OPERATIVE DENTISTRY

may-june 1993 • volume 18 • number 3 • 81-128

(ISSN 0361-7734)

OPERATIVE DENTISTRY

MAY-JUNE 1993 • VOLUME 18 • NUMBER 3 • 81-128

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.

Publisher

Operative Dentistry (ISSN 0361-7734) is published bimonthly in January, March, May, July, September, and November. *Operative Dentistry* is the official journal of the American Academy of Gold Foil Operators and the Academy of Operative Dentistry.

POSTMASTER: Send address changes to: Operative Dentistry, Inc, University of Washington, School of Dentistry, SM-57, Seattle, WA 98195, USA.

Subscriptions

Yearly subscription in USA and Canada, \$55.00; other countries, \$65.00 (sent air mail); dental students, \$25.00 in USA and Canada; other countries, \$34.00; single copy in USA and Canada, \$15.00; other countries, \$18.00. For back issue prices, write the journal office for quotations. Make remittances payable (in US dollars only) to *Operative Dentistry* and send to the above address.

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Contributors should study the instructions for their guidance printed inside the back cover and should follow them carefully.

Second class postage paid at Seattle, WA and other selected points.

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University of Washington, School of Dentistry, SM-57, Seattle, WA 98195, USA

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EDITORIAL

The Engineer

The patient in the office was a friend named Homer. Homer is a mechanical engineer with a background in metallurgy and a wonderfully active mind. He asked me if I would answer some questions about the dental preparation designs as we progressed through his appointment. Homer's interest had been piqued while he was sitting in the waiting room. He had picked up a dental journal and had actually read an article about microleakage and posterior resin restorations. I told him with pride that I was well versed in the subject, and I thought I could answer all his questions if we could communicate through the rubber dam.

As Homer settled into the chair, he asked why we used the "box-shaped" preparation for resins. As I leaned the chair back, I explained to him that in many cases resins are used as replacement restorations. The box shape was placed originally for a metallic restorative material, and the new restoration was just taking its place. Homer said he understood that, that was basic beam engineering, but the article he had just read in the waiting room had used box shapes in extracted teeth where no restoration had previously existed. "Why do you use that shape in those circumstances?"

Well, he had me there. My expert status was in jeopardy. So I told Homer to hold still and open wide while I delivered "the inferior alveolar anesthetic." The injection took his mind off that question. I asked Homer to let me know when his lip began to tingle and began to apply the rubber dam. As we proceeded, Homer and I discussed how dentists gain access to posterior cavities between the teeth by cutting away tooth structure from the chewing surface until they encountered the cavity. Once the diseased tooth structure is cut away, the mechanical design of the cut area is altered to allow receipt of the filling material. In the case of posterior teeth, where the caries exists between the teeth, that means constructing his self-described box. I was on a roll now; my expertise was showing. I explained that this form was a biomechanical design that made the tooth ready to receive dental amalgam or cast metal materials that replaced the missing tooth structure and kept the tooth and material from harm.

"Exactly!" he shouted from under the rubber dam.

"Exactly what?" I asked, beginning to worry that my cloak of expertise was slipping again.

"Exactly what I said before!" he said. "Why are you using the same box shape for these plastic materials?"

Geez, wasn't his anesthesia starting to wear off? Should I give him another injection?

Homer was too quick for me and continued. "Your box shape makes a lot of sense for the metals you use, but it makes no sense for these plastics. They don't have the same properties that the metals do. You should design a different shape that takes advantage of the plastic's properties. Why don't you just drill in from the side to remove the cavity, and then seal it with the plastic?"

Now I had him. "Well Homer, it's not that easy. Drilling in from the side is pretty tough. The visibility is very limited, and I might leave some of the decay."

"You drill in from the side on my front teeth, why not on my back teeth? Besides, the article I just read says that these materials seal enamel really well. What does it hurt to leave some of the decay, if it's sealed in? Didn't you tell me that sealing in a little decay was OK when we put those sealants on my kids?"

"Homer, you're going to have to hold still now while I finish this. I've got to tell you that it's just not that easy." I was desperate for some supporting evidence that this wasn't a good idea. "If it were that easy, we'd all be doing it. Heck, I've never seen anybody even write about it." That seemed to quiet the discussion.

Homer remained silent for the rest of the appointment, apparently lost in thought. Whew! The session reminded me of dental school. The faculty were always asking me questions I couldn't answer.

I finished the amalgam on Homer, and we exchanged parting pleasantries. As he was leaving Homer stopped and said, "I am reminded of a phrase from Richard Hooker, 'Change is not made without inconvenience, even from worse to better.' "

With that, Homer left, and my humility abruptly returned.

MAXWELL H ANDERSON
Editor

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ORIGINAL ARTICLES

Reasons for Placement, Replacement, and Age of Gold Restorations in Selected Practices

IVAR A MJÖR • JOSÉ E MEDINA

SUMMARY

A total of 745 gold restorations were surveyed concerning the reasons for their placement and replacement. Cast gold restorations (n = 480) were placed due to primary caries (23%), replacement of amalgam (39%), and composite restorations (9%), or due to failure of existing gold restorations (29%). The main reasons for replacement of cast gold restorations were fracture of tooth (36%) and secondary caries (22%).

The main reasons for the placement of compacted gold restorations (n = 265) were treatment of primary caries (40%), failure of an existing compacted gold restoration (26%), removal of another type of restoration (18%), and repair of a defective margin of a casting (16%). The main reasons for replacement of compacted gold restorations were inclusion into larger restorations (29%) and secondary caries (21%).

