr med dent, and Veltman, G, Prof dr med dent

Published by Quintessence Publishing Co, Inc, 1989. 361 pages, 344 illustrations. $68.00.

This English translation of a German textbook by dermatologists combines a unique approach to differential diagnosis, targeted for dentists and dermatologists, with excellent clinical color photographs of nearly 200 paired oral lesions that are diagnostically different but appear clinically similar. The clinical photographs of lesions affecting the oral tissues are placed above tables containing concise statements on the clinical features of each lesion. The clinical photos and charts are accompanied by text that describes salient features including mucosal and skin changes, etiology, development, a thorough list of differential diagnoses, and a section on therapy. Each differential diagnosis is described in a short paragraph.

The first chapter, "Basic Principles," is well-designed and covers anatomy of the skin and mucosa, functions of the oral mucosa, and the path to diagnosis and therapy. One section describes primary and secondary efflorescences (defined as "skin blooms"). The definitions of the various skin changes listed under efflorescences are understandable even if the term itself is not common to the dental literature. The chapter concludes with well-written sections on clinical examination and further diagnostic measures.

Chapter 2, "Tongue Changes," and Chapter 3, "Cheilitis," cover lesions of the tongue and lips respectively. Chapters 4 through 7 are grouped by the 'main symptoms' of the mucosal changes: light spot, dark spot, tissue defect, and increase in volume. Following the text is a reference section with 189 citations that is followed with a good index.

This text is a good attempt at helping the dental clinician develop a clinical differential diagnosis leading to a working diagnosis for lesions of the oral mucosa. The clinical color photographs are beautiful and the charts and text, as well as other illustrations, are concise and understandable. The major problem for the dental practitioner is that several of the terms used to describe the various oral lesions are not familiar as they are dermatologic in origin. However, the quality of the photographs, the concise nature of the text, and the book's relatively low price make this a reasonable choice for the dental practitioner looking for an atlas of oral lesions with accompanying text to assist the clinician in the diagnosis of oral lesions.

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INFLAMMATION: A Review of the Process Third Edition

Henry O Trowbridge, DDS, PhD, and Robert C Emling, MS, EdD

Published by Quintessence Publishing Co, Inc, 1989. 166 pages, 64 illustrations. $28.00.

The purpose of this book is to provide an overall, simple, and understandable description of the process of inflammation and is targeted to the health practitioners and specialty graduate students including those of the dental community. It is divided into four parts: acute inflammation, the immune system, chronic inflammation, and regeneration and repair.

Part One, "Acute Inflammation," describes the process and results of vascular permeability and the chemicals involved in initiating and maintaining it. Cells involved in acute inflammation are also described, and their role and the role that the complement system plays in the process of chemotaxis is also covered. Part Two, "The Immune System," describes briefly the cells and immunoglobulins involved in establishing this system. Major immune responses are also described. Part Three, "Chronic Inflammation," describes the major factors and conditions involved in initiating and maintaining the chronicity of certain diseases. Part Four, "Repair and Regeneration," describes different types of regeneration and wound healing.

This book adequately covers the process of inflammation at a very basic level with minimum details. The authors succeed in describing, in a very clear manner, some otherwise complicated processes such as opsonization, phagocytosis and bacterial killings, granulomatous inflammation and epitheloid macrophages. The 'check points' add to the strength of this book. They are well-designed and successfully highlight the main objectives of each chapter. The authors have also succeeded in presenting easy-to-read yet scientifically up-to-date material such as describing AIDS when applicable and the different interleukins.

The book, however, has a major weakness, namely, it lacks references. The fact that this book is directed to practicing health professionals and specialty graduate students makes it very important to adequately document major points with very recent and good references. I think the authors should seriously consider this point. I personally would find it very difficult to invest $28.00 in a book that has only four references, regardless of how well it is written.

In summary, the book on inflammation authored by Trowbridge and Emling is well-written, easy to read and to follow. It is scientifically adequate for health professionals and may be for *some* specialty graduate students. However, more references are needed and should be incorporated.

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QUALITY EVALUATION OF DENTAL RESTORATIONS
Criteria for Placement and Replacement

Edited by Kenneth J Anusavice

Published by Quintessence Publishing Co, Inc, Chicago, 1989. 424 pages, indexed. 197 illustrations (56 in color). $96.00.

This publication consists of papers delivered at the International Symposium on Criteria for Placement and Replacement of Dental Restorations held at Lake Buena Vista, Florida, 10-21 October 1987. There are 26 chapters; the last chapter includes the symposium summary statements, criteria, and recommendations. A total of 32 internationally recognized experts participated by contributing to the symposium and the book.

As stated in the preface, the symposium focused on the following subject areas: reliability of caries diagnosis, bacterial leakage versus microleakage, classification of patient risk, variability of the decision-making process, pulpal response to dental materials and microoganisms, material allergies, assessment of restoration quality, criteria for selection of dental materials, insurance consideration, and an analysis of cost versus longevity of sealants, preventive resins, composites, amalgams, cast prostheses, and PFM units. Emphasis was also placed on the assessment of clinical data and existing criteria (such as those proposed by the California Dental Association) for evaluation of restoration quality.

