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

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EDITORIAL

Procedural Requirements: Are They Necessary?

Twenty years ago, the largest segment of the curriculum in dental schools was dedicated to restorative dentistry, chiefly operative dentistry, fixed and removable prosthodontics. With the increasing demands for other clinical disciplines, there has been an overall reduction of time available for restorative procedures, as periodontics and endodontics have rightfully been incorporated into all schools' basic educational programs. We also have seen a large increase in the amount of basic sciences required. The science curriculum has expanded as a result of the explosion of knowledge occurring in the past 30 years. How is it that our "great educational planners" have the ability to see that the world is changing rapidly as regards the basic sciences and other nonclinical disciplines but have blinders in place when it comes to restorative dentistry? We too have had an explosion of knowledge, clinical procedures, and techniques, and the field of dental materials gets more complex by the minute. We have a great deal more to teach today than in the past, with less and less time allotted for teaching restorative techniques and procedures.

Besides the reduction in time available, there is continuing pressure to eliminate clinical procedural requirements. Nonclinical faculty and most dental school administrators are insisting that we do not need procedural requirements. The primary reason given is that patient care should come first, and if the students treat their assigned patients, they will automatically acquire the skills they need. That is not so; today's restorative procedures are so diverse and complex that students cannot expect to receive a well-rounded education without enough repetition built in to acquire the skills and competence necessary to practice in the modern world.

Another reason given for eliminating procedural requirements is that medical students are not trained that way, so why should we treat our students any differently? We are told we should treat them as professionals and let them learn whatever they want to from their total experience, which would result in better professionals who would have an easier time in dental school. As we constantly have the training of medical students thrown at us as an example of what we should strive for in dental education, let us take a look at the differences. Medical students graduate and are not licensed to practice medicine until they have completed a medical residency training program. In medical residencies where technical skills are important, there are requirements for training, and many of those requirements are procedural. To complete medical residencies requiring technical skills, one must accomplish given numbers and types of procedures to ensure competence. Most dental residencies also have definite procedural requirements for program certification. It seems strange to me that so many specialists in our dental schools can see the need for procedural requirements for specialty training but are against having them in the undergraduate curriculum.

Can we teach students the technical requirements of the many complicated and diverse procedures taught today without their being required to actually perform enough clinically to become proficient at any given procedure? I do not believe it can be done. How many patients would care to be treated by a dentist who has not accomplished a sufficient variety of procedures to be clinically competent at the time of graduation? Patients have a right to be protected!

Check on your dental school. Have the procedural requirements which most of you experienced been all but eliminated and, if so, to what benefit? It is time to be heard. There are too many well-meaning bureaucrats in our educational system trying to eliminate this most important means of ensuring clinical competency of the graduates. Technical skills are still required to treat today's patients and the patients of the future.

DAVID J BALES
Editor

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ORIGINAL ARTICLES

Glass-Ionomer Cements in Dental Practice: A National Survey

L H KLAUSNER • H E BRANDAU • G T CHARBENEAU

Summary

Certain characteristics of glass-ionomer cements would appear to make them desirable dental materials; however, many practitioners are reluctant to use them because of reports of postoperative sensitivity. The members of the Academy of Operative Dentistry were surveyed in order to assess quantitatively and qualitatively the use of glass-ionomer cements in their practices, as well as the incidence and nature of postoperative sensitivity.

The following data were collected: 1) the past and present use of glass-ionomer cements, 2) reasons for disuse of glass-ionomer cements, 3) products which are or have been used, and 4) the incidence of and resolution of postoperative sensitivity. The results are presented and discussed. An interesting secondary finding identified that zinc phosphate when used as a luting agent may contribute to postoperative sensitivity more often than is appreciated.

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Introduction

At present there is no "ideal" dental cement available which possesses all of the manipulation characteristics and biomaterial properties desirable in restorative dentisty. Zinc-phosphate and zinc-oxide-eugenol cements developed in the late nineteenth and early twentieth centuries may still be the most established and widely used cements today. Zinc phosphate has become the standard against which other cements are compared. The development of an adhesive cement began with the initial work of Smith (1968) through the use of polyacrylic acid as a replacement for the phosphoric acid in zinc-phosphate cements. Shortly after, the formulation of glass-ionomer restorative cements followed as a result of the development of ion-leachable glasses by Wilson and Kent (1972). These cements are formed by a setting reaction of aluminosilicate glass powders and aqueous solutions of polyacrylic acid. In addition to having prerequisite biomaterial properties such as low solubility (Mitchem & Gronas, 1978, 1981) and high compressive and tensile strengths (Kent, Lewis & Wilson, 1973; McComb, Sirisko & Brown, 1984), glass-ionomer cements produce an adhesive chemical bond to tooth structure (Charbeneau & Bozell, 1979; Hood, Childs & Evans, 1981; Smith, 1983; Brandau, Ziemiecki & Charbeneau, 1984; Lacefield, Reindl & Retief, 1985) and release fluoride (Maldonado, Swartz & Phillips, 1978; Swartz, Phillips & Clark, 1984; Retief & others, 1984; Wilson, Groffman & Kuhn, 1985). These latter characteristics would appear to make these cements extremely useful biomaterials. Since their introduction in the United States in 1977 and American Dental Association acceptance in 1979 (Council on Dental Materials and Devices, 1979), they have been used as luting agents for cast and other indirect restorations, as liners or bases beneath other restorative materials, and as a restorative filling material. Most recently their use as a lining/luting material beneath composite resins has increased as a result of their ability to adhere to both dentinal tissue and the restorative material. Previous studies have indicated that glass-ionomer cements have biological properties similar to the polycarboxylate cements and that pulpal response is similar to or less than that with zinc phosphate (Tobias & others, 1978; Pameijer, Segal & Richardson, 1981; Smith, 1983), while others have found greater pulpal inflammation in response to glass-ionomer cements (Cooper, 1980; Plant & others, 1984).

It is believed that some dentists are reluctant to use these cements because of reports of postoperative sensitivity. As a result of receiving comments from the dental profession about postoperative complications in some fixed prosthodontic restorations in which glass-ionomer cements were used as luting agents, the Council on Dental Materials, Instruments, and Equipment of the American Dental Association publicized this problem in 1984 (Council of Dental Materials, Instruments, and Equipment, 1984). Their report stated that although the incidence of sensitivity appeared infrequent, the similarity of the complaints was reason for legitimate concern. A number of investigations have explored these allegations histologically (Pameijer & others, 1981; Myers & others, 1983; Graver, Alperstein & Trowbridge, 1986; Heys & others, 1987); however, the true nature and cause of sensitivity following the use of glass-ionomer cement is yet to be elucidated.

It was believed that a broadly based survey of the dental practitioners in the United States and Canada regarding their use of glass-ionomer cements and their clinical experiences with postoperative sensitivity would be helpful in defining the magnitude of the problem, and perhaps would provide direction for further specific inquiry.

Survey Method

Consent was obtained from the Executive Council of the Academy of Operative Dentistry to survey its membership regarding their observations concerning the use of glass-ionomer cements. A nine-question survey was designed which asked respondents to report on their experiences with both glass-ionomer and non-glass-ionomer cements. The directed and open response questions related to the extent of use of glass-ionomer cements and postoperative sensitivity following the use of glass-ionomer and non-glass-ionomer cements. An area was provided at the end of the survey to allow for additional comments.

Results

Four hundred and eighty-seven (487) usable surveys were returned which represent 50% of the 980 US and Canadian members who were surveyed.

Responses to the initial questions related to the extent of use of glass-ionomer cements. Eighty-six percent (405) of the respondents have tried glass-ionomer cements. For those who have not tried them, the reasons included: why change? (33%), no reason (20%), retiring or retired (17%), and not available (11%). Ninety-three percent (376) of those that have tried glass-ionomer cements are still using these cements, while 7% (30) have discontinued using glass ionomers. Reasons presented for this included: why change? (35%), unavailability (30%), no reason (15%), and technique sensitivity (15%).

The next several questions focused upon postoperative sensitivity when using glass-ionomer cements. Ninety-five percent (359) of those who responded were not restricting the use of glass-ionomer cement to nonvital teeth. Forty-six percent of the respondents commented that their patients experienced postoperative sensitivity following use of glass-ionomer cement as a luting agent. Twenty-six percent observed hypersensitivity in patients for whom a liner/base had been placed (Table 1). Those dentists whose patients have experienced postoperative sensitivity when glass-ionomer cement was used indicated that the occurrence was infrequent (< 5 %) in 76% of the cases. Postoperative sensitivity was reported to be an occasional occurrence (5-30%) in 16% of the cases, and frequent (over 30%) in 8% of the cases (Table 2). This sensitivity is an infrequent occurrence that is believed to be primarily related to preoperative signs and symptoms plus the operative procedure (45% of the respondents), or related to the glass-ionomer cement (27%), or to both (29%). The nature, onset, and resolution of the sensitivity following the use of glass-ionomer cement was reported (Table 3). The observed onset of sensitivity occurred early on, with 90% taking place within the first seven days, and nearly one-half of these occurring during the first 24 hours. Only 15% of the patients reported the sensitivity as being severe; the remaining 85% were nearly equally divided as to whether it was light or moderate. Respondents were asked to report on isolation and moisture control; 67% of the respondents reported establishment of a "dry field," the remainder working within a "somewhat dry/moist cementation field."

One question focused upon the practitioner's experience with other types of cements. The "open response" format elicited comments that were almost entirely based on experiences with zinc-phosphate cement, with a few comments arising from experience with polycarboxylate

Table 1. Incidence of postoperative sensitivity following the use of glass-ionomer cements

Have any of your patients ever experienced postoperative sensitivity following the use of glass-ionomer liner/cement on a vital tooth for:

luting:	46%	(125/269)*
liner/base:	26%	(88/345)
core:	6%	(12/199)
restoration:	13%	(28/217)

*(total yes/no responses)

Table 2. Frequency and source of postoperative sensitivity following the use of glass-ionomer cement

Is postoperative sensitivity an occurrence that is

infrequent (<5%):	76%
occasional (5-30%):	16%
frequent (>30%):	8%

Do you attribute the postoperative sensitivity primarily to the

glass-ionomer cement:	27%
preop signs/symp + op proc:	45%
both:	29%

Table 3. Onset, nature, and resolution of the postoperative sensitivity following the use of glass-ionomer cement

How soon after the use of the glass-ionomer cement does the sensitivity usually develop?

within 24 hours:	43%
1 - 7 days:	47%
1 - 4 weeks:	9%
>1 month:	1%

Have patients reported the sensitivity as being

light:	44%
moderate:	41%
severe:	15%

How is sensitivity most often resolved?

time	59%
re-restoration	27%
endodontics	9%
occlusal adjustment	4%
other	1%

cement (Table 4). The onset and resolution of the sensitivity following the use of non-glass-ionomer cement was reported (Table 5).

Discussion

The information tabulated from this nationwide survey of dentists indicates that glass-ionomer cements have been and are currently being used by a large number of practitioners with special interest in restorative dentistry. The principal reasons given, both for not ever using the material and for discontinuing its use, appear to be satisfaction with other materials (zinc phosphate and polycarboxylate) which perform the same clinical function. Few dentists (5%) are restricting the use of the glass-ionomer cements to nonvital teeth.

Nearly one-half of the respondents using glass-ionomer cement as a luting agent report that some patients have experienced postoperative sensitivity. This corroborates information reported by the American Dental Association Council on Dental Materials, Instruments, and Equipment in 1984. While about one-quarter of these practitioners attributed the postoperative sensitivity primarily to the glass-ionomer cement, the remaining three-quarters believed that the prior condition of the tooth and the operative procedure, or these factors in combination with the cement, affected the sensitivity. Such a clinical judgment is not unexpected, since there are a multitude of factors that mediate pulpal response. Sensitivity usually develops soon after the treatment and is reported by most patients as being light or moderate in intensity. Although time alone appears to resolve the sensitivity in many instances, rerestoration or endodontic treatment was required in more than one-third of the cases. In addition, these data indicate a higher percentage of rerestoration when glass-ionomer cements resulted in postoperative sensitivity than when zinc phosphate was used. Perhaps either the duration or the severity of the sensitivity was greater when glass-ionomer cement had been used.

Interestingly, zinc-phosphate cement is reported to be associated with postoperative sensitivity by nearly double the percentage reported with glass-ionomer cement. As early as 1920 zinc-phosphate cement had been suspected of causing postoperative sensitivity and possible irreversible pulpal damage (Brännström & Nybörg, 1960; Smith & Ruse, 1986). Perhaps clinicians are not as sensitive to this issue or may have just learned to live with this problem and to adapt

Table 4. Incidence of postoperative sensitivity following the use of a nonglass-ionomer cement

Have any of your patients ever experienced postoperative sensitivity following the use of any cements <u>other than</u> glass ionomer for:

Luting:	80% (323/406)*
	number of responses
zinc phosphate:	274
carboxylate:	5
both:	9
other:	8
Liner/Base:	9% (130/268)*
	number of responses
zinc phosphate:	58
carboxylate:	2
both:	1
other:	47

*(total yes/no responses)

Table 5. Frequency and resolution of the postoperative sensitivity following the use of nonglass-ionomer cement

Is postoperative sensitivity experienced with cements other than glass ionomer an occurrence that is

infrequent (<5%):	71%
occasional (5-30%):	28%
frequent (>30%):	1%

How is the sensitivity most often resolved?

time:	69%
re-restoration:	18%
endodontics:	8%
other:	5%

clinical procedures to minimize untoward patient response, such as using resinous film-forming cavity varnishes. It may be that the introduction of glass-ionomer cement merely provided a focal point for a renewed expression of concern for an ongoing problem.

Variables that can be controlled by operator manipulation such as powder:liquid ratio, mixing time, and moisture control have an effect on the properties of dental cements (Henschel, 1943; Myers, Drake & Brantley, 1978; McLean, Wilson & Prosser, 1984). A manipulation factor that this survey sought out was the presence or absence of moisture in the cementation field. The moisture sensitivity of glass-ionomer cement during its prolonged initial setting is well-documented (Mount & Makinson, 1982; Myers & others, 1983; Smith, 1983). Two-thirds of the respondents to this survey indicated that they established a "dry" tooth in contrast to a "somewhat dry (moist)" tooth. The term "dry" is relative and could range from dehydrated to just having the surface moisture removed. It is thought that this relative "dryness" may exacerbate the effect of the lower pH values for longer time periods observed with the glass-ionomer cements (Smith & Ruse, 1986; Berry & Berry, 1987). The immediate onset of sensitivity in one-half of the reported cases would support this hypothesis. Theories of postoperative sensitivity as it relates to cement loss through dissolution or marginal leakage resulting in bacterial invasion have been discounted (Graver & others, 1986; Phillips & others, 1987).

Although survey data is by its very nature "soft" data, a better understanding of the postoperative sensitivity reported to be associated with glass-ionomer cements has been obtained. The magnitude and certain characterisics of the problem have been defined, as well as its relationship to similar treatment procedures. A basis has been provided for more definitive investigational planning.

Conclusions

From this nation-wide survey of restorative dental practitioners it was concluded that:

Glass-ionomer cements have been and are being used by a large number of practitioners as liners and bases, luting agents, core build-ups, and final restorative materials.

When glass-ionomer cements are used as luting agents, early onset of light-to-moderate postoperative sensitivity may be encountered as a result of dehydration of the tooth prior to cementation.

Zinc-phosphate cement when used as a luting agent may contribute to postoperative sensitivity more often than is appreciated.

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References

BERRY, E A III & BERRY, L L (1987) The successful use of glass ionomer luting cements without post-cementation sensitivity *Texas Dental Journal* **104** 8-10.

BRANDAU, H E, ZIEMIECKI, T L & CHARBENEAU, G T (1984) Restoration of cervical contours on nonprepared teeth using glass ionomer cement: a 4-1/2 year report *Journal of the American Dental Association* **108** 782-783.

BRÄNNSTRÖM, M & NYBÖRG, H (1960) Dentinal and pulpal response: IV. Pulp reaction to zinc oxyphosphate cement. A morphologic study on dog and man *Odontologisk Revy* **11** 37-50.

CHARBENEAU, G T & BOZELL, R R III (1979) Clinical evaluation of a glass ionomer cement for restoration of cervical erosion *Journal of the American Dental Association* **98** 936-939.

COOPER, I R (1980) The response of the human dental pulp to glass ionomer cements *International Endodontic Journal* **13** 76-88.

COUNCIL ON DENTAL MATERIALS AND DEVICES (1979) Status report on the glass ionomer cements *Journal of the American Dental Association* **99** 221-226.

COUNCIL ON DENTAL MATERIALS, INSTRUMENTS, AND EQUIPMENT (1984) Reported sensitivity to glass ionomer luting cements *Journal of the American Dental Association* **109** 476.

GRAVER, H T, ALPERSTEIN, K & TROWBRIDGE, H (1986) Microleakage of castings cemented with glass ionomer cements *Journal of Dental Research* **65** *Abstracts of Papers* p 253 Abstract 751.

HENSCHEL, C J (1943) The effect of mixing surface temperature upon dental cementation *Journal of the American Dental Association* **30** 1583-1589.

HEYS, R J, FITZGERALD, M, HEYS, D R & CHARBENEAU, G T (1987) An evaluation of a glass ionomer luting agent: pulpal histological response *Journal of the American*

Dental Association **114** 607-611.

HOOD, J A A, CHILDS, W A & EVANS, D F (1981) Bond strengths of glass-ionomer and polycarboxylate cements to dentine *New Zealand Dental Journal* **77** 141-144.

KENT, B E, LEWIS, B G & WILSON, A D (1973) The properties of a glass ionomer cement *British Dental Journal* **135** 322-326.

LACEFIELD, W R, REINDL, M C & RETIEF, D H (1985) Tensile bond strength of a glass-ionomer cement *Journal of Prosthetic Dentistry* **53** 194-198.