The longevity of failed gold restorations was recorded for 111 restorations. The mean age for failed cast and compacted gold restorations was about 18.5 years (range 5-41 years). The ages of 2564 gold restorations in situ, 1689 castings, and 875 compacted gold restorations were recorded.The median and mean ages for gold castings were about 15 and 16 years and for compacted gold restorations about 17 and 18 years.

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INTRODUCTION

Limited information is available regarding the reasons for placement of gold restorations and the reasons for their failure. Secondary caries is frequently cited as the main reason for failure of cast restorations (Lester, 1974; Fitch & others, 1982; Presern & Strub, 1983; Goto, 1984).

Recordings of the longevity of failed gold restorations are somewhat controversial. The longevity of gold castings has been estimated by clinicians to be about 20 years and that of compacted gold restorations to be about 22 years. Members of the American Academy of Gold Foil Operators estimated the longevity of compacted gold restorations to be 26 years (Christensen, 1971). Some recordings of the longevity of castings indicate that they fail to survive as long as amalgam restorations (Allan, 1969; Crabb, 1981; Jahn & Gonschorek, 1986; Weiland, Nossek & Schulz, 1988), but another study indicates that 90% survive 10 years (Bentley & Drake, 1986). Nordbø and Lyngstadaas (1992) have reported a median longevity of 34 years for gold inlays in a selected practice and 16.5 years for gold inlays inserted by clinicians with limited experience.

Gold restorations are not made routinely in general practice, and attempts to gather information about their longevity have proved difficult. It was decided, therefore, to approach clinicians in general practice known to frequently use gold restorations in their operative treatment. This selection biases the results, because these clinicians are considered as specially qualified. They may also treat a selected segment of the population.

The aim of this survey was to consecutively record all gold inlays, onlays, and compacted gold restorations placed by 20 selected operators during a three-week period. The operators recorded the reasons for placement, the longevity of failed gold restorations, and the age of functional gold restorations from patients' records.

METHODS AND MATERIALS

Forms with the following reasons for placement and replacement of gold restorations were given to the clinicians: primary caries, removal of amalgam or composite restorations, repair of a defective margin by compacted gold, and replacement of failed gold restorations due to secondary (recurrent) caries, poor margins (but no caries), loose/lost restoration, fracture of tooth, and "other reasons."

Separate forms were prepared for cast and compacted gold restorations. If more than one reason for replacement of a restoration was present, the one that influenced the decision the most was recorded by the dentist.

Provided the patients' records showed when gold restorations needing replacement had been inserted, the clinicians were asked to record the time the restorations had served until replacement in years, and months if less than four years. In addition, the clinicians were asked to record the age of all gold restorations (cast and compacted) not needing replacement on 10 of their regular patients. Special forms and instructions were provided for this purpose. Only patients who had attended the practice regularly for more than 10 years were to be included in the survey. If any gold restorations were present at the patients' first appointment, the age was to be indicated as "more than" the number of years the patient had attended the practice.

RESULTS

A total of 480 cast and 265 compacted gold restorations were inserted during the survey by 20 clinicians. The distribution of restorations and the reasons for placement and replacement are outlined in Tables 1-4.

Most cast gold restorations were inserted to replace existing restorations of different types. Relatively few were inserted in the treatment of primary caries (Table 1). The main reason for failure of cast gold restorations was fracture of some part of the tooth (Table 2). Poor margins and loss of restorations were infrequent reasons for replacement. "Other reasons" included replacement due to excessive wear, bruxism, and inclusions into bridges.

Compacted gold restorations were mainly inserted in the treatment of primary caries,

Table 1. Reasons for Placement of Cast Gold Restorations

	n	%
Primary caries	110	23
Removal of amalgam restoration	189	39
Removal of composite restoration	42	9
Replacement of failed gold restoration	139	29
Total	480	

Table 2. Reasons for Placement of Cast Gold Restoration

	n	%
Secondary caries	30	22
Poor margins	17	12
Loss of retention	8	6
Fracture of tooth	50	36
Other reasons	34	24
Total	139	

Table 3. Reasons for Placement of Compacted Gold Restorations

	n	%
Primary caries	106	40
Removal of another restoration	48	18
Repair of margin of cast gold restoration	43	16
Failure of compacted gold restoration	68	26
Total	265	

Table 4. Reasons for Replacement of Compacted Gold Restorations

	n	%
Secondary caries	14	21
Poor margin	8	12
Made part of larger restoration	20	29
Fracture of tooth	5	7
Other reasons	21	31
Total	68	

and failure of existing compacted gold restorations constituted about a quarter of all restorations (Table 3). Almost a third of the restorations were replaced because they were incorporated into larger restorations (Table 4). Secondary caries as a reason for replacement (Table 4) was at the same level as for castings (Table 2). Poor margins and fracture of tooth were infrequent reasons for replacement of compacted gold restorations (Table 4). "Other reasons" included change to composite restorations, obturation of cavity for root canal treatment, and loss of retention due to toothbrush wear.

The ages of 111 failed gold restorations were recorded. The median age of this limited material was approximately 18.5 years (range 5-41). It was marginally higher for cast gold than for compacted gold restorations.

The ages of 2564 restorations (1689 castings and 875 compacted gold restorations) not needing replacement were also recorded. The median age was about 15 years for cast gold (Figure 1) and 17 years for compacted gold (Figure 2) restorations, which correspond to the mean ages of 16 and 18 years respectively. The calculations of median and mean values did not take into account notes of "more than" ages that were quoted. Slightly lower values than the actual values are, therefore, reported.