Considering all of the complex issues involved with the placement and replacement of restorations, this book offers considerable insight into the way that dentistry is currently practiced as well as offering some guidance, and a great deal of food for thought, to the practicing dentist.

This book should be read by all dentists practicing restorative dentistry. For many, the concepts discussed and recommended will be foreign and difficult to swallow; nevertheless, it is important for all of us to be more cognizant of the limitation of our diagnostic and treatment skills. For others, this book will be a wealth of knowledge.

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Letters

ADVERTISING OF DENTAL PRODUCTS: In Whose Interest?

With regard to your editorial on advertising of dental products in the Winter 1989 issue, I wholly endorse your position regarding the modification of dental products while retaining the same name. This problem goes deeper and is compounded by the reluctance of manufacturers to put meaningful dates on their products.

The American Standards Committee No MD156 on Dental Materials, Instruments, and Equipment recommends but does not force dental manufacturers to place dates on most products. But companies resist this as it would reveal the age of the product to the end user who may wish to return the merchandise for fresh material. Having sat in many committee and subcommittee meetings over the years, I have often engaged in this debate but have been ruled out by the "lack of teeth" of our regulations. Certainly, there are shelf-life dates on products which may change properties in storage such as impression materials or composite resins. But most other products may have no more than a serial number which may or may not indicate the date of manufacture. The proper dating is important for many reasons:

a) to indicate if changes or improvements were made in the product. The date can help to distinguish when these effects took place;

b) to identify the vintage of the product if, for example, a replacement tooth is needed and the new teeth have different fluorescing agents which would mismatch in UV light;

c) to identify the age of equipment so that the proper parts may be ordered after the unit or manufacturer is out of production or even out of business. When car parts are ordered, the first things specified are the year and model of the car; and

d) The consumer has a right to know if old or fresh merchandise has been purchased.

One often gets the feeling that our ADA Councils favor the big companies over the membership. This is really not true, as they are governed by legal restrictions which are enforced by the US and international standards organizations. Yet it would still be helpful to get the whole truth about the products we purchase; it is often not needed, but when it is, it is very important.

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SCHOLARLY ACTIVITIES: Boon or Bane?

SCHOLARLY ACTIVITIES: Part 2

We feel compelled to comment on your editorial on Scholarly Activities Parts I and II. We agree that the "publish or perish at all costs" syndrome is not the best for clinical dentistry, and you make a strong point in this regard. However, we are concerned that your editorial may not have included a very significant point.

Most would agree that it is important for clinicians to increase the body of knowledge and that there are legitimate, clinically important questions that need to be answered. Unfortunately, most clinicians do not conduct *clinical* research and, therefore, must depend upon laboratory data and "in my opinion"-type publications. There is nothing wrong with in vitro or technique publications but there has to be balance. We fear that balance does not exist today. Frankly, on a percentage basis, the "dentists, basic scientists" are the ones doing research. And more than likely, they will be the ones that dictate to the clinician unless we take a hand in our own destiny. During this last decade, various dental educators have indicated the shortage of clinical researchers. This does not bode well for those of us who are clinicians if we wish to keep both ourselves and our students well-informed.

It is true that new demands are being placed upon clinical teachers which are not always compatible with the time available. Certainly chairmen and other administrators must take into consideration the time available for the faculty. But the clinicians and administrators must also review the efficiencies of their system. The system should be examined to determine if it provides reasonable time for research activities to assure that "I'm too busy to do research" is a valid reason, not a weak excuse, not to do the research.

No one will deny that clinicians are qualified to determine the clinical efficacy of new materials and techniques. Isn't it about time that the experts in clinical teaching also become the experts in clinical research so that we can take our rightful place in the university system and become the leaders in our field?

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RESPONSE

Thank you for your excellent response. I certainly agree that clinicians should conduct clinical research, particularly in restorative dentistry, and that they should also be the leaders in the clinical and laboratory assessment of dental materials as well as the development of new products. The problem as addressed in Part 1 (1988) was concerned primarily with the lack of time in the present-day university setting to allow faculty the time to conduct bona fide research. You state that chairmen and other administrators should take into consideration the time available for the faculty. The problem is that I, as a chairman, as well as most chairmen in North America, do not control our faculty allocation, and as such we are put in a position where we are forced to compel all faculty to engage in research at the expense of clinical teaching time. The students get shortchanged.

As stated before, the "publish or perish syndrome" results in faculty who recognize the need to do research just for the sake of their existing in an academic environment, but they are not provided the time or resources to do this research.

With few exceptions, research is required to be conducted with the same faculty/student staffing ratios which existed prior to the push to do research. As you know, meaningful research cannot be accomplished without the time to do so. Why not ensure that all universities recognize the need to increase the number of faculty positions to allow clinicians to be both educators as well as researchers? Given adequate faculty allocations, I would be the strongest supporter in the country; however, such allocations are not forthcoming, and it is my contention that for many educators their time would be best spent teaching, rather than doing research for which not enough time is authorized.