MALDONADO, A, SWARTZ, M L & PHILLIPS, R W (1978) An in vitro study of certain properties of a glass ionomer cement *Journal of the American Dental Association* **96** 785-791.

McCOMB, D, SIRISKO, R & BROWN, J (1984) Comparison of physical properties of commercial glass ionomer luting cements *Journal of the Canadian Dental Association* **50** 699-701.

McLEAN, J W, WILSON, A D & PROSSER, H J (1984) Development and use of water-hardening glass-ionomer luting cements *Journal of Prosthetic Dentistry* **52** 175-181.

MITCHEM, J C & GRONAS, D G (1978) Clinical evaluation of cement solubility *Journal of Prosthetic Dentistry* **40** 453-456.

MITCHEM, J C & GRONAS, D G (1981) Continued evaluation of the clinical solubility of luting cements *Journal of Prosthetic Dentistry* **45** 289-291.

MOUNT, G J & MAKINSON, O F (1982) Glass-ionomer restorative cements: clinical implications of the setting reactions *Operative Dentistry* **7** 134-141.

MYERS, C L, DRAKE, J T & BRANTLEY, W A (1978) A comparison of properties for zinc phosphate cements mixed on room temperature and frozen slabs *Journal of Prosthetic Dentistry* **40** 409-412.

MYERS, M L, STAFFANOU, R S, HEMBREE, J H Jr & WISEMAN, W B (1983) Marginal leakage of contemporary cementing agents *Journal of Prosthetic Dentistry* **50** 513-515.

PAMEIJER, C H, SEGAL, E & RICHARDSON, J (1981) Pulpal response to a glass-ionomer cement in primates *Journal of Prosthetic Dentistry* **46** 36-40.

PHILLIPS, R W, SWARTZ, M L, LUND, M S, MOORE, B K & VICKERY, J (1987) In vivo disintegration of luting cements *Journal of the American Dental Association* **114** 489-492.

PLANT, C G, BROWNE, R M, KNIBBS, P J, BRITTON, A S & SORAHAN, T (1984) Pulpal effects of glass ionomer cements *International Endodontic Journal* **17** 51-59.

RETIEF, D H, BRADLEY, E L, DENTON, J C & SWITZER, P (1984) Enamel and cementum fluoride uptake from a glass ionomer cement *Caries Research* **18** 250-257.

SMITH, D C (1968) A new dental cement *British Dental Journal* **125** 381-384.

SMITH, D C (1983) Dental cements; current status and future prospects *Dental Clinics of North America* **27** 763-792.

SMITH, D C & RUSE, N D (1986) Acidity of glass ionomer cements during setting and its relation to pulp sensitivity *Journal of the American Dental Association* **112** 654-657.

SWARTZ, M L, PHILLIPS, R W & CLARK, H E (1984) Long-term F release from glass ionomer cements *Journal of Dental Research* **63** 158-160.

TOBIAS, R S, BROWNE, R M, PLANT, C G & INGRAM, D V (1978) Pulpal response to a glass ionomer cement *British Dental Journal* **144** 345-350.

WILSON, A D & KENT, B E (1972) A new translucent cement for dentistry: the glass-ionomer cement *British Dental Journal* **132** 133-135.

WILSON, A D, GROFFMAN, D M & KUHN, A T (1985) The release of fluoride and other chemical species from a glass-ionomer cement *Biomaterials* **6** 431-433.

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Rubber Dam Usage among Practicing Dentists

R B JOYNT • E L DAVIS • P J SCHREIER

Summary

This study reports on a survey administered to graduates of the State University of New York at Buffalo School of Dental Medicine concerning usage of and attitudes toward the rubber dam. Differences in both reported usage and attitudes were found between graduates who had received minimal rubber dam training and those who had received more intensive training. Those with graduate training reported more frequent use of the dam than those with no graduate training; however, overall reported usage of the rubber dam was quite low. Comments provided by some respondents suggest that in the educational process a greater emphasis should be put on the reasons for using the dam rather than placement technique.

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INTRODUCTION

The value of the rubber dam in restorative dentistry has been well established (Murray, 1960), and is closely associated with quality patient care. While the advantages of the rubber dam are stressed in the curriculum of American dental schools (Smith & Richeson, 1981), only a small percentage of graduates utilize the rubber dam when they enter private practice (Going & Sawinski, 1967). Usage varies to some degree by geographic area and practice situation (Hagge

& others, 1984). Efforts have been made to evaluate characteristics of undergraduate training to determine what factors and/or instructional techniques lead to the highest rate of rubber dam usage by students following graduation. Wolcott and Goodman (1964) determined that rubber dam usage following graduation increased as the amount of teaching time, particularly clinical teaching time, increased.

In the late 1960s, a significant modification in teaching the use of the rubber dam was made in the Department of Operative Dentistry at the State University of New York (SUNY) at Buffalo. New instructional materials were developed and the time spent on rubber dam instruction at the preclinical and clinical levels was substantially increased. Students were required to apply the rubber dam for all direct procedures in both preclinical and clinical situations. Prior to this time, use of the rubber dam had been encouraged but not required.

To determine the long-range effects of these changes on rubber dam use, a mail survey was conducted of all graduates over the past three decades. The survey also attempted to disclose other training factors and/or practice situations that might be related to a higher rate of usage.

METHODS

Subjects included all alumni who had graduated from SUNY at Buffalo School of Dental Medicine between 1955 and 1985. These years were selected because they represent graduating classes approximately 15 years prior to and 15 years after the introduction of intensive training in the use of the rubber dam for operative dentistry procedures. The first graduates to benefit from the full modification to the rubber dam instructional program were members of the class of 1969.

The survey (figure) ascertained the type of training, if any, received after dental school (including postgraduate and residency training) and current practice situation (solo versus group, hospital and/or dental school affiliation). The questionnaire also asked respondents to indicate whether they performed amalgam, anterior composite, posterior composite and

YEAR OF GRAD ________ GP (Y/N) SPECIALTY (Y/N) ____________________

(CHECK APPROPRIATE BOXES): POSTGRAD TRAINING ☐ RESIDENCY TRAINING ☐
SOLO PRACTICE ☐ GROUP PRACTICE ☐
HOSPITAL AFFILIATION ☐ DENTAL SCHOOL AFFILIATION ☐

		DO YOU PERFORM	USE RUBBER DAM NEVER				ALWAYS
YES	NO	AMALGAMS	1	2	3	4	5
YES	NO	ANTERIOR COMPOSITES	1	2	3	4	5
YES	NO	POSTERIOR COMPOSITES	1	2	3	4	5
YES	NO	ENDODONTICS	1	2	3	4	5

HOW DO YOU FEEL ABOUT YOUR DENTAL SCHOOL TRAINING IN THE USE OF THE RUBBER DAM?

INADEQUATE 1 2 3 4 5 ADEQUATE

DO YOU FEEL RUBBER DAM HAS/WOULD HAVE ANY EFFECT ON THE QUALITY OF YOUR RESTORATIVE DENTISTRY?

NONE 1 2 3 4 5 GREAT

COMMENTS: ____________________

Survey response form, rubber dam usage endodontic procedures and, if so, how often they used the rubber dam for each procedure. Frequency of rubber dam use was measured on a scale of 1 (Never) to 5 (Always). Respondents also rated the adequacy of their dental school rubber dam training, on a scale of 1 (Inadequate) to 5 (Adequate), and the effect they thought the rubber dam had or would have on the quality of their restorative dentistry, on a scale of 1 (None) to 5 (Great). Additional space was provided for comments.

The survey was printed on 3 x 5-inch pre-addressed, postage-paid business reply cards and mailed in the summer of 1985 to all 1,726 alumni from the graduating classes of 1955 to 1985, based on the current mailing list of the dental school's Alumni Association.

RESULTS

Demographics

Responses were received from 1014 alumni, resulting in a response rate of 59%. We believe that this is a conservative estimate of response rate, as it is likely that some nonrespondents either were deceased or did not receive the survey due to change of address. Most respondents (76%) were in general practice. Breakdown by specialty for those respondents reporting a specialty practice (n = 177; 17%) appears in Table 1. Sixteen percent of the survey respondents indicated that they had undergone graduate training. One quarter (24%) had received or were undergoing residency training. Fifty-five percent indicated a solo practice, while 29% reported a group practice affiliation. Nineteen percent were affiliated with a hospital, and 9% reported a dental school affiliation.

Table 1. Breakdown of Specialists by Specialty (n = 177)

	N	%
Orthodontics	47	26.5
Pedodontics	43	24.3
Oral Surgery	28	15.8
Endodontics	21	11.9
Periodontics	20	11.3
Fixed Prosthodontics	10	5.6
Removable Prosthodontics	7	3.9
Oral Medicine	1	0.6

Rubber Dam Usage

Respondents were asked to indicate a) whether they performed amalgams, anterior composites, posterior composites, and endodontics, and b) how often they used the rubber dam for these procedures. Distribution of responses appears in Table 2. The percentage of dentists reporting that they always use the rubber dam for restorative procedures was relatively low (10 to 17%). Many indicated that they never use the rubber dam for restorative dentistry (40 to 45%). This trend is reversed for endodontic procedures, with the majority reporting that they always use the rubber dam (62%).

Attitudes Toward Rubber Dam Compared to Rubber Dam Training

Students at SUNY at Buffalo School of Dental Medicine first received intensive rubber dam instruction in the fall of 1968. Beginning with the graduating class of 1969 and continuing to the present, students have been required to use the rubber dam for all direct clinical operative procedures as well as for endodontics. Therefore, comparisons between dentists who had received minimal rubber dam training (all graduating classes prior to 1969) and those who had received intensive training in rubber dam use (graduating classes from 1969 to 1985) were made. All but three respondents indicated their year of graduation. Sixty-five percent of the sample (n = 663) graduated between 1969 and 1985.

Comparisons between the two groups were made on the basis of attitudes toward the adequacy of their rubber dam training and the effect the rubber dam has or would have on the quality of their restorative dentistry. Those with intensive dental school training in rubber dam technique were more likely than those with minimal training to consider their training to have been adequate (64% vs 29%), and were more likely to consider the rubber dam to have a great or fairly

*Table 2. Frequency of Rubber Dam Use by Restorative Procedure**

PROCEDURE	USE OF RUBBER DAM					Total
	Never				Always	
	1	2	3	4	5	N
Amalgams	396 (45.4)	216 (24.8)	84 (9.6)	86 (9.9)	90 (10.3)	872
Anterior composites	355 (40.1)	228 (25.8)	122 (13.8)	82 (9.3)	98 (11.1)	885
Posterior composites	245 (39.9)	132 (21.5)	70 (11.4)	62 (10.1)	105 (17.1)	614
Endodontics	94 (11.0)	38 (4.4)	65 (7.6)	127 (14.8)	532 (62.1)	856

*Row percentages in parentheses

great impact on the quality of their restorative dentistry (52% vs 39%). These differences do not take into account whether respondents use the rubber dam, but merely reflect attitudes.

Rubber Dam Usage Compared to Rubber Dam Training

A comparison was also made of rubber dam usage versus rubber dam training (intensive versus minimal). A statistically significant difference in rubber dam usage versus training was noted for each of the four dental procedures included in the survey. Among those with minimal rubber dam training, 56 to 61% reported that they never use the rubber dam for restorative procedures, compared to only 31% of those with intensive rubber dam training. Fewer than one-half of those with minimal training indicated that they always use the rubber dam for endodontics (46%), compared to 69% of those who had received intensive rubber dam instruction in dental school.

Usage Compared to Perceptions of Rubber Dam Effect

For reasons of simplicity in analysis and interpretation, 5-point scales were collapsed to 3-point scales for all remaining analyses. Values of 1 and 2 were collapsed, as were values of 4 and 5.

The relationship between reported rubber dam usage and perceptions of the effect of the rubber dam on the quality of restorative dentistry was also studied. Dentists who stated that the rubber dam has or would have little or no effect on the quality of their restorative dentistry also reported that they never or rarely use the rubber dam (91 to 99%).

Among respondents who indicated that the rubber dam has or would have a great or fairly great effect on the quality of their restorative dentistry, a slightly higher percentage use the rubber dam (always or usually) as do not (never or rarely) for amalgam and anterior composite restorations. More than twice as many from this group use the rubber dam as do not use it for posterior composite restorations (60 vs 24%). Positive attitudes toward the effect of the rubber dam on quality of restorative dentistry seem to be a necessary but not sufficient condition for rubber dam use.

This relationship can also be discussed in terms of a comparison of the perceptions of rubber dam effectiveness between those who use the rubber dam and those who do not. Among those who always or usually use the rubber dam for restorative procedures, there appears to be a strong belief that the rubber dam has a great or fairly great effect on their restorative dentistry (89 to 97%). Those who rarely or never use the rubber dam vary in their attitudes toward effect of the rubber dam. Approximately half of these dentists stated that the rubber dam would have little or no effect on the quality of their restorative dentistry (50 to 55%), while nearly one-fourth indicated that it would have a great or fairly great effect (16 to 25%). This pattern also emerged when the sub-group with intensive rubber dam training was examined alone, suggesting that among those who do not use the rubber dam, perceptions of the effect of the rubber dam on quality of restorative procedures are unrelated to training in dental school.

Usage Compared to Graduate Training

Comparisons of rubber dam usage were made between those with graduate training and those without. These results indicated a significantly higher reported usage for restorative procedures among those with graduate training (32 to 38%) than among those with no graduate training (19 to 26%). No significant differences in rubber dam usage were found for endodontics.

Usage Compared to Practice Situation

Comparisons of rubber dam usage with practice situations revealed a significantly higher percentage of those in group versus solo practice reporting use of the rubber dam for anterior composite (23 vs 16%) and endodontic procedures (84 vs 72%). There were no differences between the two groups in reported rubber dam usage for amalgam or posterior composite restorations.

Open-ended Responses

Respondents were given the opportunity to provide additional comments at the end of the survey. Over one-third of the sample (n = 377; 37%) offered comments.

The most frequent negative comment concerned the time involved in using the dam (16%). Sample remarks included: "Time factor makes routine use of dam difficult in private practice," and "... takes more time than it's worth." Another frequent negative comment addressed a concern that rubber dam use was overemphasized in dental school (14%). These comments included: "The rubber dam was presented more as another obstacle to overcome than as a helpful tool", "... use ... is indicated in dental school because it makes life easier. As you become proficient in your technique ... it is not required," and "overkill!!!". Other common remarks concerned appropriateness of the rubber dam in selected situations (11%), negative attitudes on the part of patients (11%), and the belief that better methods of isolation are available (11%).

The most common positive response reflected attitudes toward use of the technique (16%). These remarks included "one of the greatest tools in dentistry", "I feel I perform a more superior restoration with the rubber dam," and "... can't imagine anyone doing dentistry without it."

DISCUSSION

A number of trends are apparent from these data. First, most dentists surveyed report that they rarely or never use the rubber dam for restorative procedures. Further, a surprisingly small percentage (62%) report routine use of the rubber dam for endodontics.

Dentists who had received intensive instruction in rubber dam usage were more likely to report that they use the rubber dam for both restorative and endodontic procedures and that rubber dam usage has or would have a great impact on the quality of their restorative dentistry than those who had received minimal instruction.

Dentists who reported that the rubber dam has little or no effect on the quality of restorative dentistry indicated that they never or rarely use the rubber dam; however, positive attitudes appear to be necessary but not sufficient for rubber dam use. Among those who stated that the rubber dam has an effect on the quality of their restorative procedures, about the same number reported using the rubber dam as not for amalgam and anterior composite resin restorations, while two and one-half times as many use the dam for posterior composites as do not.

One interesting finding was that nearly one-fourth of those who do not use the rubber dam report that use of the dam would have a great or fairly great effect on the quality of their restorative dentistry. It is likely that the perception of the time needed to place the rubber dam, noted by 16% of those who provided open-ended comments, outweighs the perceived benefits of using the rubber dam for this group of respondents.

Greater rubber dam usage was reported among those with graduate training than among those with no graduate training. It may be that this training provided dentists with more time to practice efficient placement of the rubber dam. Those in group practice reported using the rubber dam more frequently for anterior composite restorations and endodontics than those in solo practice. The reason for this difference is not clear.

These data suggest that the introduction of an intensive program of rubber dam training at the State University of New York at Buffalo has resulted in an increase in rubber dam usage by its graduates. However, there are common perceptions among many dentists that use of the rubber dam has little or no effect on the quality of their restorative dentistry, that it is a waste of valuable clinic time, and that the rubber dam is not a necessary component of the dentist's armamentarium.

It is possible that rubber dam instruction itself has had a negative impact on students. Several comments (14%) focused on overemphasis of the rubber dam in dental school. As one graduate put it, "isolating entire arches for operative work always seemed unnecessary in school. Stressing a practical, realistic approach would aid in greater acceptability."

As dental educators, we must take care not only to instruct students in the proper placement and usage of the rubber dam, but also to provide the rationale for its use and to make clear to the student its importance and relevance in the practice of modern dentistry.

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References

GOING, R E & SAWINSKI, V J (1967) Frequency of use of the rubber dam: a survey *Journal of the American Dental Association* **75** 158-166.

HAGGE, M S, PIERSON, W P, MAYHEW, R B, COWAN, R D & DUKE, E S (1984) Use of rubber dam among general dentists in the United States Air Force dental service *Operative Dentistry* **9** 122-129.

MURRAY, M J (1960) The value of the rubber dam in operative dentistry *Journal of the American Academy of Gold Foil Operators* **3** 25-31.

SMITH, G E & RICHESON, J S (1981) Teaching of rubber dam technique in North America *Operative Dentistry* **6** 124-127.

WOLCOTT, R B & GOODMAN, F (1964) A survey of rubber dam Part 1: instruction *Journal of the American Academy of Gold Foil Operators* **7** 28-34.