DISCUSSION

The selection of the most appropriate restorative material is dependent on a number of factors, e g, the clinical condition, including the extent of destruction of the tooth, the oral hygiene of the patient,

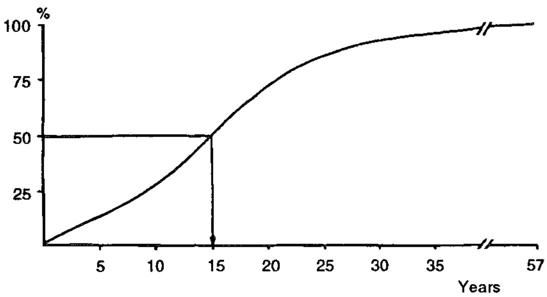

Figure 1. *Accumulated percentage distribution of the age of functional cast gold restorations. The point where the horizontal 50% line crosses the curve represents the median age of the restorations.*

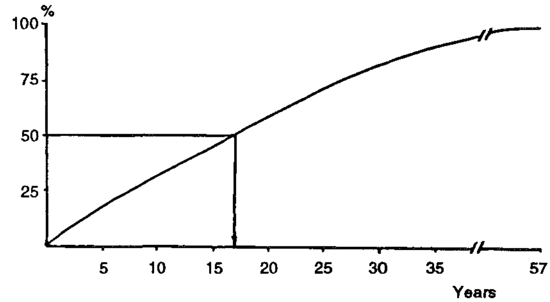

Figure 2. *Accumulated percentage distribution of the age of functional compacted gold restorations. The point where the horizontal 50% line crosses the curve represents the median age of the restorations.*

esthetic concerns, and cost of the treatment. Cast restorations, including inlays, onlays, and different types of crowns, are particularly suitable for extensively broken-down teeth. Compacted gold restorations are mainly indicated for small, one-surface restorations or repairs.

A patient selection for gold restorative therapy is generally believed to exist, since only patients with good oral hygiene are provided such treatment. Gold alloys are not considered as esthetically acceptable as tooth-colored restorative materials. Strong marketing efforts have promoted tooth-colored restorative materials, but factors other than esthetics enter into the selection of the most appropriate restorative material, such as the caries activity of the patient and the initial and long-term cost of restorative treatment.

Frequent replacement of restorations may result in the loss of tooth structure to a point where cast restorations may be the only feasible alternative. The present survey confirms that cast gold restorations are often used to replace other restorations, especially amalgam restorations.

Fracture of tooth and secondary caries were the primary reasons for failure of gold restorations. The present material does not allow a differentiation between inlays and onlays, i e, it cannot confirm or deny if any wedging tendency of inlays is important for tooth fracture. The frequency of secondary caries in the present study was slightly lower than that reported in a recent review (Beetke, Gatzer & Ritter, 1990), but higher than that reported in other studies (Goto, 1984; Nordbø & Lyngstadaas, 1992).

Gold castings have a limited use in the treatment of primary caries (Goto, 1984). The reverse relationship exists for compacted gold restorations. Most of these restorations are used to treat primary caries and to repair defective gold restorations. Only a few of these restorations replace other types of restorations.

The longevity of restorations reflects the sum of all factors affecting the restoration, including material properties, handling characteristics, and patient factors like oral hygiene and bruxism. Considerable information is available related to the longevity of restorations that have failed, especially for amalgam and composite restorations. However, information regarding the age of restorations that remain functional is indeed scarce (Jokstad, Mjör & Qvist, 1990). Such information is unlikely to stem from longitudinal clinical studies, because they rarely exceed five years of observation time. The need for data from patients' records in general practice is, therefore, urgently needed to assess the cost-benefit of different types of restorative treatment. Data from general practice, despite all the variables encountered in the recordings, have the advantage of representing "real-life dentistry," including those from selected practices. Clinical studies performed by specially trained operators working under optimal conditions on selected patients and without time constraints in a dental school environment are not considered to reflect general practice.

The limited number of recordings published on the longevity of replaced gold restorations indicate a similar mean age to that of functional restorations not needing replacement. The recorded mean longevities for cast and compacted gold restorations are slightly lower than those estimated by Christensen (1971) and slightly higher than those reported by Maryniuk and Kaplan (1986). A change in esthetic demands over the last two decades may explain this difference. It should also be noted that a significantly higher longevity was also estimated for amalgam restorations in these surveys (Christensen, 1971) than that reported in the literature (Mjör, Jokstad & Qvist, 1990). The complexity of the restoration is also a factor that affects longevity (Maryniuk & Kaplan, 1986).

The median longevity of failed gold restorations in the present study exceeds that of failed amalgam restorations (Mjör & others, 1990) in general practice by a factor of about 2, more for multisurface than for one-surface restorations. Thus, the present results agree with those reported by Bentley and Drake (1986) in that cast gold restorations last significantly longer than amalgam restorations.

Failed resin-based composite restorations in general dental practice are considered to have a median longevity of four years (Mjör, 1992). Compared to the longevity of cast gold restorations reported by Christensen (1971), Nordbø and Lyngstadaas (1992), and in the present study, these cast gold restorations last four times longer than large composite restorations. Small gold restorations, like those of compacted gold, have a median longevity that exceeds that of composite restorations by a factor of 2.5. Thus, the initial relatively high cost of operative treatment with gold restorations will be modified by differences in longevity in a long-term perspective (Mjör, 1992).

The cost of dental treatment is important for the individual patient, the dentist, and insurance companies or other third-party payment agencies. Prevention is undoubtedly the most cost-effective approach to caries, but when restorations are needed, the long-term cost plays an important part in the decision of treatment alternatives.

The cost of cast gold restorations exceeds that of similar amalgam restorations by a factor of 8 to 9 (Christensen, 1989; Wilson, 1991). The price ratio between similar posterior composites and cast gold restorations, according to Christensen (1989), would be approximately 1:4, while according to the schedule indicated by Wilson (1991), the ratio may be estimated to be 1:7, due to the relatively low fee for composite restorations reported from general practice. However, the long-term cost of restorative dentistry is not only dependent on the cost at the time of initial insertion, but also on the longevity of the restorations. The time has come to focus on the cost of restorative treatment over a lifetime, rather than solely on the cost at the time of placement of a restoration.