As concerns the "dentist/basic scientist" trained to the PhD level for conducting research, experience has shown that such individuals are no longer clinicians, but outstanding basic science researchers. Do we need this type of faculty? Of course we do, but they should be supplemental to teaching faculty. It seems to me that there is a concerted move in this country to require faculty of the future to not only have graduate training but to be trained to the level of a PhD in a basic science for the purpose of conducting basic research. If that occurs, where are the clinical dentists going to come from? We will then be in the same position as dental schools in other parts of the world which have stressed basic scientific research to the point where they no longer have clinicians among their faculty. As a result their graduating dentists sadly lack clinical skills.

The solution is for universities to recognize that both clinical dentistry and research require adequate numbers of faculty to get the job done, and this translates into a requirement for adequate funding. It is my contention that this is seldom the case.

DAVID J BALES, DDS, MSD
Editor

Announcements

Chronological Listings of Direct Gold References

Compiled by the Literature and Research Committee of the American Academy of Gold Foil Operators, under the chairmanship of Dr Michael Cochran, this comprehensive, up-to-date bibliography is now available in bound form for $25.00.

Please make check payable to AAGFO and mail to:

Administrative Office AAGFO,
Mrs Nell M Faucett,
2514 Watts Road
Houston, TX 77030.

AAGFO MEETING for 1989

Plan now to attend what promises to be an outstanding event, the annual meeting of the American Academy of Gold Foil Operators to be held in Seattle, Washington from 1-2 November.

Please note that this meeting will be held one day earlier than usual (Wednesday and Thursday). This is to accommodate those leaving for the ADA and related meetings in Hawaii.

On Wednesday morning, 1 November, there will be 30 clinicians demonstrating clinical procedures at the School of Dentistry, University of Washington. This is an unusually large number of clinicians and results from the number of Associated Ferrier Study Clubs members who will be offering clinics as well as many members from other regions of North America, and it promises to provide us with a great variety of direct gold demonstrations. In addition to the classical preparations, other uses of direct golds will be shown, such as obliteration of endodontic access openings and crown repairs.

For Wednesday afternoon, there is planned a tour of the Seattle Underground located at Pioneer Square. A splendid evening social event is planned for the same evening at the meeting hotel, the Olympic Four Seasons.

The lecture session will occur on Thursday. It is not too late to make plans to attend. To do so, please contact Nell Faucett at the address shown above.

Please note the dates for the annual meeting of the Academy of Operative Dentistry for 1990 as a result of the Chicago Midwinter Meeting being scheduled earlier than usual. It is not too soon to make your reservations! This meeting promises to be excellent.

NOTICE OF MEETINGS

American Academy of Gold Foil Operators

Annual Meeting:
1-3 November 1989
University of Washington
Seattle, WA

Academy of Operative Dentistry

Annual Meeting:
8-9 February 1990
Westin Hotel
Chicago, IL

DIRECT GOLD RESTORATIONS FOR GENERAL PRACTITIONERS

Sponsored by the Associated Ferrier Study Clubs

DATES: 21, 22, 23 September 1989

Tuition: $300.00

Instructors:
Dr J Martin Anderson, Dr Richard H Johnson, Dr Ralph G Stenberg, and Dr Richard D Tucker

Synopsis:

This course will be presented with lectures and clinical demonstrations by the instructors and will focus on direct gold restorations that enhance the quality of operative dentistry in general practice. Each level of instruction will be available. Teaching will be directed to those who have had no exposure to direct gold restorations as well as to those who have extensive clinical experience. The course participants will place a minimum of four restorations under the close supervision of the instructors. Special emphasis will be directed to show how direct gold restorations enable the clinicians to build excellent restorative practices with excellent restorative services. Course participants will be prepared to place direct gold restorations in their own practices, and this course will be an excellent foundation for those clinicians who would like to participate in direct gold study club activity. A direct gold technique syllabus will be provided for each participant.

Applications are available from:

Dr Martin J Anderson
221 South 2nd Avenue
Kent, WA 98032

INSTRUCTIONS TO CONTRIBUTORS

Correspondence

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

Exclusive Publication

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

Manuscripts

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

Authors who prepare their manuscripts on a word processor are encouraged to submit an IBM compatible computer disk of manuscript (3½ or 5¼ inch) in addition to original typed manuscript; authors need to identify the word processing program used.

Tables

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

Illustrations

Submit two copies of each illustration. Line drawings should be in india ink or its equivalent on heavy white paper, card, or tracing vellum; any labeling should be on an extra copy or on an overleaf of tracing paper securely attached to the illustration, not on the illustration itself. Type legends on separate sheets. Photographs should be on glossy paper and should be cropped to remove redundant areas. For best reproduction a print should be one-third larger than its reproduced size. Maximum size of figure is 15x20 cm (6x8 inches). The cost of color plates must be met in full by the author. On the back of each illustration, near the edge, indicate lightly in pencil the top, the author's name, and the number of the figure. Type legends on a separate sheet. Where relevant, state staining techniques and the magnification of prints. Obtain written consent from holders of copyright to republish any illustrations published elsewhere.

References

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

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