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Effect of Retarder on Compression Set of an Addition Silicone

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Summary

Use of a retarder with a light-bodied addition silicone according to the manufacturer's recommendations increased the working time but resulted in poorly fitting crowns fabricated from these impressions. The compression set of the retarded mixes at the recommended time of removal was 3.2% compared with 0.08% for the nonretarded control. Increasing the time for removal by one minute resulted in a satisfactory compression set of 0.19%. It is recommended that if a retarder is used with an addition silicone, the correct time of removal should be determined by the compression set.

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Introduction

Addition silicones have been shown to have superior properties compared to the other rubber impression materials. They have low percent permanent deformation values, small dimensional changes on setting, and moderately short working and setting times (Craig, 1977). The working time of an impression material is an important property over which the operator has little control; however, extended working times may be desirable when working on difficult or extensive cases, while using the syringe-tray technique, or in a teaching environment where unfamiliarity with manipulation requires increased working times. It is not uncommon to attempt to adjust the working and setting times of these elastomeric impression materials by altering the base-to-catalyst ratio listed by the manufacturer. It is believed that increasing or decreasing the amount of catalyst will accelerate or decrease the working time. This situation is true for polysulfide, polyether, and condensation silicone impression materials (Braden, 1966). Some addition silicone impression materials like President (Coltene, Altstätten, Switzerland) (Stannard & Sadighi-Nouri, 1986), Baysilex (Cutter Dental, Emeryville, CA 94608), and Reflect (Kerr/Sybron, Romulus, MI 48174) (Ohsawa & Finger, 1986) have an extended working time when the catalyst-to-base ratio is increased. Also it has been reported that a decrease in catalyst-to-base ratio shortens the working and setting times of Baysilex and Reflect (Finger & Ohsawa, 1986). This observation is contrary to what one might expect. Some manufacturers have marketed retarder systems for their products, which allow the working and setting times to be increased. The retarders are supplied as liquid or pastes that are added to the impression material before mixing. Information on retarders such as formulation, modes of action, and impact on other properties is often unavailable from the manufacturers, but it is believed that they are low molecular weight siloxanes. The addition of a retarder to an addition silicone impression material extends not only the working time but also the setting time. Removal prior to the setting time results in excessive permanent deformation, because the material lacks sufficient elastic qualities to recover from the deformation resulting from the forces of removal.

During the summer of 1987, dental students and faculty at the University of Michigan School of Dentistry were experiencing difficulty in handling an addition silicone impression material (Reprosil, Caulk Dentsply International Inc, Milford, DE 19963-0359). This difficulty was related to shortened working and setting times that were caused by warm temperatures and high humidity. The recommended catalyst-to-base ratio was listed at 1:1 for optimal performance, and it was stated that variations in the relative amounts of base or catalyst did not significantly increase nor decrease the working or setting times. When dispensed in equal lengths of base and catalyst and mixed streak-free in 30-35 seconds, the light-bodied material had a working time of 2.5 minutes and a minimum removal time of eight minutes from start of mix. The manufacturer advocated the use of a retarder (De Trey Retarder, De Trey Dentsply, De Trey AG, CH-8037 Zurich) to extend the working and setting time by one minute, necessitating that the impression remain in the mouth for one additional minute. The retarder was used according to the manufacturer's recommendations, which required mixing the retarder with the catalyst prior to mixing it with the base and leaving the impression in the mouth for nine minutes after start of mixing. It was found that the working time was increased, but crowns fabricated with dies made from these impressions did not fit. It was suspected that the time in the mouth was insufficient, thereby producing an inaccurate impression. The purpose of this study was to examine the effect of a retarder on the compression set of the light-bodied addition silicone in relation to its setting time.

Materials and Methods

The light-bodied addition silicone impression material was tested for compression set according to ADA Specification No 19 for dental elastomeric materials (Council on Dental Materials and Devices, 1977). Fifteen samples were fabricated utilizing a 19-mm-high metal ring with an inside diameter of 20 mm into which a 20-mm-high metal mold with an inside diameter of 12.5 mm was inserted. The brass mold was used to form the sample as well as to express voids. The molds were lubricated with silicone grease (high-vacuum type) to prevent the impression material from adhering to it.

A total of 15 samples of light-bodied material were fabricated using equal lengths (5 cm) of base and catalyst. The samples were distributed into one control group of five and two experimental groups of five samples each containing retarder. Following the manufacturer's ratio of retarder, the experimental groups had 1 cm of retarder mixed into the catalyst paste within 30 seconds of the onset of mixing, and the resultant homogeneous mixture was mixed with the base material for the completion of the mixing time, a total of 75 seconds. This time is longer than the 45 seconds when no retarder was present. The resultant mixture when incorporated into the base material remained orange; it was placed into the mold and compressed between two poly(methylmethacrylate) plates to extrude the excess material from the mold.

At 1.5 minutes from the start of the mix, the mold and accompanying plates were immersed in a water bath set at 32 ± 1 °C. The mold and plates remained in the water bath for 6.5, 7.5, and 8.5 minutes respectively for the control and experimental groups. These times represented total times of eight, nine, and 10 minutes from the onset of mixing. The manufacturer's minimum recommended time for removing the material from the mouth when the retarder is added is nine minutes from start of mixing or one minute longer than when no retarder is used.

According to the specification for dental elastomeric materials, the specimens were tested for compression set one minute after removal from the water bath. The samples were compressed 12% for 30 seconds, allowed to recover 30 seconds, and then tested for permanent deformation. The compression set was calculated from the permanent deformation and the length of the sample and was reported to the nearest 0.01%.

After testing for compression set, the specimens were sectioned lengthwise, and the samples found to contain visible bubbles or voids were discarded.

Results and Discussion

The compression set values for the two experimental groups and the control groups, their means and standard deviations are listed in the table. The mean compression set values for the control group at eight minutes was 0.08% and for the experimental groups to which retarder was added it was 3.2% at nine minutes and 0.19% at 10 minutes. There was no statistical difference (using a Student *t*-test at $P = 0.05$) for the control and the mean values for samples with retarder left in the bath at 32 °C for 10 minutes. The mean value for the samples with retarder left in the bath at 32 °C for nine minutes were statistically higher than the other two groups using a Student *t*-test at $P = 0.05$.

ADA Specification No 19 defines setting time as a transitional period when plastic properties permitting molding are lost, and elastic properties allowing removal over undercut areas are acquired. Silicone impression materials continue to polymerize after the material has reached initial set, and the mechanical properties improve with time. Premature removal of the impression results in higher than acceptable permanent deformation.

Manufacturers claim that the advantages of a retarder are the increased working and setting times of addition silicone impression materials during complicated impression procedures. The recommended removal time of nine minutes when using a retarder was compared with an eight-minute removal time for a nonretarded control group and a 10-minute removal time of another group of samples containing a retarder.

The elastic recovery of the samples containing retarder removed at nine minutes was adversely affected with higher compression set values than the nonretarded control at eight minutes or the samples containing retarder removed at 10 minutes. Thus, the compression set values are a better estimate of the appropriate time in the mouth than the working or setting times. In order to achieve an acceptable compression set, the time in the mouth of a material to which a retarder has been added must be increased from the manufacturer's minimum recommended time of nine to 10 minutes. This finding suggests that impressions containing a retarder and removed at the recommended nine minutes would result in inaccurate impressions, and problems with the subsequent fit of crowns made from these impressions would be likely. Subsequent to these findings, whenever a retarder is used, the students and faculty of the University of Michigan increase the time in the mouth to 10 minutes; this has resolved the problem of nonfitting crowns.

Compression Set for an Addition Silicone Control and Mixes Containing a Retarder

	Control	**Silicone + Retarder**	**Silicone + Retarder**
Time (minutes) at 32 °C	**8**	**9**	**10**
Sample			
1	0.01	3.10	0.15
2	0.11	3.90	0.20
3	0.19	2.60	0.05
4	0.05	3.60	0.01
5	0.04	2.60	0.56
Mean (SD)	0.08 (0.07)	3.2 (0.6)	0.19 (0.20)

Conclusions

1. The addition of a retarder to a

light-bodied addition silicone increased the working and setting time.

2. The manufacturer's minimum recommended time of nine minutes for removing the addition silicone containing the retarder from the mouth is inadequate with respect to maintaining a low compression set.

3. There was no detrimental effect on the percentage of recovery after compressive strain during removal of an addition silicone containing a retarder if the impression remains in the mouth a minimum of 10 minutes.

4. Compression set values are more appropriate than working- or setting-time values in determining the correct time in the mouth of addition silicones containing retarder.

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References

BRADEN, M (1966) Characterization of the setting process in dental polysulfide rubbers *Journal of Dental Research* **45** 1065-1071.

COUNCIL ON DENTAL MATERIALS AND DEVICES (1977) Revised American Dental Association Specification No 19 for Non-aqueous, elastomeric dental impression materials *Journal of American Dental Association* **94** 733-741.

CRAIG, R G (1977) A review of properties of rubber impression materials *Journal of the Michigan Dental Association Journal* **59** 254-261.

FINGER, W & OHSAWA, M (1986) Effect of mixing ratio on properties of elastomeric dental impression materials *Dental Materials* **2** 183-186.

OHSAWA, M & FINGER, W (1986) Working time of elastomeric impression materials *Dental Materials* **2** 179-182.

STANNARD, J G & SADIGHI-NOURI, M (1986) Retarders for polyvinylsiloxane impression materials: evaluation and recommendations *Journal of Prosthetic Dentistry* **55** 7-10.

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Histological Study of an Acid Red Caries-disclosing Dye

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Summary

When 20 extracted teeth were examined histologically after using a 1.0% acid red caries-disclosing dye before excavation of carious dentin, 25% showed the presence of bacteria in the dentin. The use of a solution of 1.0% acid red in propylene glycol to identify infected dentin will greatly decrease but not completely eliminate the changes of viable bacteria remaining in a cavity preparation.

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Introduction

Results of various investigations using optical microscopy (Takuma & others, 1967; Zerosi, 1970), electron microscopy (Takuma & Kurahashi, 1962; Sarnat & Massler, 1965; Takuma & others, 1967), histochemistry (Fusayama, 1980) and bacteriology (Crone, 1968; Edwardsson, 1974; Friedman, 1979) are in fairly close accord concerning the principal characteristics of dentin caries. Fusayama (1979) characterized the dentinal carious lesion as consisting of two distinct layers with different ultramicroscopic and chemical structures. The outer (most superficial) layer is contaminated with bacteria and the organic matrix is destroyed, is not remineralizable and must be removed. The inner carious dentin does not contain bacteria and the organic matrix is not significantly altered, is remineralizable and must be preserved.

Cavity preparation is a surgical procedure that attempts to remove all infected dentin prior to placing a restorative material (Gilmore & others, 1982). Traditionally the color and texture of the dentin at the base of the cavity preparation served as subjective indicators of caries penetration (Fisher, 1981; Baum, Phillips & Lund, 1985). Various dye techniques have been developed and tested for more accurate detection of cariously altered dentin. Use of a 0.5% basic fuchsin dye in propylene glycol is said to be an objective, reliable guide for the complete and safe removal of infected dentin (Sato & Fusayama, 1976). According to Fusayama (1979), this solution will selectively stain the outer carious dentin in a lesion so that it can be removed accurately. His studies have shown that with the removal of all red-stained dentin, all of the bacteria in the lesion will also be removed (Fusayama, 1980). In order to eliminate a carcinogenic potential of basic fuchsin, a 1.0% acid red propylene glycol solution is now being used and is capable of differentiating the two layers of carious dentin in a manner similar to fuchsin solution (Fusayama, Takatsu & Itoh, 1979).

Histological and bacteriological experiments performed to determine whether viable organisms remain on the dentinal surface at the termination of routine cavity preparation have shown that only a proportion of the teeth are sterile after preparation (Crone, 1968; Friedman, 1979). One series showed that half of the prepared teeth when investigated by histological techniques still contained microorganisms (Crone, 1968). When using a 0.5% basic fuchsin solution, 72% of the teeth demonstrated fuchsin-stained material after routine cavity preparation and caries removal judged by visual and tactile criteria (Anderson & Charbeneau, 1985). Deep lesions contained cultivatable bacteria as frequently as 94% of the time.

Besic (1943) showed that bacteria left in a cavity preparation could survive for longer than a year. Other investigators found that fermentative organisms remained viable under nonantiseptic restorations for as long as 139 days (Schouboe & Macdonald, 1962). The long-term fate of residual bacteria is as yet unknown. Since bacteria left in the dentin of the cavity floor can live for a long time, complete removal of infected dentin would seem to be desirable to prevent recurrence of decay.

A recent bacteriological study using the basic fushsin caries-disclosing dye found that the deepest portion of approximately 40% of the carious lesions tested contained low numbers of bacteria after removal of the fuchsin-stainable dentin (Anderson, Loesche & Charbeneau, 1985). Another study (List & others, 1987) comparing caries excavation with and without the aid of a caries-staining dye showed that 15% of the specimens excavated with the use of the dye still contained bacteria. To date there have been no clinical histological reports on the effectiveness of using a 1.0% acid red dye in propylene glycol as a caries-disclosing solution.

The purpose of this study was to determine histologically the ability of a 1.0% acid red dye in propylene glycol solution to selectively stain infected, decayed dentin and thereby result in the removal of all bacteria from the lesion.

Materials and Methods

Twenty permanent teeth with apparently large carious lesions involving the dentin were extracted from patients in the Dental Center at Overlook Hospital, Summit, New Jersey. Prior to obtaining the patient's consent to participate in this study, a treatment plan involving extraction of the specimen tooth was formulated and presented independently to the patient by a dentist not involved in this study. In addition, each patient was informed of any alternatives to extraction of the involved tooth. Patients who chose extraction as the treatment of choice and agreed to participate in this study signed a release form to this effect.

All sample teeth tested vital prior to extraction and exhibited no clinical or radiographic signs of periapical pathology. Teeth employed in this experiment had not been previously restored and contained extensive primary coronal caries extending well into dentin; however, none showed clinical or radiographic signs of carious pulpal involvement. Patient age ranged between 18 and 67, and the medical histories were essentially negative, allowing for routine extraction in each case. Generally the teeth were extracted for prosthetic or periodontal reasons.

Following extraction of the sample tooth by a dentist not involved in this study, all experimental procedures were performed by the primary author under 2.5 magnification using operating loupes (OptiLOUPE, Donegan Optical Co, Lenexa, KS 66214). All instruments and materials were sterilized in the usual manner. Wearing sterile gloves, the operator held the sample tooth in a piece of sterile gauze moistened with sterile water. Any overlying, unsupported enamel was immediately removed from the carious lesion using a sterile #557 straight-fissure carbide bur in a high-speed handpiece with air-water cooling. The lesion was exposed to the fullest extent by extending the lateral walls until a visually and tactually sound dentinoenamel junction (DEJ) was established.

One drop of a 1.0% acid red solution (Sulforhodamine B, Sigma Chemical Co, St Louis, MO 63166, Lot #54F-3577) in propylene glycol was applied to the surface of the decayed dentin using a plastic squeeze bottle with a blunt-end, 27-gauge needle applicator (Imax Pocket Care Applicator, Stram Dental, Inc, Northbrook, IL 60062) for precise placement of the solution. The caries-detector solution was allowed to remain on the lesion for 10 seconds, and then excess dye was washed from the tooth for an additional 10 seconds with a stream of water from a dental air-water syringe. One-half of the red-stained dentin was excavated completely with a sterile #6 round bur in a slow-speed contra-angle handpiece while the other half was left untouched and served as the control. The tooth was restained with caries-detector solution for 10 seconds, washed off, and any stained dentin removed in the same half of the lesion excavated previously. This procedure was repeated until the pulpal wall in the excavated half of the lesion no longer stained red when acid red solution was applied. A record was kept of the number of times that the caries-detector solution had to be applied until no further absorption of the dye could be demonstrated.

Following this, the roots were cut off several millimeters apical to the cervix of the tooth, using a #557 bur in a high-speed handpiece with air-water cooling to allow for more rapid penetration of fixative. Crowns were stored in 10% neutral formalin in individual air-tight glass specimen jars for 90 to 200 days at room temperature until all 20 teeth were collected. A code number was assigned to each specimen.

A schematic diagram was made of each specimen, illustrating the extent and location of the excavated and unexcavated portions of the carious lesion. A color photographic record was made of each specimen using Kodachrome film (ASA 64) showing the surface of the lesion to the greatest possible advantage for visual reference when sectioning the tooth. A dental radiograph was taken of each specimen using a #2 packet of Kodak Ultraspeed film and exposing at a cone-object distance of 16 inches for 48 impulses at 70 KVP. Radiographs were developed in a standard automatic dental x-ray film processor.

Each specimen was then transferred to a plastic specimen cup and decalcified in 1-N formic acid for at least 24 days until repeated, daily radiographs taken of the specimen showed no evidence of any remaining mineralization (Brain & Eastoe, 1962). The formic acid solution was changed every three days. Decalcified specimens were rinsed in three changes of sterile, distilled water and returned to 10% neutral formalin for 81 days of storage prior to processing for histological examination.

Each decalcified crown was cut in half longitudinally using a new sterile #15 scalpel blade for each tooth. This longitudinal cut passed through both the excavated and unexcavated halves of the tooth, approximately parallel to the expected path of the dentinal tubules in the area. Therefore, each half of the original specimen contained half of the excavated portion and half of the unexcavated portion of the lesion.

Decalcified tissues were dehydrated and embedded in paraffin blocks using automatic tissue-processing equipment. Consecutive serial sections 5 to 7 μm thick were then prepared at representative depths from two separate areas of the specimen in order to reduce the possibility that infected tubules may be missed due to the plane in which the section had been cut. Four to 15 sections were cut for each specimen. The number of sections obtained was determined mainly by the size of the lesion. Sections were mounted on glass slides, deparaffinized, hydrated, and stained with hematoxylin and eosin (Brain & Eastoe, 1962) or Brown and Brenn gram-stain (Franco & Kelsey, 1981) for observation under the light microscope. Photomicrographs were taken at low and high power to confirm the location of the bacterial invasion front. Each slide was examined independently by both authors for the presence or absence of bacteria in the treatment and control portions of the lesions.