CONCLUSIONS

Cast gold restorations are the optimal treatment for replacement of large, failed restorations of any type. Compacted gold restorations may be used for small restorations. The initial cost of gold restorations is higher than that for amalgam and composite restorations, but the longevity of gold restorations exceeds that of any alternative by a factor of 2 to 4. Therefore, the long-term cost of gold restorations competes favorably with some of the alternatives, especially for large restorations.

Acknowledgment

The authors would like to acknowledge the collaboration of the clinicians who willingly spent time to do the recordings that form the basis of this study.

(Received 9 January 1992)

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Retention of Class 3 Composite Restorations: Retention Grooves versus Enamel Bonding

J B SUMMITT • D C N CHAN • F B DUTTON

Clinical Relevance
Retention grooves appear unnecessary in acid-etched resin restorations surrounded by enamel.

SUMMARY

This study compared the tensile loads required to dislodge class 3 composite restorations with and without retention grooves. Thirty extracted human maxillary central incisors were divided into two groups of 15 teeth each. A C-shaped class 3 preparation with lingual access was cut into one approximal surface of each incisor to standardized dimensions using a #329 bur. A 0.5-1.0 mm 45° bevel was prepared on the lingual and gingival enamel margins. In one group, an incisal retention point and a gingival retention groove were prepared with a #1/4 round bur to a depth of 0.25-0.5 mm; the other group had no retention grooves/points. A nonretentive 2 mm round "well" with diverging walls was cut 0.5-1.0 mm into the axial dentin to accommodate the head of a pin that was inserted prior to composite restoration. Each pin shaft extended approximally from its incisor. A bonding agent (Universal Bond 3 Primer and Adhesive, L D Caulk) was applied to each preparation, and composite resin (Prisma APH, L D Caulk) was inserted incrementally. Each increment was exposed to 40 seconds of polymerization light. Restoration surfaces were finished and polished with Sof-Lex disks (3M Dental Products). Specimens were thermocycled 6 to 60 °C, for 500 cycles, with a 30-second dwell time. They were then positioned in an aligning device, and

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pins were loaded in tension in an Instron Testing Machine at a head speed of 2 mm/minute to restoration failure. Mean (SD) failure loads in Newtons were: no grooves 83.6 (19.8); grooves 69.6 (18.1). Using independent group *t*-tests, no difference occurred between groups ($P > 0.05$). Results support the conclusion that retention grooves do not increase retention of class 3 composite resin restorations when resin is bonded to etched enamel that surrounds the preparation.

LITERATURE REVIEW

Traditionally, retention grooves and points have been used in class 3 preparations for composite resin. Current texts in operative dentistry advise the use of gingival, incisal, and in some cases, facial undercut retention in class 3 preparations, made with a #1/4 or #1/2 bur (Charbeneau, 1988; Sturdevant & others, 1984; Baum & McCoy, 1984; Baum, Phillips & Lund, 1985). In class 4 preparations for composite resin, the texts advise, at least for replacement of a small amount of tooth structure, that the restoration can be retained with enamel bonding techniques as first described by Buonocore (1955), even though class 4 restorations are exposed to more functional stress.

The need for undercut retention in preparations that are bounded by adequate enamel for etching and bonding has been questioned. In a recent study, Caplan, Denehy, and Reinhardt (1990) showed that, in class 2 restorations, retention grooves added significantly to the retention of amalgam restorations under compressive loading, but in composite restorations in which enamel bonding was used, retention grooves did not enhance failure resistance under the load. Strassler and Buchness (1990) suggested that etched enamel provides adequate retention for class 3 composite restorations and that undercut retention features are unnecessary.

The purpose of this study was to determine whether, in class 3 restorations, undercut retention, in addition to enamel bonding techniques, provides any supplementary retention when compared to enamel bonding techniques alone.

METHODS AND MATERIALS

Thirty extracted human maxillary central incisors, with at least one approximal surface free of caries and restorations, were collected, sorted by mesiodistal crown dimensions, and divided evenly into two groups of 15 teeth. A C-shaped class 3 cavity was prepared in either the mesial or distal surface of each incisor. Each preparation extended to the lingual surface to simulate a clinical situation in which there was an adjacent tooth. A #329 pear-shaped bur (Midwest Dental Products Corp, Des Plaines, IL 60018-1884) in a high-speed handpiece (Star Futura 2, Star Dental, Valley Forge, PA 19482) was used to cut each nonundercut preparation to the following dimensions (Figure 1):

Lingual marginal ridge to facial cavosurface margin: 2.25-2.75 mm,

Incisogingival dimension of lingual access: 2.00-2.25 mm, and

Axial depth at incisal wall: 1.25-1.75 mm.