Results

The results of the histological study using a 1.0% acid red caries-disclosing dye in 20 extracted teeth before and after excavation of carious

Results of Histological Study Using a Caries-disclosing Dye before and after Excavation of Carious Dentin

Specimen #	Tooth #/Surface with Lesion	# Times Dye Applied	Bacteria in Control Portion	Bacteria in Treatment Portion	# of Sections Examined
101	16, occlusal	5	yes	no	6
102	11, incisal	4	yes	no	6
103	26, mesial	5	yes	yes*	15
104	15, occlusal	5	yes	no	7
105	15, distal	4	yes	yes	10
106	2, distal	5	yes	yes	9
107	1, mesial	3	yes	no	14
108	8, mesial	3	yes	no	4
109	1, occlusal	9	yes	no	12
110	22, distal	3	yes	no	15
111	21, distal	4	yes	no	11
112	24, distal	3	yes	no	15
113	15, distal	7	yes	no	8
114	19, distal	7	yes	yes**	13
115	19, buccal	6	yes	no	8
116	29, distal	6	yes	no	14
117	26, mesial	6	yes	no	10
118	16, occlusal	8	yes	yes	8
119	16, buccal	3	yes	no	6
120	15, distal	4	yes	no	10

* 2 of 15 sections showed bacteria remaining in treatment portion.
** 3 of 13 sections showed bacteria remaining in treatment portion.

dentin are summarized in the table.

After the initial 10-second application of the dye, the carious dentin stained a definitive bright red color. The staining was limited to the area of the lesion and was not present on the adjacent enamel, clinically sound dentin, or root surface. The boundary between the stained and unstained dentin was very clear. Following each application of the dye, each specimen exhibited a clinically distinct visual endpoint for excavation of carious dentin.

A depth of excavation was eventually reached whereby further dye application did not result in staining of the dentin. At this level, the surface of the excavated dentin contained no dye when examined under 2.5 magnification but usually exhibited a tan or brown discoloration as the result of the carious process. The number of dye application/excavation cycles varied from three to nine times among the 20 specimens.

In all sections examined under the light microscope, the unexcavated control portions of all specimens revealed bacteria in the dentinal tubules. The bacteria were seen in large numbers, usually clogging and distending the dentinal tubules and at times disrupting the general tubular structure of the dentin (Fig 1). Also in all

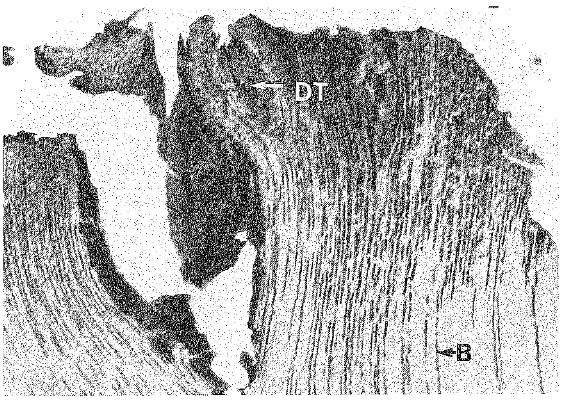

FIG 1. *Bacteria in the unexcavated portion of the carious lesion from specimen #105. Note the larger number of bacteria and the distortion of dentin tubular structure. Magnification X48. B = bacteria, DT = distorted tubules*

sections examined, the excavated experimental portions of 15 specimens revealed no evidence of bacteria in the dentinal tubules of the floor of the cavity preparation.

Bacteria were present, however, in the tubules of the excavated, experimental portions of the remaining five specimens in some histological sections. One specimen exhibited bacteria in two of 15 sections, while another specimen showed bacteria in three of 13 sections. The three remaining specimens contained bacteria in all histological sections. These bacteria were located from 0.1 mm to 2.4 mm pulpal to the base of the excavated portion of the lesions measured on the histological sections, using a calibrated ocular micrometer. Individual bacteria could often be discerned (Fig 2). They were relatively few in number, thinly distributed, and found only within occasional dentinal tubules.

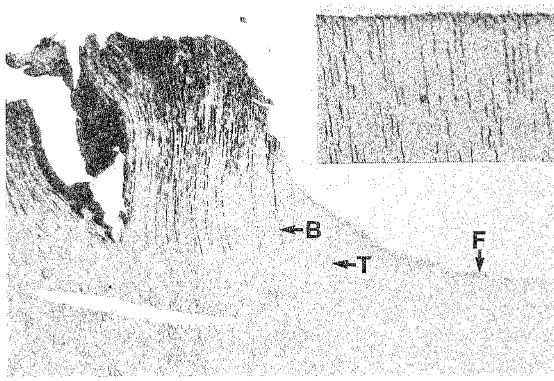

FIG 2. *Low-power view of both the unexcavated (left) and excavated (right) areas of the carious lesion from specimen #105. Note the evenness of the level of excavation determined by dye application. Original magnification X40. Insert: High-power view showing bacteria in the unstained dentin pulpal to excavated cavity preparation floor. Magnification X46. F = excavated cavity floor, B = bacteria, T = dentinal tubules*

Discussion

In this study a 1.0% acid red propylene glycol dye was used to identify infected dentin. Only the presence of bacteria in the dentinal tubules was recorded; no attempt was made to quantify them. The results indicate that 75% of the specimens excavated with the use of the dye were free of bacteria. However, the remaining specimens contained bacteria in the dentinal tubules located as far as 2.4 mm pulpal to the base of the excavated portion of the lesion.

According to Fusayama (1979) the stained outer carious dentin is infected, whereas the unstained inner carious dentin is not. A zone of softened but intact dentin containing no bacteria is located pulpal to the front of bacterial invasion. Excavation, guided by this method of staining with a caries-disclosing solution, is always deeper than the bacterial penetration, even in acute decay in which bacteria are widely scattered. According to Fusayama, use of caries-disclosing solutions is a reliable clinical guide for the compete removal of infected dentin.

In the present study, however, the caries-disclosing solution did not stain dentin pulpal to the bacterial front of the lesion in 25% of the cases examined. The present study confirmed the results of two previous investigations (Anderson & others, 1985; List & others, 1987) which showed the presence of bacteria in the dentin after using a caries-disclosing solution. The acid red dye solution used in this study actually does not stain bacteria; it stains the irreversibly altered organic matrix of carious dentin (Fusayama, 1980). This staining appears to correlate reasonably well with bacterial penetration in most lesions, but it is important to realize that acid red staining and bacterial penetration are somewhat independent phenomena. Therefore, it is possible that caries-disclosing solutions will not stain carious dentin pulpal to the bacterial front in all cases, and the deepest portion of a carious lesion may contain low numbers of bacteria in advance of acid red stainable dentin. In addition, Brännström (1982) offers another explanation for the presence of bacteria in the dentin after using a caries-disclosing solution. The results of his investigations indicate that bacteria are not only present in decalcified dentin but also can be present deep in the tubules of mineralized dentin beneath carious lesions.

The bacteriological study by Anderson and others (1985) found a significant number of specimens contained bacteria in the unstained dentin pulpal to the cavity floor. The sampling and culturing methods used in this study had a minimum sensitivity threshold, so it is possible that more of the specimens tested did indeed contain bacteria in the subjacent dentin but that the numbers were too small to provide positive cultures. The present study may also have understated the true number of specimens containing bacteria. Representative histological sections were taken at various depths within the lesion, resulting in a sampling of approximately 1 to 2% of the total lesion. Examination of serial histological sections of all lesions may have resulted in a higher number of specimens exhibiting bacteria in the subjacent dentin.

It is also possible that in some lesions a significant amount of noninfected dye-stained dentin is being excavated if the dye stains significantly pulpal to the bacterial front. The capacity of the caries-disclosing dyes to stain significantly beyond the bacterial front still needs to be determined.

The presence of bacteria in dentinal tubules has been considered a reasonable indicator of the presence of carious dentin (Miller & Massler, 1961; Massler & Pawlak, 1977); therefore, complete removal of all bacteria should be the goal when treating a carious lesion. Recurrent decay and/or pulpal damage may result if residual bacteria are allowed to proliferate under a restoration because nutrients are available to them either through marginal leakage or diffusion from the pulp. Bacteria can apparently remain viable under a restoration for years, and so the potential for activation of these organisms is a continual threat to the integrity of the tooth. Since recurrent decay is a major reason for replacement of restorations (Dahl & Eriksen, 1978; Boyd & Richardson, 1985), fewer replacements may be required if all dentin infected with bacteria could be routinely and reliably removed.

The removal of all carious dentin before restoring a tooth has long been the goal in clinical dentistry; however, dentists are apparently unable to detect cariously infected dentin by tactile discrimination or visual cues based on natural discoloration. A clinical study found dye-stainable dentin remaining in a high proportion of cavity preparations certified as free of decay by experienced operators using tactile and optical criteria (Franco & Kelsey, 1981). However, the use of caries-disclosing dyes should be viewed as an adjunctive clinical procedure to aid the dentist in treatment of carious teeth, especially for those individuals who do not possess a high degree of clinical expertise for removing decay. The use of a 1.0% acid red propylene glycol dye to identify infected dentin (Fusayama, 1979) will greatly decrease but not completely eliminate the chances of viable bacteria remaining in a cavity preparation. Other aspects of the dentinal carious lesion need to be studied as they relate to the acid red staining. Location of endotoxins, immunoglobin distribution, pH and noncollagenous protein alterations also must be investigated. A more definitive consensus can then be made as to the clinical applications of the acid red caries-disclosing dye.

Conclusions

In this study, use of a 1.0% acid red propylene glycol solution to stain infected dentin correlated with bacterial penetration in 75% of the carious lesions examined. It appears, however, that acid red staining and bacterial penetration are somewhat independent phenomena, and the deepest portion of a carious lesion may contain low numbers of bacteria in advance of the acid red stainable dentin. The use of a 1.0% acid red propylene glycol dye to identify infected dentin will greatly decrease but not completely eliminate the chances of viable bacteria remaining in a cavity preparation. Other aspects of the dentinal carious lesion need to be studied as they relate to the acid red staining so that a more definitive consensus can be made as to the clinical applications of the acid red caries-disclosing dye.

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References

ANDERSON, M H & CHARBENEAU, G T (1985) A comparison of digital and optical criteria for detecting carious dentin *Journal of Prosthetic Dentistry* **53** 643-646.

ANDERSON, M H, LOESCHE, W J & CHARBENEAU, G T (1985) Bacteriologic study of a basic fuchsin caries-disclosing dye *Journal of Prosthetic Dentistry* **54** 51-55.

BAUM, L, PHILLIPS, R W & LUND, M R (1985) *Textbook of Operative Dentistry,* 2nd edition pp 145-147 Philadelphia: W B Saunders Co.

BESIC, F C (1943) The fate of bacteria sealed in dental cavities *Journal of Dental Research* **22** 349-354.

BOYD, M A & RICHARDSON, A S (1985) Frequency of amalgam replacement in general dental practice *Journal of the Canadian Dental Association* **10** 763-766.

BRAIN, E B & EASTOE, J E (1962) Studies in the decalcification of dental tissues for histological purposes *British Dental Journal* **112** 277-283.

BRÄNNSTRÖM, M (1982) *Dentin and Pulp in Restorative Dentistry* pp 67-89 London: Wolfe Medical Publications Ltd.

CRONE, Fr L (1968) Deep dentinal caries from a microbiological point of view *International Dental Journal* **18** 481-488.

DAHL, J E & ERIKSEN, H M (1978) Reasons for replacement of amalgam dental restorations *Scandinavian Journal of Dental Research* **86** 404-407.

EDWARDSSON, S (1974) Bacteriological studies on deep areas of carious dentine *Odontologisk Revy* **25 Supplement 32** 7-143.

FISHER, F J (1981) The treatment of carious dentine *British Dental Journal* **150** 159-162.

FRANCO, S J & KELSEY, W P (1981) Caries removal with and without a disclosing solution of basic fuchsin *Operative Dentistry* **6** 46-48.

FRIEDMAN, M M (1979) The qualitative and quantitative bacterial content of stained dentin: an experimental study *General Dentistry* **27(6)** 38-44.

FUSAYAMA, T (1979) Two layers of carious dentin: diagnosis and treatment *Operative Dentistry* **4** 63-70.

FUSAYAMA, T (1980) *New Concepts in Operative Dentistry* pp 15-58 Chicago: Quintessence Publishing.

FUSAYAMA, T, TAKATSU, T & ITOH, K (1979) New composition of caries detector *Japanese Journal of Conservative Dentistry* **22** 37.

GILMORE, H W, LUND, M R, BALES, D J & VERNETTI, J P (1982) *Operative Dentistry* pp 52-53 St Louis: C V Mosby Co.

LIST, G, LOMMEL, T J, TILK, M & MURDOCH, H G (1987) Use of a dye in caries identification *Quintessence International* **18** 343-345.

MASSLER, M & PAWLAK, J (1977) The affected and infected pulp *Oral Surgery, Oral Medicine, Oral Pathology* **43** 929-947.

MILLER, W A & MASSLER, M (1961) Permeability and staining of active and arrested lesions in dentine *British Dental Journal* **112** 187-197.

SARNAT, H & MASSLER, M (1965) Microstructure of active and arrested dentinal caries *Journal of Dental Research* **44** 1389-1401.

SATO, Y & FUSAYAMA, T (1976) Removal of dentin by fuchsin staining *Journal of Dental Research* **55** 678-683.

SCHOUBOE, T & MACDONALD, J B (1962) Prolonged viability of organisms sealed in dentinal caries *Archives of Oral Biology* **7** 525-526.

TAKUMA, S & KURAHASHI, Y (1962) Electron microscopy of various zones in a carious lesion in human dentine *Archives of Oral Biology* **7** 439-453.

TAKUMA, S, SUNOHARA, H, SEKIGUCHI, K & EGAWA, I (1967) Electron microscopy of carious lesions in human dentin *Bulletin of the Tokyo Dental College* **8** 143-165.

ZEROSI, C (1970) Critical appraisal of the literature on deep carious lesions *International Dental Journal* **20** 297-308.

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Quantitative Evaluation of Approximal Contacts in Class 2 Composite Resin Restorations: A Clinical Study

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W A GREGORY J B DENNISON

Summary

The purpose of this study was to develop an accurate and reproducible intraoral method of measuring the distance between two teeth, and to conduct a clinical pilot study of the effect of placement of a class 2 posterior resin restoration upon this intertooth dimension. A Kaman Sciences KD-2611 noncontact displacement measuring system with a 1U unshielding sensor, based upon the variable resistance of eddy current, was used for the intraoral measurement. Seven patients requiring conservative interproximal restorations (initial placements or replacements) on the premolars were selected. Addition silicone impressions were taken of the posterior quadrants from which low-fusing metal (Cerrolow-136) casts were made. Composite resin copings constructed on modified rubber dam clamps were fabricated for the restoration and adjacent teeth upon these metal casts. Aluminum targets and Plexiglas holders for the sensor were attached to the bow of the rubber dam clamp with light-activated composite resin. Quantitative measurements of intertooth distance were made preoperatively, postoperatively, and at one-week and 4½-month recalls after placement of class 2 composite resin restorations for 11 teeth. Four unrestored premolars served as a control.

The data were tabulated and analyzed using one-way analysis of variance. The results indicated that the mean postoperative intercoping distance for restored teeth increased after a multiple wedging technique had been applied during restorative procedure. At the one-week recall, these distances had decreased. The 4½-month measurements

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showed a further decrease with an average loss of 15 μm from the preoperative baseline.

INTRODUCTION

Inadequate wear resistance and technique sensitivity have been two major drawbacks to the use of composite resin in posterior teeth. Although wear of occlusal surfaces is well-recognized, the evidence that approximal wear exists and the technical difficulty of establishing sound approximal contacts using composite resin have received less attention.

The purpose of this study was to develop an accurate and reproducible intraoral method of measuring the positional relationship between two teeth, and to conduct a clinical pilot study of the effect of placement of a class 2 posterior resin restoration upon this intertooth dimension. A method for the direct measurement of the intertooth positional relationship preoperatively, postoperatively, and at subsequent postoperative intervals should provide valuable information regarding the selection of appropriate dental materials and restorative techniques.

REVIEW OF THE LITERATURE

In 1981 the American Dental Association established standards for acceptance of a composite resin for use in occlusal class 1 and class 2 restorations (Council on Dental Materials, 1981). The manufacturer must submit clinical data for the product from two independent studies. The material must perform within minimal limits in regard to color matching, interfacial staining, loss of anatomic form, loss of approximal contour and recurrent caries during a specific time period. In order for a material to be "provisionally accepted" it must demonstrate less than 50 μm wear loss per year from the occlusal surface over a three-year period. Full compliance is not awarded unless the wear rate is less than 50 μm per year over a five-year period. For primary teeth, two-year and four-year studies may be considered for provisional acceptance and full compliance respectively. As of July 1988, four composite resins have been classified as "provisionally acceptable" for permanent teeth by the council. However, this does not imply their unlimited use as routine restorative material in stress-bearing areas in all situations. The profession has been advised to be cautious in the manipulation and application of composite resins because of technique sensitivity. The American Dental Association has advised dentists to be aware of the limited amount of information available in regard to long-term clinical evaluation of composite resins in posterior restorations (Report of the Council, 1986). Although many quantitative methods have been developed to investigate the occlusal wear of posterior composite resin, few measuring techniques and only little clinical data have been published regarding evaluation of approximal wear in posterior composite restorations.

The importance of approximal contact relations have been reported (Black, 1924; Hirschfeld, 1930; Fee, 1940; Miller, 1943; Beube, 1953; Glickman, 1953; Ramfjord, 1952; Sanjana, 1965; Gould & Picton, 1966; Alexander, 1968; Hancock & others, 1980; Nielsen, Glavind & Karring, 1980; Jernberg, Bakdash & Keenan, 1983). Inadequate approximal tooth contacts allow food impaction and debris retention which contribute to periodontal complications, caries, and tooth migration.

Methods devised for measuring tooth mobility have ranged from simply moving the tooth by two rigid instruments (Miller, 1950), to vibratory (Manly, Yurkstas & Reswick, 1951), mechanical (Mühleman, 1951; Mühleman, 1954; Mühleman, 1960; O'Leary & Rudd, 1963; O'Leary, 1974), electronic device (Picton, 1957; Parfitt, 1958; Parfitt, 1960; Korber, 1971; Hellie & others, 1985; Gregory, 1983; Pameijer & Stallard, 1973; Persson & Svensson, 1980), laser light (Rydén, Bjelkhagen & Söder, 1974; Rydén, Bjelkhagen & Sandström, 1979; Rydén, Bjelkhagen & Söder, 1982; Liljeborg, Johannsen & Rydén, 1985; Wedendal & Bjelkhagen, 1974), hologram (Burstone, Pryputniewicz & Bowley, 1978; Burstone, Every & Pryputniewicz, 1982), and stereophotogrammetry (Browning, Meadors & Eick, 1986; Browning, Eick & McGarrah, 1987). Hellie and others (1985) measured the mesiodistal tooth movement by forceful wedging utilizing a noncontact measuring system. The system was based on the principle of resistance variation in an eddy current field between an aluminum target and a sensor. Measurements as small as 1 μm were possible with this device. The approximal tooth mobility during placement of class 2 amalgam restorations was investigated by Gregory (1983) using the same device. The reproducibility and accuracy of this noncontact measuring system were well-established for the methods used in these studies.

MATERIALS AND METHODS

A Kaman Science KD-2611 noncontact displacement measuring system (Kaman Sciences Corporation, Colorado Springs, CO 80933) with a 1U unshielded sensor was selected for the intraoral measurement. This system has been described previously by Hellie and others (1985).

Fabrication of Composite Coping for Intraoral Measurement

An addition silicone impression (President, Coltene, Inc, Hudson, MA 01749) was made of the quadrant including the tooth to be restored. The impression was poured in low-fusing alloy (Cerrolow-136, Marmon Group Inc, Alloy Department, Bellefonte, PA 16823). This alloy melts at 136 °F, has zero shrinkage in one hour and is stable at 0.0002 inch per inch five hours after casting.

Ivory rubber dam clamps (Columbus Dental Mfg Co, St Louis, MO 63102) W2 and 00 were used in combination with a composite resin occlusal-buccal-lingual coping to orient and secure the sensor and target to adjacent teeth. The clamps were modified to closely fit on the low-fusing metal cast. A light-cured composite (Silux, 3M Center, St Paul, MN 55144) coping was formed around the buccal-occlusal and lingual-occlusal aspect of the crown to grasp the bows. The composite copings were trimmed so they did not contact soft tissue or one another, but did contact a large area of their respective teeth in order to provide maximum stability.

An aluminum target and a Plexiglas cylinder holder for the sensor were attached to the bows of the rubber dam clamps. The completed composite copings with modified rubber dam clamps upon the low-fusing metal cast are illustrated in Figure 1.

Clinical Evaluation of the Reproducibility of Intercoping Measurement

A subject with a normal complement of teeth and healthy supporting tissues was selected to test the reproducibility of seating the adjacent copings in the mouth in order to measure the intertooth distance.

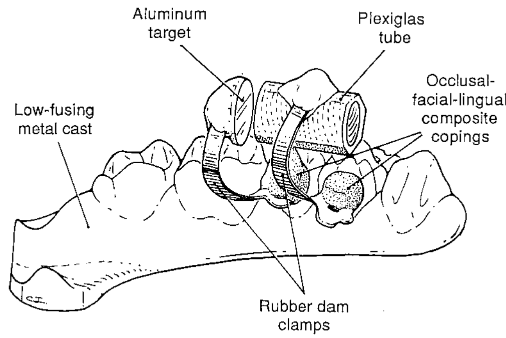

FIG 1. An aluminum target and Plexiglas tube attached to the bows of rubber dam clamp/composite copings on a low-fusing metal cast

Composite resin copings were constructed on maxillary first and second premolars in the manner described. The measuring system was calibrated and allowed to warm up 20 minutes prior to intraoral measurement. The composite resin coping holding the target was placed on the maxillary second premolar. The stability of the coping was checked by removing and replacing it on the tooth several times. The same procedure was employed to place the composite resin coping holding the Plexiglas cylinder on the maxillary first premolar. The sensor was securely screwed into the Plexiglas cylinder. The intercoping distance was recorded while the patient's head remained in a static position (Fig 2).

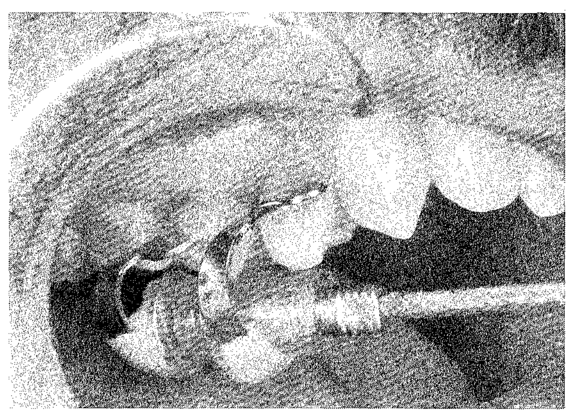

FIG 2. The target and sensor mounted on the rubber dam clamps/composite copings in place on the maxillary premolars

The sensor coping was then completely removed while the target coping remained in the mouth. The sensor coping was repositioned as described previously, and the intercoping distance was recorded again. This repositioning sequence was repeated 10 times, and the data of intercoping measurements were recorded for each replacement. The accuracy and reliability of intercoping measurements in the mouth are shown in Table 1.

Table 1. Intraoral intercoping measurements (mm)

Measurement	mm
#1	0.523
#2	0.503
#3	0.532
#4	0.515
#5	0.512
#6	0.522
#7	0.536
#8	0.506
#9	0.495
#10	0.525
Minimum	0.495
Maximum	0.536
Mean	0.518
Standard Deviation	0.013

Clinical Evaluation of Approximal Contacts in Class 2 Composite Resin Restorations

Patients requiring conservative interproximal restorations (initial placements or replacements) on the premolars were selected. During the first appointment, verbal explanation of the project procedure was presented to each patient and a consent form was signed by the patient. After a history review and clinical examination, impressions were made of the experimental and control quadrants. Copings were fabricated on the low-fusing metal cast in the manner described.

At the second appointment, the measuring system was allowed 20 minutes to warm up and was calibrated. The interproximal contacts of the respective quadrants were evaluated using unwaxed dental floss (POH, Oral Health Products, Tulsa, OK 74147). The criteria shown in Figure 3 were used to maintain the consistency of these evaluations. Preoperative intercoping measurements were made in the manner described. Five measurements were made to establish the preoperative baseline. The mean of the five measurements was used to compute the data.

Following anesthesia and rubber dam placement, a contoured hardwood wedge was inserted between the two target teeth with firm pressure. A class 2 cavity was prepared using the principles of amalgam design but with more rounded internal line angles. No bevel was placed on the cavosurface margins in this study. The hardwood wedge was then removed and reinserted with firm pressure. A thin layer of glass-ionomer base (G-C lining cement, G-C International Corp, Scottsdale, AZ 85260) was applied to all dentin surfaces for pulp protection. Following acid-etching of the enamel, a properly contoured 0.0015-inch thin universal matrix band was placed using a Tofflemire retainer. The band was tightened and the wedge reinserted. The retainer was loosened one-quarter turn to assure that the band was against the adjacent tooth.

A thin layer of bonding agent (Prisma Universal Bond, L D Caulk Co, Milford, DE 19963) and composite resin (Ful-Fil Posterior Restorative, L D Caulk Co) were placed in sequence according to the manufacturer's instructions. A flame-shaped 12-fluted carbide bur was used to finish approximal margins. Occlusal anatomy was formed using round carbide finishing burs at slow speed. Composite finishing disks and points (Shofu Dental Corp, Menlo Park, CA 94025) provided the final finish. Occlusal contacts were finally adjusted using articulating paper following rubber dam removal. The approximal contacts of the quadrant were again evaluated with unwaxed dental floss. Postoperative intercoping measurements were made. The patient was recalled at one week and 4½ months, and the same evaluations and measurements were made.

A total of 11 class 2 composite resin restorations were placed on four male and three female adult patients. The patients' mean age was 27 years, ranging from 18 to 34 years. Among the 11

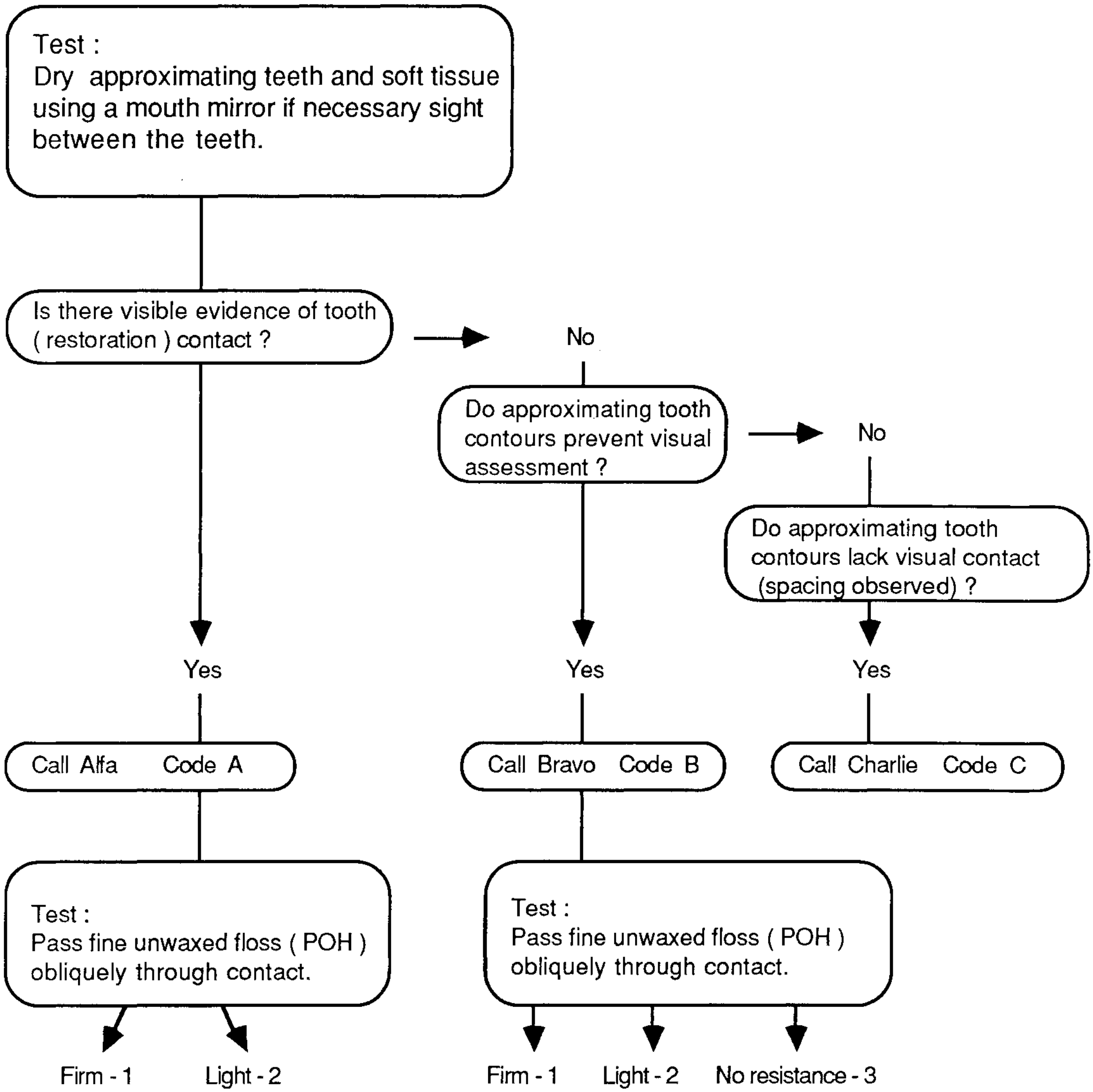

FIG 3. Approximal contact evaluation chart (adapted from Gerald T Charbeneau, DDS, MS research protocol "A Clinical Evaluation of a Strontium Glass Composite Resin," The University of Michigan, Ann Arbor, MI 48109)

restored teeth, five teeth were first premolars and the other six were second premolars. Seven restored teeth had approximal contacts with natural enamel while the other four teeth had contact with amalgam restorations. In addition to the 11 restored teeth, contralateral premolars were selected from four of the patients to serve as nonrestored controls. Intercoping measurements were made at preoperative, one-week, and 4½-month recalls for these control teeth.

RESULTS

The net intercoping measurements and

statistical analysis for 11 restored teeth are shown in Table 2. The mean differences between the positional relationship of the restored tooth and the tooth adjacent at the 4½-month and preoperative, 4½-month and postoperative, 4½-month and one-week times are significant at the 0.01 level. There was no significant difference between preoperative and postoperative, preoperative and one week, postoperative and one-week mean intercoping measurements. For four control teeth, there were no significant differences between preoperative, one-week, and 4½-month intercoping measurements (Table 3).

Table 2. Summary of net intercoping measurements (mm) and statistical analysis for restored teeth

Tooth	Pre-op	Post-op	1 Week	4.5 Months
#1	0.000	0.003	-0.006	-0.021
#2	0.000	-0.001	-0.002	-0.019
#3	0.000	0.001	-0.011	-0.029
#4	0.000	0.009	-0.018	-0.023
#5	0.000	0.006	0.000	-0.025
#6	0.000	0.003	-0.004	-0.015
#7	0.000	0.014	-0.012	-0.011
#8	0.000	0.010	-0.002	-0.014
#9	0.000	-0.003	-0.010	0.000
#10	0.000	0.025	0.001	-0.006
#11	0.000	0.006	-0.016	-0.007

Newman-Keuls Test

Samples (n=11)	Mean difference	SD	Significance
Post / Pre	0.007	0.008	NS
1 week / Pre	-0.001	0.011	NS
4.5 M / Pre	-0.016	0.015	S*
1 week / Post	-0.007	0.007	NS
4.5 M / Post	-0.023	0.011	S*
4.5 M / 1 week	-0.015	0.009	S*

NS--Not Significant S--Significant *--Probability < 0.01

Table 3. Summary of net intercoping measurements (mm) and statistic analysis for control teeth

Tooth	Pre-op	Post-op	1 Week	4.5 Months
#1	0.000	.	0.002	-0.004
#2	0.000	.	-0.002	-0.001
#3	0.000	.	0.000	-0.001
#4	0.000	.	0.003	-0.006

Newman-Keuls Test

Samples (n=4)	Mean difference	SD	Significance
1 week / Pre	0.001	0.002	NS
4.5 M / Pre	-0.002	0.001	NS
4.5 M / 1 week	-0.003	0.002	NS

For the 11 restored teeth, the postoperative intercoping measurement was greater than the preoperative except for tooth #2 and tooth #9. The mean intertooth distance increased 7 μm from baseline. One week after the restorative appointment, the intercoping measurements of all teeth had decreased except for tooth #10. The mean decrease was 7 μm from the postoperative measurement. In all teeth the 4½-month measurements indicated a further decrease in intertooth distance showing a net loss of 15 μm from the preoperative measurement. Compared with restored teeth, the change of intercoping distance for four control tooth pairs was insignificant (Table 4, Fig 4).

When comparing the net intercoping measurements for the four patients who had contralateral controls, there was no significant difference between treatment side and control side at one week. However, the mean difference between these two groups was significant at the 0.05 level at the 4½-month recall with the treatment side showing intertooth distance loss.