A 0.5-1.0 mm 45° bevel was prepared on the lingual and gingival enamel margins using a #7901 flame-shaped 12-fluted finishing bur (Midwest) in the high-speed handpiece (Star Dental). In one group of 15 incisors, no undercut retention was placed in the dentin. In the other group of 15 incisors, using a #1/4 round bur (Midwest) in the same handpiece, an incisal retention point was cut in the dentin at the junction of the axial wall

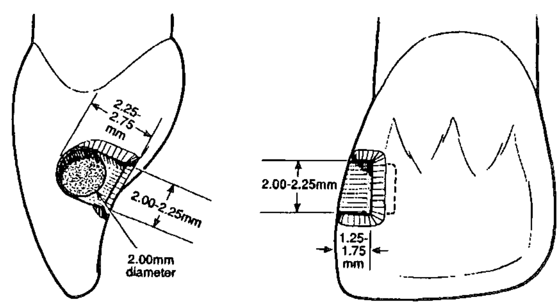
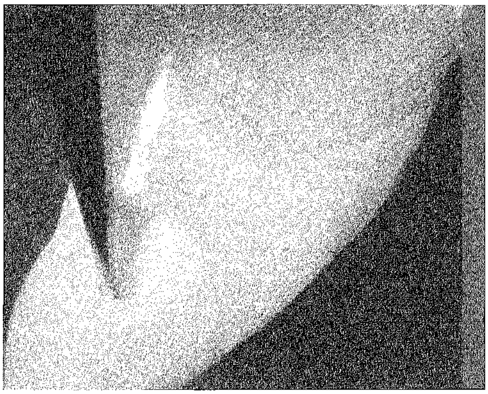
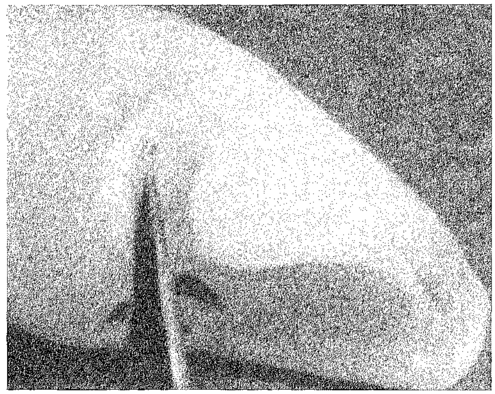


Figure 1. *Diagram of C-shaped class 3 preparation with lingual access, showing ranges of dimensions used, location of bevels, and location and size of well for pin head*



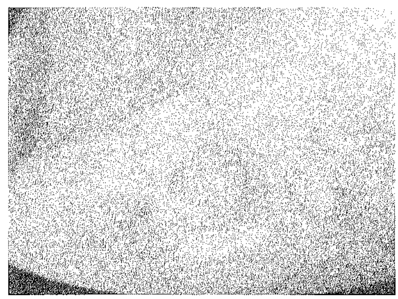
a. Incisal retention point



b. Gingival retention groove

Figure 2. *Undercut retention being cut into dentin*

a. Being prepared with a #170 bur in the axial wall of a class 3 preparation



b. Completed

Figure 3. *2 mm-in-diameter well to contain head of silk pin*

and the incisal wall of the preparation (Figure 2a); a gingival retention groove was cut in the dentin at the junction of the axial wall and the gingival wall (Figure 2b). The depth of each point and groove was controlled to a range of 0.25 to 0.50 mm.

After completion of the preparation in each tooth, a nonretentive 2 mm-in-diameter round "well" with diverging walls was cut with a #170 bur (Midwest) 0.5-1.0 mm into the dentin of the axial wall to accommodate the head of a silk pin (Figures 3a & 3b). Enamel bevels and walls were etched (Tooth Conditioner Gel, L D Caulk, Milford DE 19963-0359) for 20 seconds, rinsed for 20 seconds in a water stream, and dried. Universal Bond 3 Primer (L D Caulk) was applied to all dentinal walls of each preparation according to the manufacturer's instructions, and liquid resin (Universal Bond 3 Adhesive, L D Caulk) was applied to dentin and etched enamel and polymerized for 20 seconds using a visible light source (Coltolux 11, Coltene-Whaledent, New York, NY 10001).

The head of a silk pin (Silk Pins, nickel-plated steel, size 17, Dritz Corp, Spartanburg, SC 29304) was inserted into the "well" in each axial wall so that the entire head was axial to the level of the original axial wall of each preparation. Each pin was oriented so that the pin shaft extended from the preparation at an angle perpendicular to a tangent to

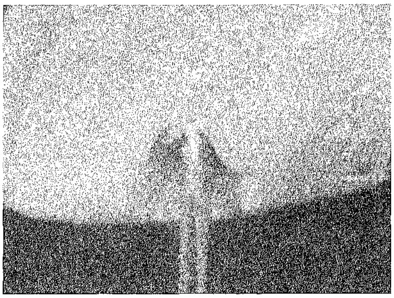


Figure 4. *Pin was oriented at a perpendicular angle to a tangent to the approximal surface of the tooth and luted with liquid resin.*

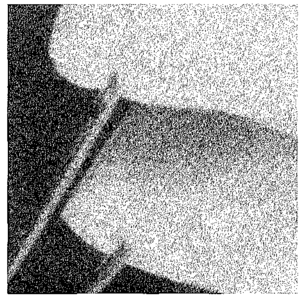


Figure 5. *Completed restoration with shaft of silk pin protruding through approximal surface of restoration (photographed on mirror)*

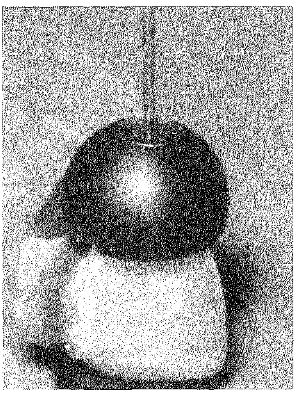


Figure 6. *Steel hemisphere attached to approximal surface with pin shaft extending through center channel; the 3 mm diameter of the center channel allowed the load to be applied with only approximal enamel (not the restoration) supported by the hemisphere.*