DISCUSSION

Since composite resin cannot be truly

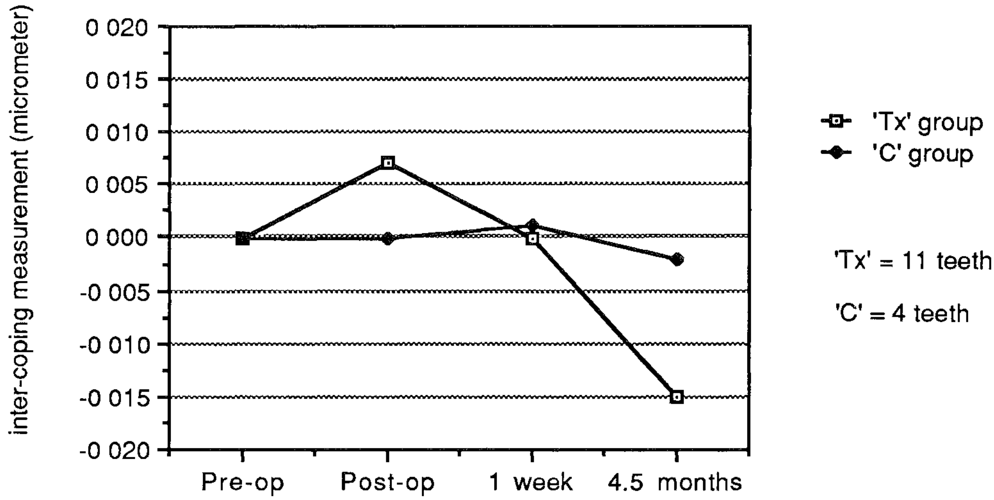

FIG 4. Mean change of intercoping measurements for 11 restored teeth and 4 control teeth over the 4½-month clinical trial period

Table 4. Mean change of intercoping measurements (mm) between each period for restored and control teeth

	Pre-op	Post-op	1 Week	4.5 Months
'Tx' group				
N	11	11	11	11
Minimum	0.000	-0.003	-0.018	-0.029
Maximum	0.000	0.025	0.001	0.000
Mean	**0.000**	**0.007**	**-0.007**	**-0.015**
SD	0.000	0.008	0.007	0.009
'C' group				
N	4	4	4	4
Minimum	0.000	.	-0.002	-0.006
Maximum	0.000	.	0.003	-0.001
Mean	0.000	.	0.001	-0.003
SD	0.000	.	0.002	0.002

condensed during placement, an adequate approximal contact for class 2 restoration relies on forceful wedging alone to provide sufficient approximal tooth displacement to compensate for the thickness of the matrix band. Earlier work by Hellie and others (1985) indicated that three consecutive wedgings during the same appointment slightly increased maximum displacement for the posterior teeth over that obtained by a single wedging. It was hypothesized that repeated forceful wedging would be helpful in restoring firm approximal contacts for class 2 posterior resin restorations. The multiple-wedging technique was applied in this study to restore 11 class 2 composite resin restorations. During the restorative sequence, a contoured hardwood wedge was positioned interproximally with firm pressure prior to and during cavity preparation. The wedge was again reinserted firmly after cavity preparation and after placement of matrix band. The results showed that 10 out of 11 restored teeth had clinically acceptable approximal contact as evaluated both visually and tactilely. When comparing the intercoping distance from preoperative measurements, the postoperative measurements revealed an increased intertooth distance with an average of 7 μm. After a period for the restored teeth to readjust under normal function, intercoping measurements were made at the one-week recall. It was interesting to note that all intertooth distances decreased from the postoperative measurement and almost all restored teeth revealed a decrease in the intertooth distance at one week from the preoperative measurement. The overcompensated position of the restored tooth has a tendency to return to its original preoperative position. Statistical results, however, indicated that there was no significant difference among the preoperative, postoperative, and one-week intercoping measurements for the restored teeth. Based upon the above information, we reaffirm that the multiple-wedging technique is appropriate for class 2 composite resin restorations to help achieve firm approximal contacts.

The largest net increase in intercoping distance, 25 μm, was noted from preoperative to postoperative for tooth #10. This distance did not decrease as for the other teeth, but remained constant at the one-week recall. It was observed preoperatively that tooth #10, whose distal surface required restoration, had no mesial contact. The multiple wedging technique was more than adequate initially for attaining approximal contact for this tooth with single adjacent approximal contact.

At the 4½-month recall, the intercoping distances for all restored teeth showed a decrease. The mean intercoping distance loss was 15 μm from the preoperative baseline. This decreased intertooth distance is a probable result of loss of composite resin through wear, or loss of adjacent contacting tooth substance (enamel or amalgam) through wear, or a combination of these factors.

Vinci (1985) developed an indirect method of measuring intertooth distances using specially marked metal copings and a traveling microscope. It was found that the multiple wedging technique was more than adequate for initially attaining approximal contact. The mean intertooth dimensional loss following placement of a class 2 posterior composite resin restoration was 46 μm during a 4½-month period. The results of the current study are of a lesser magnitude than those shown by Vinci. These differences could result from nonstandardized wedging force, variation of relapse from tooth separation among patients, different experimental material, and the measuring system.

The method developed for this study has a defined accuracy and is a noninvasive direct measuring method for intertooth distance. The accuracy was approximately 10 μm for 50 intercoping measurements in the patient's mouth. The accuracy and reliability of this measuring system was affected by tooth morphology. Teeth with definite cusp tips, line angles, and larger crown surfaces were better candidates since these anatomical characteristics permitted less variability in reseating the sensor. A separating medium was not necessary when composite copings were fabricated on a low-fusing metal cast. However, the surface detail reproduced by the low-fusing metal cast did not appear as good as that of the stone cast. Compared to the stone cast, the low-fusing metal cast set faster, but flowed under pressure. Therefore, the completed, modified rubber dam clamp with composite resin coping should not be left on the low-fusing metal cast for a long period of time. Ideally, this direct measuring method should be used in small, conservative class 2 lesions in order to attain high accuracy. Another concern about using this direct measuring system for long-term follow up is the question of the attrition or abrasion of teeth and the effect of this on the accuracy of measurement. This needs to be investigated further.

CONCLUSIONS

The results obtained from this study permit the following conclusions to be made:

1. The Kaman KD-2611 noncontact measuring system with the 1U unshielded sensor together with composite resin copings fixed to modified rubber dam clamps for carrying the target and sensor provides a direct intraoral method for measuring intertooth distances with an accuracy of ±10 μm.

2. A mean intertooth distance loss of 15 μm was observed over a 4½-month period following placement of class 2 (MO, DO) composite resin restorations in premolar teeth. This distance ranged from 0 to 29 μm.

3. The mean differences in intertooth distance between the preoperative-4½-month, the postoperative-4½-month, and the one week-4½-month times are statistically significant at the 0.01 level for the 11 restored teeth.

4. The mean difference between the intertooth distance of the four restored teeth and their

contralateral unrestored controls was significant at the 0.05 level at 4½ months.

5. For the four unrestored control teeth, there were no significant differences in intertooth distance between the preoperative-4½-month or the one week-4½-month times.

6. The multiple wedging technique gains sufficient tooth separation of posterior teeth in order to establish initially clinically acceptable interproximal contact when placing class 2 (MO, DO) restorations in premolar teeth.

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References

ALEXANDER, A G (1968) Periodontal aspects of conservative dentistry *British Dental Journal* **125** 111-114.

BEUBE, F E (1953) *Periodontology; Diagnosis and Treatment* New York: MacMillan.

BLACK, G V (1924) *Operative Dentistry* 6th edition Chicago: Medico-Dental.

BROWNING, J D, MEADORS, L W & EICK, J D (1986) Movement of three removable partial denture clasp assemblies under occlusal loading *Journal of Prosthetic Dentistry* **55** 69-74.

BROWNING, J D, EICK, J D & McGARRAH, H E (1987) Abutment tooth movement measured in vivo by using stereophotogrammetry *Journal of Prosthetic Dentistry* **57** 323-328.

BURSTONE, C J, PRYPUTNIEWICZ, R J & BOWLEY, W W (1978) Holographic measurement of tooth mobility in three dimensions *Journal of Periodontal Research* **13** 283-294.

BURSTONE, C J, EVERY, T W & PRYPUTNIEWICZ, R J (1982) Holographic measurement of incisor extrusion *American Journal of Orthodontics* **82** 1-9.

COUNCIL ON DENTAL MATERIALS, INSTRUMENTS, AND EQUIPMENT (1981) Expansion of the acceptance program for dental materials, instruments, and equipment: composite resin materials for occlusal Class I and Class II restorations *Journal of the American Dental Association* **102** 349-350.

COUNCIL ON DENTAL MATERIALS, INSTRUMENTS, AND EQUIPMENT (1986) Posterior composite resins *Journal of the American Dental Association* **112** 707-709.

FEE, A H (1940) Contacts and contours *Journal of the American Dental Association* **27** 1035-1045.

GLICKMAN, I (1953) *Clinical Periodontology; The Periodontium in Health and Disease* Philadelphia: W B Saunders.

GOULD, M S E & PICTON, D C A (1966) The relation between irregularities of the teeth and periodontal disease: a pilot study *British Dental Journal* **121** 20-23.

GREGORY, W A (1983) An evaluation of proximal tooth stability during placement of Class 2 amalgam restorations: a pilot study. Master's Thesis, The University of Michigan School of Dentistry, Ann Arbor, MI.

HANCOCK, E B, MAYO, C V, SCHWAB, R R & WIRTHLIN, M R (1980) Influence of interdental contacts on periodontal status *Journal of Periodontology* **51** 445-449.

HELLIE, C M, CHARBENEAU, G T, CRAIG, R G & BRANDAU, H E (1985) Quantitative evaluation of proximal tooth movement effected by wedging: a pilot study *Journal of Prosthetic Dentistry* **53** 335-341.

HIRSCHFELD, I (1930) Food impaction *Journal of the American Dental Association* **17** 1504-1528.

JERNBERG, G R, BAKDASH, M B & KEENAN, K M (1983) Relationship between proximal tooth open contacts and periodontal disease *Journal of Periodontology* **54** 529-533.

KORBER, K H (1971) Electronic registration of tooth movements *International Dental Journal* **21** 466-477.

LILJEBORG, A, JOHANNSEN, G & RYDÉN, H (1985) The laser reflection method: computerized analysis of speckle pattern *Swedish Dental Journal* **9** 213-218.

MANLY, R S, YURKSTAS, A & RESWICK, J B (1951) An instrument for measuring tooth mobility *Journal of Periodontology* **22** 148-155.

MILLER, S C (1943) *Textbook of Periodontia* 2nd edition, Philadelphia: Blakiston.

MILLER, S C (1950) *Textbook of Periodontia* 3rd edition, Philadelphia: Blakiston.

MÜHLEMANN, H R (1951) Periodontometry, a method for measuring tooth mobility *Oral Surgery, Oral Medicine, and Oral Pathology* **4** 1220-1233.

MÜHLEMANN, H R (1954) Tooth mobility. The measuring method. Initial and secondary tooth mobility *Journal of Periodontology* **25** 22-29.

MÜHLEMANN, H R (1960) 10 years of tooth-mobility measurements *Journal of Periodontology* **31** 110-122.

NIELSEN, I M, GLAVIND, L & KARRING, T (1980) Interproximal periodontal intrabony defects. Prevalence, localization and etiological factors *Journal of Clinical Periodontology* **7** 187-198.

O'LEARY, T J & RUDD, K D (1963) An instrument for measuring horizontal tooth mobility *Periodontics* 1 249-254.

O'LEARY, T J (1974) Indices for measuring of tooth mobility in clinical studies *Journal of Periodontal Research* **Supplement 14** 94-105.

PAMEIJER, C H & STALLARD, R E (1973) A method for quantitative measurements of tooth mobility *Journal of Periodontology* **44** 339-345.

PARFITT, G J (1958) The development of an instrument to measure tooth mobility *Journal of Dental Research* **37** *Abstracts of Papers* pp 64-65 Abstract 163.

PARFITT, G J (1960) Measurement of the physiological mobility of individual teeth in an axial direction *Journal of Dental Research* **39** 608-618.

PERSSON, R & SVENSSON, A (1980) Assessment of tooth mobility using small loads *Journal of Clinical Periodontology* **7** 259-275.

PICTON, D C A (1957) A method of measuring physiologic tooth movements in man *Journal of Dental Research* **36** 814 Number 25.

RAMFJORD, S P (1952) Local factors in periodontal disease *Journal of the American Dental Association* **44** 647-655.

RYDÉN, H, BJELKHAGEN, H & SANDSTRÖM, U (1979) A laser instrument for measuring tooth movements *Journal of Periodontology* **50** 265-269.

RYDÉN, H, BJELKHAGEN, H & SÖDER, P-O (1974) The use of laser beams for measuring tooth mobility and tooth movement: an in vitro study *Journal of Periodontology* **45** 283-287.

RYDÉN, H, BJELKHAGEN, H & SÖDER, P-O (1982) Movements of healthy and periodontally involved teeth measured with laser reflection technique *Journal of Periodontology* **53** 439-445.

SANJANA, M K et al (1965) Incidence of localized periodontal disease of the interdental papilla in the premolar-molar regions and its relation to the dimensions of the contact points concerned *Journal of All India Dental Association* **28** 201-205.

VINCI, R C (1985) Stability of proximal relationships in Class 2 composite resin restorations: a clinical study. Master's Thesis, The University of Michigan School of Dentistry, Ann Arbor, MI.

WEDENDAL, P R & BJELKHAGEN, H I (1974) Dental holographic interferometry in vivo utilizing a ruby laser system *Acta Odontologica Scandinavica* **32** 131-145.

DENTAL REVIEW

The History of Cavity Preparation in Dental Schools in North America

HAROLD E SCHNEPPER

No one knows for certain when, where, or by whom the operation of filling teeth was introduced. Giovanni da Vigo, whose authoritative surgical treatise was published in 1514, discussed the way carious teeth were filled with gold: "Corrosion occurs in the great teeth through rottenness with sharp and evil moisture which grows and bites them. You may remove the corrosion with trephines, files, and other convenient instruments, filling the cavities afterward with leaves of gold" (Ring, 1985). Even da Vigo recognized how important healthy teeth are, for he stated, "The teeth serve for comeliness, for chewing meat, and for pronunciation, and therefore they must be cured with all diligence" (Ring, 1985).

Low-fusing molten metal was poured into the tooth cavity in early times; however, this technique was soon discarded because the extreme heat of the metal often destroyed the pulp. In addition, gaps often appeared around the edges of the cooling metal that would trap material which would later produce decay. Silver and tin foil were also tried, but with only moderate success. Various cements were also tried and then in time were discarded or were retained only as temporary filling materials. "Most reputable dentists used only gold foil; the eminent Leonard Koecker insisted that this was the only material to be used" (Ring, 1985).

Not too many years passed before the need for more continuity in dental filling materials and

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methods became evident among practicing dentists. On 6 March 1840 the first dental college in the world, the Baltimore College of Dental Surgery, was chartered by the state of Maryland, due to the efforts of Horace H Hayden and Chapin A Harris. The faculty of four operated under the supervision of a board consisting of nine physicians, four ministers, and two dentists. Only five students enrolled in the first class, which began on 3 November. The requirements for the new DDS degree were as high as, if not higher than, those for the MD degree. Only two members of the class graduated. One, Robert Arthur of Baltimore, was later (1852) to gain renown as the founder of the third American dental college, the Philadelphia College of Dental Surgery, later the Pennsylvania College of Dental Surgery, of which he became dean in 1856 (Ring, 1985). The second dental school, The Ohio College of Dental Surgery, was organized in 1845 by Dr James Taylor, a friend of Chapin Harris.

The New York College of Dentistry, established in 1865, is one of three dental schools in the world that have continued in existence uninterrupted from the nineteenth century to the present. The next dental schools to be founded were Missouri Dental College (later Washington University) in 1866 in St Louis, and Harvard Dental School, the first to be affiliated with a university, in 1867 (Ring, 1985).

Prior to the first founding of dental schools, dental procedures differed widely. The founders themselves came from differing backgrounds in both training and experience. Regarding gold foil restorations, the first method used in filling teeth was by gold foil pellets. Sometimes the pellet, after its introduction, was pierced centrally with a sharp instrument, and a cone-shaped roll of gold was formed into the consequent aperture, thus wedging laterally. According to an 1876 textbook, "For a long time after its introduction as a material for filling there was no manufacture of the metal expressly for dental purposes. A dentist in need of gold for filling procured gold coins, and had them rolled by the gold beater into such thickness as suited his purpose" (Dexter, 1876). The text went on to state, "Some dentists allowed the filling to finally extend beyond the level of surface of the adjoining tooth substance that it might be further consolidated by mastication. This method wouldn't produce even a good filling except by the application of great force to which there were many obvious objections" (Dexter, 1876). The foil was then made thinner, with four to six grains the average weight of leaf, and some foil being made with as low as two grains to the leaf.

The first mention of cavity form was made in conjunction with the use of files. Reasons for the use of the file were listed in 1873 by Woofendale, as follows: "Teeth are filed on various accounts, viz: to remove broken or jagged points, which happen either from accident or decay, and are liable to injure the cheek or tongue; to stop the progress of a beginning or advancing caries; to round off the edges of teeth (though not decayed or broken) that grow irregular and prove troublesome to the cheek or tongue; and lastly, for ornament" (Dexter, 1876). He added, "Some universally condemn filing the teeth; on the other hand, some are for having all teeth filed. . . . I apprehend some teeth cannot be filed without being injured by it; others cannot be saved by any other method" (Dexter, 1876).

Soon, certain guidelines were established that formed the basis for teaching procedures. Robert Arthur announced a technique in 1855 for the use of cohesive gold foil, which opened the way for the making of fillings which should establish occlusal and approximal contact. This technique added to the efficiency of the filled teeth, and greatly increased the protection of the interproximal gingivae by excluding food from interproximal spaces (Gillett, 1927).

Arthur is credited with the earliest discovery of the cohesive property of gold foil; however, in 1870, A Westcott, once professor of operative and mechanical dentistry in the Baltimore College of Dental Surgery and later professor in the New York College of Dentistry, recalled his experience in 1840 in New York, where he was practicing dentistry. He published a statement in *Dental Cosmos* describing an order for an eighth ounce of gold foil by mail from a druggist in Syracuse.

> It being in the days of high postage, and Mr F knowing that my extra pennies were few, undertook to do me the favor of economizing for me by removing the intervening papers from between the leaves of foil. I received the foil in this way, and to my surprise, and I may well say, dismay, I was wholly unable to separate the leaves of foil from each other. They had, by some

> magic, which had never before come to my notice, literally 'grown together.' What was to be done? I was not only foiled in regard to my promised operations, but I must await the going and coming of the slow coach, the long distance of 30 miles, before I could take another step, and meanwhile writhe under the uncertainty of being able to better myself after all. More than this, I was in danger of suffering (for me) a heavy pecuniary loss, unless I could convince Mr Finch that the responsibility was upon his shoulders, in consequence of the blunder which he had committed, in the removal of the aforesaid papers. Here was presented to my mind the triple misfortune of the probable loss of my 'job,' the actual loss of two or three days time, and the possible loss of a whole eighth ounce of gold foil! (Wescott, 1870).

Westcott wrote to Mr F asking him to please get another eighth ounce of gold leaves to him and to "leave the papers where he found them" (Wescott, 1870). This gentleman (Mr F), being concerned that there must be something wrong with the foil, immediately wrote to Mr Barrett, who had made the foil, for an explanation. Mr Barrett apologized to Mr F for having sent him such a batch of foil, and added that "once in awhile foil would prove sticky, but he never sent out such foil when he knew it--all of which would have been very consoling to me had it accompanied the original package of foil sent to me by Mr Fitch" [*sic*] (Wescott, 1870).