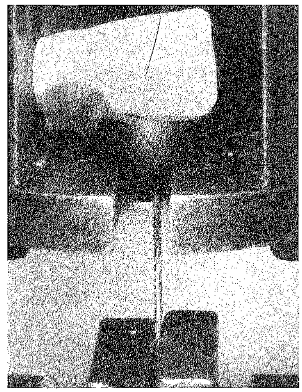
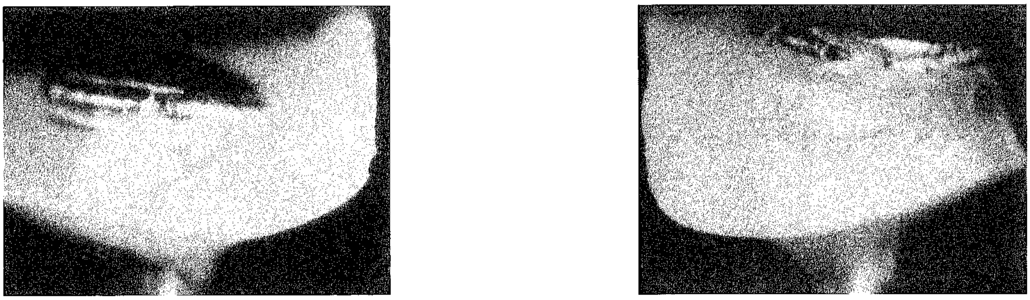


Figure 7. *Specimen mounted in Instron for loading. Round portion of hemisphere is inserted into socket to allow adjustment of position by rotation during initial loading. Pin shaft is firmly held by air grips of Instron.*

the approximal surface of the tooth (Figure 4); pins were luted into position using a small amount of additional liquid resin, then the extra-light (XL) shade of a composite resin, (Prisma APH, L D Caulk) was inserted incrementally into each preparation so that no increment exceeded 1.0 mm in depth. Small amalgam condensers were used to assure that the composite resin was pushed into all parts of the cavity preparations, including the grooves. Each increment was polymerized for 40 seconds from the approximofacial and 40 seconds from the approximolingual to assure that the shadow of the pin did not inhibit polymerization. Restorations (Figure 5) were finished and polished using Sof-Lex disks (3M Dental Products, St Paul, MN 55144-1000).

Specimens were thermocycled from 6 to 60 °C for 500 cycles with a 30-second dwell time. They were stored in tap water at room temperature at all times when not being prepared, thermocycled, or tested.

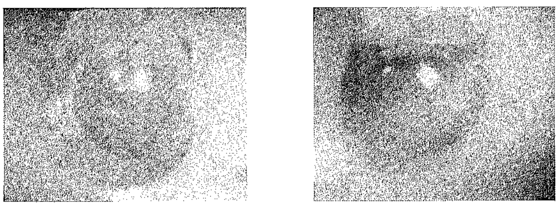
After thermocycling, roots were sectioned 2 mm apical to the cementoenamel junction. A 9 mm-in-diameter, steel, hemisphere-shaped holding device with a 3 mm-in-diameter cylindrical channel through it was positioned over the pin, which protruded from each restoration, so that the flat side of the hemisphere rested against the approximal enamel and the pin shaft passed through the cylindrical channel (Figure 6). The tooth was positioned so that the restoration was centered over the entrance to the channel; the entire restoration could be viewed through the channel. The hemisphere was held in position on the tooth with rope wax (No 94493, Columbus Dental, St Louis, MO 63188) while the spherical side of the hemisphere was inserted into the matching socket of a mounting fixture (Figure 7) for tensile loading using an Instron Testing Machine (Model 1125,



a. Restoration from preparation with no undercut retention

b. Restoration from preparation with undercut retention

Figure 8. *Typical resin restorations that had been dislodged from class 3 preparations, with silk pins still in place*



a. *b.*

Figure 9. *Cavities from which restorations in Figure 8 were dislodged*

Instron Corp, Canton, MA 02021). The pin shaft was grasped with Instron Air Grips. A tensile load was applied via the pin to the restoration at a head speed of 2 mm/minute until restoration failure.

RESULTS

All specimens failed by cohesive failure and dislodgement of the bulk of the restoration, with small amounts of composite resin remaining on the bevels and walls and in the undercut retention areas of the cavities. Figure 8a shows an example of the restorations dislodged from the preparations with no undercut retention; Figure 8b shows an example of the restorations dislodged from the preparations that had undercut retention. Figures 9a and 9b show the respective cavities from which the dislodged restorations in Figures 8a and 8b were pulled. The tensile failure load in Newtons was recorded for each specimen. Mean failure loads for each group are summarized in Table 1; the failure load for each individual specimen is shown in Table 2. The data were analyzed using independent

Table 1. Mean Failure Loads [Newtons (N)] of Class 3 Approximolingual Composite Restorations in Maxillary Central Incisors either with No Undercut Retention or with Gingival Retention Grooves and Incisal Retention Points

Group	Load to Failure	SD
No undercut retention	77.7	±29.2
Gingival retention groove; incisal retention point	69.6	±18.1

There was no significant difference between groups ($P > 0.05$).

Table 2. Raw Data Showing Failure Load [Newtons (N)] for Each Specimen

Specimen #	Group 1 (no grooves)	Group 2 (grooves)
1	49 Newtons	66 Newtons
2	88	67
3	88	50
4	87	54
5	61	80
6	91	50
7	79	72
8	86	86
9	137	121
10	61	74
11	88	49
12	83	72
13	82	63
14	76	75
15	98	65

group *t*-tests. No difference in the load required to cause failure was found between groups ($P > 0.05$).

DISCUSSION

This study evaluated the effect of mechanically cut undercut retention in dentin when used in class 3 preparations with margins totally in etched enamel. In the early part of this century, class 3 cavity preparations for directly inserted metal restorations, of necessity, included undercut retention in dentin (Black, 1908; Johnson, 1915). With the advent of tooth-colored materials that were not bonded to teeth (e g, silicate, resin), undercut retention remained an important part of the cavity preparation (Bell & Grainger, 1971; Gilmore, 1967; McGehee, True & Inskipp, 1956). With the introduction and development of the acid etching of enamel and the evolution of enamel bonding techniques, textbooks in operative dentistry have continued to advocate the use of undercut retention in class 3 preparations (Charbeneau & others, 1975; Gilmore & Lund, 1973; Gilmore & others, 1977; Gilmore & others, 1982). Current textbooks have maintained the tradition of using both undercut retention in dentin and enamel bonding in class 3 restorations (Charbeneau, 1988; Sturdevant & others, 1984; Baum & McCoy, 1984; Baum, Phillips & Lund, 1985).

The results of this study suggest that the need for undercut retention in preparations for composite resin, when the preparation margins are in enamel, should be reassessed. The relatively long-term retention of porcelain and resin veneers (Rucker & others, 1990) and of resin pit and fissure sealants (Simonsen, 1991) that are attached to teeth only with etched enamel gives support to the probable dependability of enamel bonding alone to adequately retain composite resin restorations.

CONCLUSIONS

Under the conditions of this study, the class 3 preparations that included dentin undercuts in addition to etched enamel were no more retentive for composite resin restorations than preparations that included etched enamel alone.

(Received 11 November 1992)

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A Clinical Comparison of Glass Ionomer (Polyalkenoate) and Silver Amalgam Restorations in the Treatment of Class 5 Caries in Xerostomic Head and Neck Cancer Patients

R E WOOD • W G MAXYMIW • D McCOMB

Clinical Relevance
Glass-ionomer restorations can be damaged by repeated use of NaF gels.

SUMMARY

Fifty-four pairs of restorations (one glass ionomer and the other amalgam) were placed in the mouths of 36 xerostomic head and neck cancer patients. Patients were either fluoride users or fluoride nonusers. In patients who used a daily application of a mildly acidic (pH 5.8) sodium fluoride gel, glass-ionomer cements failed and amalgam restorations did not ($P < 0.0001$). In patients who neglected to use their topical fluoride as directed, glass-ionomer cement restorations did not fail, but amalgam restorations did ($P < 0.001$). The mean time to restoration loss for both restorative materials was 8.5 months. In severely xerostomic patients these findings were exaggerated.

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INTRODUCTION

It is well known that therapeutic anticancer ionizing radiation has a deleterious effect on the health of the human dentition (Anneroth, Holm & Karlsson, 1985; Brown & others, 1978). Irradiation of the salivary glands, a consequence of many head and neck radiation treatment regimens, results in hyposialia, radiation mucositis, and atypical carious lesions (Anneroth & others, 1985). These atypical carious lesions, so-called radiation caries, occur soon after radiation treatment. They are thought to result from a combination of xerostomia, qualitative changes in saliva, and an increase in carbohydrate intake by the patient (Keene & others, 1981; Maxymiw & Wood, 1990). These patients typically develop a large number of carious lesions (Brown & others, 1978). The problem is compounded because in many radiation centers there is no preventive dental care available and little follow-up after radiation treatment. Current preradiation management has also changed. Previously, all patients' teeth were extracted prior to undergoing radiation therapy, thus eliminating any chance of radiation caries development. This practice has been curtailed in favor of maintenance of the dentition and daily application of a caries-preventative fluoride gel (Myers & Mitchell, 1988).

Radiation caries typically presents as softening or cavitation at the neck of a tooth (class 5 caries). Discoloration may or may not be present, and the lesions may progress rapidly circumferentially, until the crown of the tooth is amputated. Subsequent exposure of the pulp chamber to the oral environment allows ingress into the bone of pathogenic bacteria. In addition, grossly carious teeth often require extraction. These two sequelae in tandem may result in osteoradionecrosis of the jaw. A key to preventing such dire events is permanent restoration of the carious lesion prior to its rapid progression and an aggressive prevention program to minimize new or recurrent decay. This is normally achieved by advocating scrupulous oral hygiene and application of topical fluoride in custom trays on a daily basis. The precise contents of the fluoride gel used at our institution has been previously described (Daly, 1973).

Topical fluoride gels have been used extensively as a means of preventing radiation caries in vivo (Jansma & others, 1989; Myers & Mitchell, 1988). Three major groups of fluoride have been used: stannous fluoride, acidulated phosphate fluoride, and sodium fluoride. They all vary significantly in their physical and biological properties and are most often used in the form of a daily self-application using custom fluoride trays in which the fluoride is placed. Such programs are effective in preventing the occurrence of radiation caries (Myers & Mitchell, 1988).

Restorative treatment is required for many radiation caries lesions. The materials used include silver-mercury amalgam, composite resins, and glass-ionomer (polyalkenoate) cements. Amalgam has been the most commonly used direct restorative material in our clinic, with composite resin usually reserved for aesthetic locations. The concern with using composite resins in mouths with high caries susceptibility is due to their documented shrinkage, their lack of cariostatic properties, and the inherent difficulties in achieving a reliable bond between resin and the root surface.

Glass-ionomer (polyalkenoate) cements were first introduced for use as a direct restorative material in 1972 by Wilson and Kent. The development of their material was based on the observation of rapid hardening between certain ion-leachable glass powders and aqueous solutions of polyacrylic acid. The precise structure and chemical interactions are described by Wilson (1974). Tay and Lynch (1989a,b) have reviewed their physical properties as well as handling characteristics. Their clinical properties are summarized in Table 1 (McLean & Wilson, 1977a,b; Retief & others, 1984; Tay & Lynch, 1989a,b).