Westcott started thinking about using the same property of gold foil which had caused it to be welded together in a mail bag to weld it together in the mouth. He started working with it and practicing, and he said that the first filling in the tooth that he did with this foil was the first perfect polished filling that he had ever seen. And "thus was my vexation turned into joy far more exceeding" (Wescott, 1870). He wrote to Mr Barrett, asking him to save all of his "sticky foil" for him.

Arthur discovered that "by annealing gold and increasing its cohesiveness by passing it through flame of an alcohol lamp, he could insert it with little pressure into a tooth cavity and, using tiny pluggers with serrated points, could construct elaborate and extensive fillings" (Ring, 1985).

With the advent of the various types of cohesive and noncohesive gold, new and modified instruments were required. Plugging condensers made their appearance. At first simple, growing more complex in time, the most marked alteration in condensers, introduced in 1842, was a swivel fulcrum and changeable points (Dexter, 1876). The most radical change in filling teeth was wrought by the mallet, causing alarm among conservative clinicians. As one clinician wryly observed,

> Some operators actually employ a hammer and punch to drive the metal into the cavity of the tooth. I have seen the most alarming consequences proceed from this barbarous practice, particularly in the cases of several ladies who consulted me in Philadelphia. Many of their teeth, especially the incisors, or front teeth and [cuspids], had been plugged in this manner. Some . . . were so tender, from the violence that had been used, that the least pressure upon them caused exquisite pain (Dexter, 1876).

This observation was published prior to 1822. Not more than 44 years later, The American Dental Association, at the meeting of 1866, passed a resolution of thanks to Dr Atkinson "for the introduction of the mallet in dental practice and for his kind and efficient teachings in its use" (Dexter, 1876). Still, however, there was very little mention of cavity form. Carious teeth were simply cleaned out with whatever instrument was available before filling the tooth.

In 1864 Dr S C Barnum of New York introduced the rubber dam. Members of the dental profession were not slow to recognize its merits, and in 1870 a call for subscriptions to a 'testimonial fund' for the benefit of its inventor was published in *Dental Cosmos*. It is interesting that over 100 years ago, this development was held in such esteem. "It was almost universally conceded to rank with the greatest advances in the Materiel of operative dentistry" (Marshall, 1901).

References to cavity preparation focused on the instruments themselves more than on specific cavity designs. The same textbook in which the rubber dam was discussed (Marshall, 1901) presented a description of cutting and drilling instruments, and the differences between those in use in 1901 and those from earlier eras.

> Where now each instrument has its own particular handpiece, generally one in material and workmanship with itself, it was then the mode to have each tool separate, but all fitting into one handle, which was generally of different material from the implement, as wood, bone, ivory, or mother of pearl. The last two were in the greatest demand and were often adorned by elegant carving and even with jewels; and the instrument cases were so made as to exhibit, in all their radiant splendor, the then costly implements of the profession to the wondering gaze of the dazzled patient (Marshall, 1901).

In cavity preparation, scalers were initially more important than cutters because few clinicians were willing to attempt cutting at first, and, when cutting was done, a few chisels and spear drills sufficed.

No discussion of dental development would be complete without including reference to Greene Vardiman Black, for it was Black who truly brought dentistry into the modern world and put it on the solid, scientific foundation it now occupies.

Black became associated with the dentist J C Speer at age 21 and after four months moved to Winchester, Illinois, and hung out his shingle as a dentist. In 1862 he entered the Union Army, but a knee injury led to his discharge in 1864. He moved to Jacksonville, which was considered an intellectual center, boasting of three dentists and half a dozen physicians. Among his children was Arthur D Black, who was later to carry on his traditions in dentistry.

G V Black became licensed as a physician in 1878 and helped write the first Illinois Dental Practice Act, which became law in 1881, and from 1881 to 1887 he served as president of the State Board of Dental Examiners.

He attended meetings of the Illinois Dental Society beginning in 1868 and presented papers there for more than 30 years. The subject of his first address, given in 1869, was gold foil, a "particular interest" to him because he "had become aware that gold fillings, in time, lost their cohesiveness, and had decided to find out why. To do so he taught himself chemistry and fitted up a laboratory" (Ring, 1985).

An indefatigable researcher, Black invented numerous machines for testing alloys. He also did more to standardize operative procedures than any dentist before or since. Two major contributions were his principle of "extension for prevention," bringing the margins of a filling out to the point where they can be readily reached by a toothbrush, and his standardized rules of cavity preparation. In that day, photographic slides were nonexistent, and Black devised oversize models of teeth and mammoth hand instruments to demonstrate to his students exactly how teeth should be prepared for filling (Ring, 1985).

In Black's time gold foil and amalgam constituted almost all of the permanent restorations. The Amalgam War had divided the profession, and Black was in the process of investigating and improving dental amalgam. The New Department Creed had been advanced in 1877. One point of the creed typified the struggle within the profession at that time: "The use of plastic filling materials tends to lower that dentistry which has for its standard of excellence ability to make gold fillings but very much extends the sphere of usefulness of that dentistry which has for its standard of excellence ability to save teeth" (Welk & Laswell, 1970).

Because of the limitations of available instrumentation (i e, foot-driven or hand-powered drills, steel burs, and hand instruments had not reached present refinement), it was not as easy to remove noncarious tooth structures during G V Black's time. Also, local anesthetic was not in use for restoration procedures, and the cutting of noncarious tooth structure was painful.

There were no significant preventive measures available, such as the systemic and topical fluoride systems of today. Furthermore, the appreciation of the public for oral hygiene had not developed to the level that is observed today.

It was in this atmosphere that Black formulated his ideas of cavity preparation design to include:

1. Outline Form
2. Resistance and Retention Form
3. Convenience Form
4. Removal of Caries
5. Finish of Enamel Walls
6. Toilet of Cavity Preparation (Welk & Laswell, 1970).

In 1891 *Dental Cosmos* published his articles on cavity preparation for gold foil. These were published later in book form. Black's cavity preparation "eventually became the accepted procedure in all teaching of gold foil filling technique, and it remains so today. It is also the foundation upon which all theories of inlay cavity preparation are based." (Gillett, 1927).

Still at work on the mottling of tooth enamel associated with fluorosis, Black died on 31 August 1915 at the age of 79, having immeasurably enriched the field of dentistry. Nineteen years earlier, in 1896, he had made a prophetic statement to some of the students he so markedly influenced: "The day is surely coming, and perhaps within the lifetime of you young men before me, when we will be engaged in practicing preventive, rather than reparative, dentistry. When you will so understand the etiology and pathology of dental caries that we will be able to combat its destructive effects by systematic medication" (Ring, 1985).

A textbook published in 1887 made reference to cavity form being considered before the placement of "gold plugs" in the carious lesion. "The preparation of carious cavities for the reception of gold or tin may be divided into three general procedures: the opening of the orifice which includes the definition of healthy margins; the excavation of the carious portion; and the formulation of the cavity to adapt it to receive and retain the filling" (Litch, 1887). This is one of the first written considerations on cavity form and retention of the filling.

> The chisel is one of the most important instruments at the present used in the first stages of the preparation of cavities, it taking the place of files and drills, which formerly were much employed for this purpose. The advantages of the chisel consist in the facility with which it can be used to cut at whatever part requires removal, without the danger of cutting parts not needing removal; the enhancement of the comfort of the patient; and the promotion of the speed of the operation. . . . The cutting of enamel in opening cavities is performed by two methods--by splitting on the line of cleavage of the enamel-prism, and by planing, which is most easily done by a movement somewhat oblique to the line of cleavage (Litch, 1887).

In 1887 the profession began to place more emphasis upon complete removal of caries. "The removal of caries should always be made with caution and with reference of the probability of the proximity of the disease to the pulp. This caution is in the interest and for the comfort of both the patient and operator" (Litch, 1887).

The cavity form itself later became a concern: "The opening of the cavity is commenced by trimming of the labial wall to a state of smoothness, permitting as much to remain as can be retained; at the same time its sharp irregularities should be removed, in order that the line of gold when finished shall be in agreeable curves" (Litch, 1887).

Clinicians also began to select gold for the anterior teeth. "Labial cavities are usually not deep and generally are not of great extent; nor are they difficult of execution by correct procedure. As, however, they are in an exposed situation, the fillings are required to be very healthy constructed, the gold should be securely packed and when completed have a beautifully finished surface" (Litch, 1887).

It was stated that the gold selected for class 3 restorations should in all cases be soft cohesive gold. The reason given for this was that this type of gold, when densely packed, is more nearly the color of the teeth and does not acquire a higher burnished appearance by the friction of cleansing as do the hard golds.

Another reference discussed platinized foil: "Platinized gold, because of its slight grayishness of tint, is well adapted to bluish teeth. . . . This kind of gold is however only adapted to surfacing the filling, and should not be employed until the filling process approaches completion" (Litch, 1887). This is the first mention of veneering foil with platinized foil; the method is still used today.

Dr Kirk identified that operations of the anterior teeth that are exposed to view require the greatest degree of artistic skill. They should be made as pleasing as possible to the eye. "The original outline of tooth should be restored with the gold, because it presents a better appearance than a space between it and the adjoining tooth" (Kirk, 1897).

Until the latter part of the nineteenth century, little or no concern was placed on cavity design or even esthetics in the placement of gold foil restorations. Neither dental schools nor the men who were connected with them led the field for cavity design. Rather, individual dentists with great drive and leadership for the advancement of dentistry have brought dentistry to the state of refinement that it enjoys today.

Clinicians from various parts of North America led in the progress of gold foil cavity design and the development of instruments. It was G V Black who became known as the father of modern dentistry. About the time of Black's death, Dr Charles E Woodbury picked up the gauntlet of leadership and continued Black's study club teaching with further development of the class 3 cavity design and refinement (Figs 1-4).

In 1913 Drs Wedelstaedt and Searle came out to the Northwest to give courses in gold foil. These men were from the G V Black study club group in Minnesota. Wedelstaedt usually did the talking, while Searle did the operating. Each man designed certain instruments such as the "Searle swager" and the "Wedelstaedt curved chisels," which are still used today. Their visit encouraged the organizing of gold foil study clubs in the Northwest.

W I Ferrier became a member and mentor of the Seattle Dental Study Club, and soon began giving courses of his own cavity design and refinement (Figs 5, 6). He aided in the development of instruments, clamps, and separators.

During the 1940s, Drs R O Green, W J Simon, and Dr Arthur Gabel added their versions of cavity design for the class 3 foil restoration (Figs 7, 8).

In the late 1940s and 1950s, patients and clinicians alike became more conscious of appearance. More thought was given to preparations with a lingual approach. Drs Harry True, Ernie Jones, Alex Jeffery, and Bruce Smith all designed preparations that required a lingual access (Figs 9-13). True had been one of Woodbury's students in the Midwest. He was the first to develop the inconspicuous class 3 design. Alex Jeffery and Ernie Jones were students of W I Ferrier. They each designed their own lingual-approach class 3 preparations. Dr Jones's preparation became known as the "slot" preparation.

In the 1960s the Loma Linda Gold Foil Seminar developed still another lingual approach for the class 3 preparation (Figs 14, 15). Powdered gold, as developed by one of the seminar members, Dr Lloyd Baum, became an important adjunct for all of the lingual-approach restorations. With the use of the rotated binangle hatchets and angleformer designed by Dr Alex Jeffery and the hand condensers designed by the Loma Linda Gold Foil Seminar, the lingual approach class 3 foil has been the most popular design used today by the dental profession.

Since 1980 three independent surveys (Lambert, 1980; Bales, 1985) have been conducted that ask the amount of time spent teaching direct gold restorations in dental schools. In the 1987 survey to which many dentists responded, the type of preparation design being used was also asked. These surveys revealed a decrease, between 1980 and 1987, in the time spent teaching direct gold restoration in dental schools. All three surveys showed that the lingual approach was

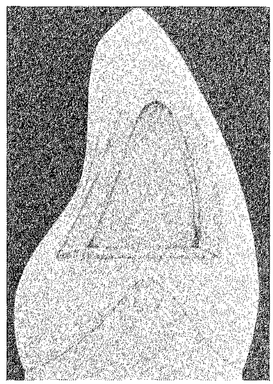

FIG 1. *G V Black's preparation, showing normal extension, facial approach*

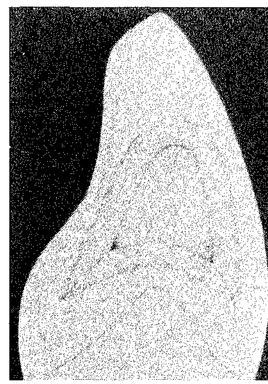

FIG 2. *G V Black's preparation, showing extreme extension, facial approach*

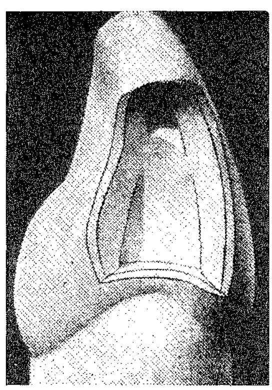

FIG 3. *Charles Woodbury's preparation, facial approach*

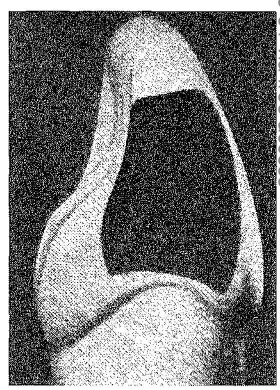

FIG 4. *Charles Woodbury's restoration with direct gold filling material*

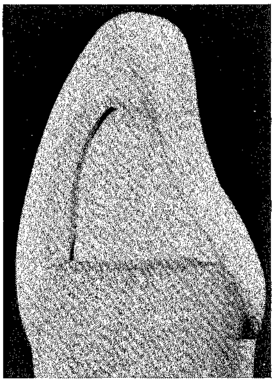

FIG 5. W I Ferrier's preparation, facial approach

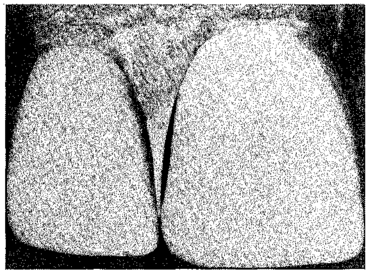

FIG 6. *W I Ferrier's restoration, showing the harmonial outline with the distal lobe of the tooth*

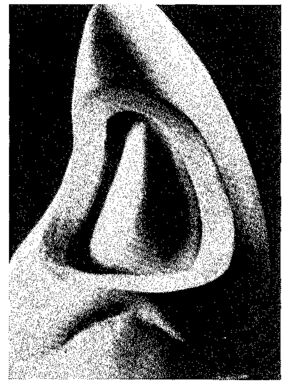

FIG 7. *Arthur Gabel's preparation, showing axial wall curvature, rounded facial gingival, lingual gingival cavosurface angles*

FIG 8. *Lingual view of Arthur Gabel's class 3 preparation. Compare outline form with that of W I Ferrier's, FIG 6.*

FIG 9. *Harry True's class 3 direct gold preparation. Note the similarity of outline with Charles Woodbury's, FIG 3.*

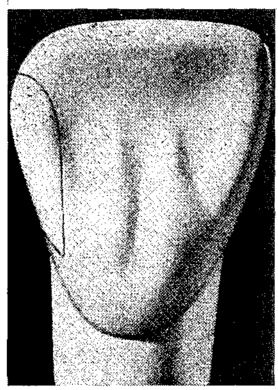

FIG 10. *Lingual outline of Harry True's preparation. Note large lingual incisal access for preparation and condensation.*

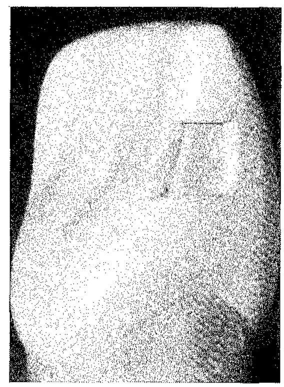

FIG 11. *Ernie Jones's lingual access "slot" preparation, also known as the Ingraham slot design. Note sharp cavosurface line angles.*

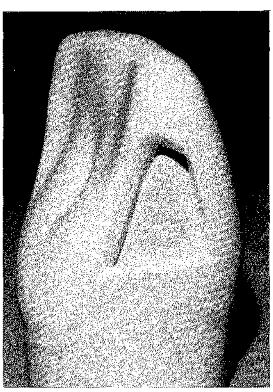

FIG 12. *Alex Jeffery's "inconspicuous" class 3 design, lingual approach access*

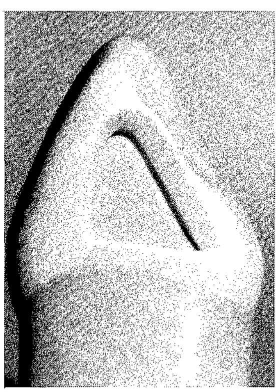

FIG 13. *Bruce Smith's lingual approach class 3 preparation for mesial of maxillary cuspid*

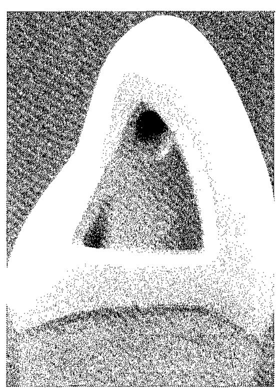

FIG 14. *Loma Linda's class 3 lingual approach design. Note the absence of lingual wall and lingual axial line angle. Larger retentive points are needed for use of powdered gold.*

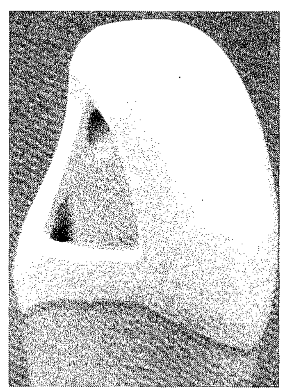

FIG 15. *Loma Linda's class 3 lingual approach design. Note harmony of labial cavosurface outline with the facial curvature of the tooth.*

the most commonly taught design (Tables 1-4).

This statement by Marshall, published in 1901, sums up the history of cavity preparation:

> The ideal filling-material, like the 'fountain of life,' still lies within the realm of the undiscovered. No substance or combination of substances yet discovered possesses all of the features and characteristics necessary to fulfill the requirements of the ideal material for filling teeth. Such a filling must be indestructible in the fluids of the mouth, and not susceptible to chemical change in the presence of substances which enter the mouth as aliment or as medicinal remedies; it must be easy of adaptation and capable of making a moisture-tight plug; it must be so dense in structure as to retain its form and resist the abrasion of mastication; capable of being colored to match any shade of the natural teeth, and polished or glazed to imitate the enamel; it must be a non-irritant and a non-conductor of thermal changes; incapable of shrinkage or of staining the tooth-structure, and possessed of such adhesive and cohesive qualities as will retain it in any imaginable location and permit of the most elaborate contouring; and, finally, it should possess such therapeutic properties as to make it preservative of tooth structure.

Table 1. Number of Schools Teaching Gold Foil Theory or Technique Comparing Three Surveys

Survey/ Year	Responses	Teaching Gold Foil	Not Teaching Gold Foil
Lambert 1980	63	58	5
Bales 1984	54	49	5
Schnepper 1987	40	31	9

Table 2. Number of Schools Requiring Practice in Gold Foil Technique Comparing Three Surveys

Survey/ Year	Responses	Required	Elective
Lambert 1980	63	38	20
Bales 1984	54	35	11
Schnepper 1987	40	23	8

*Table 3. Summary of Type of Class 3 Preparations Commonly Used Comparing Three Surveys**

Survey/	Lingual				Facial		
Year	Jeffery	LL	Slot	Other	Woodbury	Ferrier	Other
Lambert 1980	12	23	14	–	–	17	7
Bales 1984	4	19	–	–	3	7	–
Schnepper 1987	–	11	–	5	–	10	3

TOTALS	Lingual	Facial
1980	49	24
1984	23	10
1987	16	13

*Several schools teach more than one technique concurrently

Table 4. Number of Schools Currently Using Lecture and Clinical Practice to Teach Gold Foil Technique

Harold E Schnepper Survey, 1987

Survey Category	Number of Schools
Lecture Only	5
Lecture and clinical less than 5 hours	7
Lecture and clinical more than 5 hours	16
Elective less than 5 hours	3
Neither lecture nor clinical hours	9
TOTAL RESPONSES	40

References

BALES, D J (1985) An evaluation of the future potential of direct filling golds *Gold Leaf* January.

DEXTER, J E (1876) *A History of Dental and Oral Science in America* pp 52-124 Philadelphia: Samuel S White.

GILLETT, H W (1927) Gold inlays by the indirect system *Dental Items of Interest* **49** 765-771.

KIRK, E G, ed (1897) *The American Textbook of Operative Dentistry* p 203 London: Henry Kimpton; Philadelphia: Lea Bros.

LAMBERT, R L (1980) A survey of the teaching of compacted gold *Operative Dentistry* **5** 20-23.

LITCH, W F (1887) *The American System of Dentistry* pp 65-125 Philadelphia: Lea Bros.

MARSHALL, J S (1901) *Principles and Practice of Operative Dentistry* pp115-251 Philadelphia: J B Lippincott.

RING, M E (1985) *Dentistry: An Illustrated History* pp 76-274 New York: Abrams; St Louis: C V Mosby.

WELK, D A & LASWELL, H R (1970) Rationale for design of cavity preparations *Journal of the American Academy of Gold Foil Operators* **13** 75-85.

WESTCOTT, A (1870) Adhesive gold foil--its discovery, history and use *Dental Cosmos* **12** 57-66.

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Marquette University, WI	Roger John Kaneshiro

DEPARTMENTS

Press Digest

The editor wishes to thank the General Dentistry Residents, Class of 1990, Wilford Hall USAF Medical Center, for their assistance in the preparation of the following abstracts.

The dimensions of everyday class-II cavity preparations for amalgam. *Jokstad, A (1989) ***Acta Odontologica Scandinavica*** **47 89-99.**

(*Asbjorn Jokstad, Department of Anatomy, Dental Faculty, PO Box 1052, Blindern, University of Oslo, N-0316 Oslo 3, Norway)

The aim of this study was to access the morphology of routine cavities prepared for amalgam restorations. Epoxy plastic models, in which class 2 cavities for amalgam restorations had been prepared by eight Scandinavian dentists, were examined at various locations on the tooth. The results showed that the outlines of the cavity preparations were relatively large, with mean buccolingual extensions at 50% of the intercuspal distance and 40% of the approximal surface, with the preparations getting larger towards the posterior part of the mouth. These preparations could be the result of using outdated cavity designs that were employed when modern instrumentation was not available, these ideas not being adjusted to the potential of the smaller bur working at high speeds. Clinical thinking should be focusing on the caries, with the minimal removal of sound tooth structure.

Topical ice: A precursor to palatal injections. *Harbert, H (1989) ***Journal of Endodontics*** **15 (1) 27-28.**

(Contact Williams & Wilkins, Publishers, *Journal of Endodontics*, 428 East Preston Street, Baltimore, MD 21202-3993)

Many patients find palatal injections painful, and dentists may react by becoming reluctant to use them. The topical numbing effect of ice was found to relieve the discomfort of and promote acceptance of palatal injections. An ice-stick is held against the palatal tissues for 45 seconds. The ice is moved away from the injection site slightly and the anesthetic needle gently placed into the palatal tissues. Slow injection of anesthetic allows diffusion of the solution and anesthesia is obtained. The technique is reported to be comfortable, safe, effective, and readily accepted by apprehensive adolescents and adults.

Adhesion of a glass ionomer cement to bleached and unbleached bovine dentin. Titley, K C, *Torneck, C D, Smith, D C, & Applebaum, N B, (1989) ***Endodontics & Dental Traumatology*** **5 132-138.**

(*Department of Endodontics, Faculty of Dentistry, University of Toronto, 124 Edward Street, Toronto, Ontario M5G 1G6, Canada)

In this study the adhesive bond between bleached and unbleached bovine dentin and

Fuji II glass-ionomer cement was compared. Bovine dentin was bleached with 35% hydrogen peroxide for 60 seconds. Results showed a significant decrease in shear and tensile strength when compared to dentin subjected to 0.9% saline. Authors speculate that an interaction takes place between the cement and residual hydrogen peroxide or peroxide-derived material; this residuum was not eliminated by 37% phosphoric acid etch.

Bond strength of resin to amalgam as affected by surface finish. *Cooley, R L, McCourt, J W, & Train, T E (1989) *Quintessence International* 20 237-239.

(*Associate Professor, Department of General Practice, The University of Texas Health Science Center, 7703 Floyd Curl Drive, San Antonio, TX 78284-7914)

Cover-Up II purportedly chemically bonds composite resins to amalgam. Panavia, though not touted as an amalgam bonding agent, has reported high adhesion to sandblasted base metals. Bond strengths of Cover-Up II and Panavia to diamond stone- or air-polished amalgam surfaces were determined. Cover-Up II had bond strengths in the 6-7 MPa range when the surface was finished with a diamond stone, strengths that were significantly higher than Panavia. Amalgam surfaces treated with a diamond stone had higher bond strengths than those finished with air polishing. There was no significant difference between any of the air-polished groups.

Cusp movement of molar teeth with composite filling materials in conventional and modified MOD cavities. *Pearson, G J & Hegarty, S M (1989) *British Dental Journal* 166 162-165.

(*Department of Experimental Dentistry, University College London Dental School, Mortimer Market, London WV1E 6FD, England)

This study investigated the effect of three different cavity designs (conventional MOD, parallel-sided MOD, and a slit cavity design) on cusp movement and marginal adaptation on molar teeth using P-30 and Heliomolar with Scotchbond dentin bonding agent. Cusp movement was monitored using linear variable displacement transducers, and subsequent marginal adaptation was evaluated using dye studies. The cavity design did not play a significant part in determining the degree of cusp movement caused by polymerization shrinkage. Significant dye penetration was noted only in the small number of samples where cusp movement occurred in the same or opposite directions, and not in the majority where cusp flexure occurred toward the center of the tooth.

The effect of three filling techniques on marginal leakage around class II composite resin restorations in vitro. Koenigsberg, S, *Fuks, A, & Grajower, R (1989) *Quintessence International* 20 117-121.

(*Department of Pedodontics, The Hebrew University-Hadassah, Faculty of Dental Medicine, PO Box 1172, Jerusalem, Israel)

Leakage at cervical and occlusal margins of class 2 composite restorations (P-30, 3M Dental Products Div) using three different fill techniques was compared. Incremental filling gave rise to less dye penetration at cervical margins than bulk filling. There was no significant difference between incremental filling in a buccolingual and gingivo-occlusal direction. The lowest penetration of dye was at occlusal margins.

Herpes labialis treatment with acyclovir 5% modified aqueous cream: A double blind, randomized trial. *Raborn, G W, McGaw, W, Grace, M, Percy, J, and Samuels, S (1989) *Oral Surgery, Oral Medicine, Oral Pathology* 67 676-679.

(*Department of Dentistry, University of Alberta Hospitals, Edmonton, Alberta, Canada T6G 2B7)

The efficacy of 5% acyclovir in a newly modified aqueous cream formulation was tested in the treatment of recurrent herpes labialis. A randomized, double-blind study was conducted on 51 patients. The patients were instructed to apply the cream formulation within one hour of onset of prodromal symptoms. In terms of lesion characteristics and healing response, no significant differences were demonstrated between the acyclovir cream and the controls.

Book Reviews

CARIOLOGY
Third Edition

Ernest Newbrun, DMD, PhD
Published by Quintessence Publishing Co, Inc, 1989. 400 pages, 97 illustrations. $58.00.

The third edition of Dr Newbrun's text, *Cariology*, is intended for "students who have already completed courses in general biochemistry, histology, microbiology, nutrition, and pharmacology." A very current knowledge of these topics is critical to the understanding of much of the material contained in the text. The material is of a very detailed nature and would be ideal as a text for the dental student trying to find relevance in the basic science courses. A basic science instructor for dental students would do well to use this text as a bridge between disciplines. For the dentist trying to improve treatment of caries in clinical practice, there is some useful information, but this book would better fit the dentist who desires to keep current with caries research.

The text covers theories of the carious process, both historical and current. It also reviews the microbiological literature relevant to caries formation and the histopathology of the carious lesion. Bibliographies and suggested reading lists are extensive. The inclusion of a glossary for the dentist who has been away from the basic sciences for a while would have been helpful. Especially interesting are the chapters on the cariogenicity of foods and sugar substitutes. Dr Newbrun provides useful information relating to the substrate for dental caries which can be applied by the clinician who addresses diet modification with his caries-prone patients. Most useful is the discussion on newly developed products designed to "fight plaque," both mouthrinses and toothpastes. Several tables comparing dentrifices as to their abrasivity and therapeutic actions are presented.

It is remarkable that one author is able to discuss such a diversity of topics with such authority. The book is complete with regard to the initiation, progression, and prevention of dental decay. The text is most suited for the dental student freshly out of the sciences or the clinician who strives to keep current with caries research.

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PERIODONTAL CONTROL: AN EFFECTIVE SYSTEM FOR DIAGNOSIS, SELECTION, CONTROL AND TREATMENT PLANNING IN GENERAL PRACTICE

A M Grace, BDS, and F C Smales, PhD, BDS, FDS

Published by Quintessence Publishing Co, Ltd, London, 1989. 144 pages, indexed, 67 charts and drawings. $32.00.

The responsibility of the general dentist to properly document the diagnosis and appropriate treatment or referral of patients with periodontal disease is an established medico-legal fact. This text by two British authors, one a general dentist and the other a periodontist, presents a systematic method of diagnosing and monitoring the ongoing periodontal condition of patients. In addition to providing a readily observable continuous history of the periodontal status of a patient, the system also provides a tangible patient motivational tool and indicator of appropriate treatment needs.

Following an opening chapter which presents current thinking regarding the episodic bursts of periodontal breakdown in site-specific areas of the mouth, the remaining 11 chapters are divided into two sections. Chapters 2 through 6 deal with periodontal indices, focusing initially on the Community Periodontal Index of Treatment Needs (CPITN). The CPITN is an epidemiological index developed by the World Health Organization and the International Dental Federation. Chapters 7 through 12 focus on the use of these indices in determining treatment needs for individual patients.

The book's subtitle states its major strength: an "effective system for diagnosis, selection, control and treatment planning in general practice." It presents a systematic, reliable, and well-documented method of assessing a patient's periodontal health history and predicting treatment needs. There are weaknesses, but not so much with the book as with the system it presents. The authors state that the CPITN, which is foundational to the system, "relies entirely for its scoring on a special type of periodontal probe which was developed by the WHO solely for this index." Should the findings of the initial CPITN identify the need for any treatment, even "simple scaling and occasional plaque control instruction," additional indices are required, using a standard-type probe. Recordings are required on two or three separate charts and then transferred to a Monitoring Chart. A separate Probing Depth Chart may also be necessary.

For the general dentist who is looking for a systematic and reliable method of diagnosing and monitoring patient periodontal health, as well as predicting potential treatment needs, this book would be most helpful. For those who already use a workable method, the cumbersome system presented would probably not warrant a change.

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The cautious seldom err.
--Confucius (551-479 BC)

Letters

THE NEED FOR OPERATIVE DENTISTRY SERVICES; PROJECTING THE EFFECTS OF CHANGING DISEASE PATTERNS

Thank you for moving the article on the future need for dentistry by John W Reinhardt and Chester W Douglass forward in the print list. It contains significant information that dental school administration and university directors should have before them when making decisions about reorganization or even closure of dental schools.

I compared the conclusions of the article as to the hours of operative treatment needed to meet the needs of the US population with the numbers of available dentists projected by the AADS Manpower Project report #1 for 1985-2020 by Eric S Solomon. In 1972 there were 114 000 active dentists and 125 million hours of operative treatment needed. Thus each dentist would have to spend 1096 hours that year to meet the needs of the US population. For 1990, with 149 680 active dentists and 150 million hours of treatment needed, each one would spend 1002 hours. For 2020, the last year of the AADS projection, there will be 137 365 active dentists. This figure is about 11 000 less than the 148 187 dentists projected for 2010. If the decline in dentists should continue, there would be about 126 000 active dentists in 2030. Thus with 192 million hours of treatment needed, each dentist would have to spend 1524 hours providing operative treatment. This exceeds the average number of hours (1500) a dentist spends in a year doing *all* phases of dentistry.

The above figures do not take into account the fact that not all dentists provide operative treatment and that many dentists do not practice full-time. Of course the US population does not seek dental treatment at a level which would meet all needs.

But at least these figures show that starting in the very near future, there will probably be too few dentists to provide the care most Americans expect.

It is incumbent upon universities to plan for future needs, not merely to react to present exigencies. It seems that my own university, Georgetown, has now sacrificed the opportunity for future service upon the altar of present financial expediency.

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RESPONSE

I agree with the conclusions of Dr Robbins that there will be a progressive increase in the number of hours of restorative need per dentist in the US beginning in the near future. On the supply side, the number of dental graduates has declined rapidly over the past five years. On the demand side, patient utilization of dental services has increased significantly (from about 47% in 1970 to between 57 and 63% in 1986 who had visited a dentist in the 12 months preceding).

The formula used in our study to determine total hours of restorative need in the US population at any given point in time does not assume that all those people will seek treatment. As Dr Robbins points out, those numbers should be viewed with the knowledge that not everyone seeks care. Likewise, not all dentists provide restorative treatment. The best interpretation of those calculations is that they represent a relative measure of disease available for treatment at a given point in time.

Finally, with respect to the economic condition of our aging population, currently 26% of US citizens are 50 years of age or older. However, those 50 and older have 50% of the discretionary income. As the health-conscious baby boom generation ages, those percentages will both be rising. The effect upon the need and demand for restorative dentistry is very apparent.

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DIRECT GOLD INTEREST ALIVE AND WELL IN GERMANY

In June about 20 members of the American Academy of Gold Foil Operators offered a two-day presentation of lectures and clinical demonstrations for educators, practitioners, and dental students at the University of Göttingen, West Germany. This endeavor was organized by Dr Josef Schmidseder of Munich, Professor Alex Motsch of Göttingen, and Dr Allan Osborn of Winnipeg.

Covering the whole spectrum of direct golds, from materials to specific styles of restorations, the speakers did an outstanding job (at their own expense). There were several hundred in the audience, and response was excellent. Students were eager to learn more about the materials, though they had gained some experience in dental school. And students also volunteered as patients for the clinical demonstrations.

A general impression received by the American visitors was that the level of dental education in Germany was quite good, and facilities at this particular school were excellent. Those who attended had an opportunity to enjoy not only the outstanding foods from the regions, but also to satisfy appetites with the fantastic scenery throughout the country.

The group is now considering plans for a similar venture in Italy in the next year or so. Auf Wiedersehen!

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NOTICE OF MEETINGS

American Academy of Gold Foil Operators

Annual Meeting:
31 October - 2 November 1989
University of Washington and
Four Seasons Olympic Hotel
Seattle, WA

Academy of Operative Dentistry

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

OPERATIVE DENTISTRY

ACADEMY OF AMERICAN GOLD FOIL OPERATORS

ACADEMY OF OPERATIVE DENTISTRY

volume 14
1989

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OPERATIVE DENTISTRY

Aim and Scope

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

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