The release of fluoride into surrounding dental hard tissues makes the glass-ionomer cement an attractive direct restorative material for irradiated patients. It is anticipated that the fluoride released by the restoration would prevent nearby or recurrent decay. Paradoxically glass-ionomer cements are susceptible to fluoride ion damage from topically applied fluorides (Lynch & Tay, 1989a,b; Billington, Williams & Strang, 1987). The material selected for use in this investigation was Ketac-fil (ESPE, Seefeld/Oberbay, Germany). It has been shown to be impervious to denigration by

Table 1. Clinical Properties of Polyalkenoate Cements

1. They set rapidly with sufficient working time.
2. They have minimal temperature rise during setting, making them thermally innocuous to the pulp.
3. They have high compressive strengths.
4. They have translucency similar to enamel, making them aesthetically superior to metallic amalgam restorations.
5. They adhere directly (with a chemical bond) to enamel and dentin.
6. They are resistant to acid erosion.
7. They release fluoride into the surrounding hard tissues, thereby preventing further dental decay.
8. They are bland to the pulpal tissue from a chemical standpoint, causing no biological harm to the pulp when used appropriately.

fluoride-containing topical agents (Lynch & Tay, 1989a,b; Moore, Platt & Phillips, 1984; Akselsen, Afesth & Rolla, 1988). It has been accepted for worldwide clinical use for many years and has been the subject of clinical investigations previously, in which it performed well (Teo, 1986; Knibbs, 1987; Knibbs, 1988).

The purpose of this investigation was to evaluate the performance of glass-ionomer cement restorations as compared to amalgam restorations. The hypothesis at the commencement of the investigation was that glass-ionomer cements would be preferable to silver amalgam restorations on the basis of their superior esthetics and documented cariostatic properties.

METHODS AND MATERIALS

Fifty-four pairs (one amalgam and one glass ionomer) of restorations of each type were placed in a series of xerostomic patients who had been treated with radiation therapy as the primary anticancer treatment modality. All patients were xerostomic at the time of their postradiation follow-up examinations. Xerostomia was judged on a subjective basis based on clinical examination by two of us concurrently at a single visit. Patients were scored on a subjective numerical scale from 1 (mild xerostomia) to 3 (severe xerostomia) based on clinical experience alone. There was no attempt to further "quantify" or define xerostomia beyond that of a clinically dry mouth. All consecutive patients presenting with two or more carious lesions in separate teeth in the same sextant of the mouth were eligible for the study. Caries was defined as either frank visible cavitation or clinically significant softening of the dental hard tissue as determined by manual probing after the tooth had been treated with prophylaxis.

The instructions for placement rely heavily on the manufacturer's instructions. Restorations were placed by two operators and both restorations were placed at the same appointment. Local anaesthetic was used, and where possible a rubber dam was applied. However, because of the location of radiation caries (primarily at the cervix of the tooth) and the presence of marked xerostomia in our patients, dry-field isolation was achieved even in the absence of rubber dam placement. Box-form cavity preparations with retention grooves as indicated clinically were used for all restorations. Calcium hydroxide lining cement was used where appropriate. Two coats of copal-ether varnish were applied prior to amalgam placement, and the spherical alloy used (Sybralloy, Sybron/Kerr, Romulus, MI 48174) was triturated according to the manufacturer's instructions. Insertion followed routine procedure. Polishing was performed after a minimum of 24 hours. Glass-ionomer insertion involved the use of a precontoured burnishable metallic matrix (cervical matrices, ESPE/Premier, Norristown, PA 19404) for five minutes, after which copious glass-ionomer cement varnish (ESPE) was applied. Appropriate contouring was achieved under the protection of varnish using a sharp blade or gold-foil knife. Varnish was reapplied and dried. Polishing was performed after a minimum of 24 hours using Sof-Lex disks (3M Dental Products, St Paul, MN 55144) with water. Extensive surface contouring was carried out prior to disking using multifluted carbide burs and a high-speed handpiece with water spray. Following placement of the material, six monthly follow-up appointments were made, at which time the condition of the restoration was evaluated according to the parameters outlined in Table 3. At each appointment patients were asked to estimate the percentage of time they used their daily fluoride applications. A visual analog scale was utilized to facilitate this observation (Figure 1). In addition, the patients' medical charts were checked to see if prescriptions for topical fluoride were indeed filled by the pharmacy at our institution, which is the sole supplier of our patients' fluoride. This allowed for evaluation of the patients' reliability and truthfulness in relaying accurately their fluoride use. Patients were unaware that this check was made.

Evaluation was done by two observers using criteria listed in Table 2. Patients were analyzed by the two observers prior to initiation of the study in order to ensure that the two observers' measurements were in agreement with how the measuring criteria were to be applied. Study restorations were not evaluated by both observers because of time constraints and difficulty in getting both the patient and two observers in the same place at the same time. Photographs of the restorations were taken after the restorations were finished, and again after they failed, or after the two-year study

Table 3. Marginal Adaptation Score (MAS), Anatomical Form Score (AFS), and Adjacent Caries Results (ACS) for Glass-Ionomer Restorations and Amalgam Restorations (GIC = glass-ionomer cement; Amal = amalgam)

	GIC 6-Month MAS	Amal 6-Month MAS
mean	2.53	1.17
SD	1.22	0.51
n	51	53
confidence limits		
95% upper	2.87	1.31
95% lower	2.19	1.03
	GIC 6-Month AFS	**Amal 6-Month AFS**
mean	2.02	1.11
SD	0.83	0.38
n	51	53
confidence limits		
95% upper	2.26	1.22
95% lower	1.78	1.01
	GIC 6-Month ACS	**Amal 6-Month ACS**
number with caries next to restoration	0	6
n	51	53

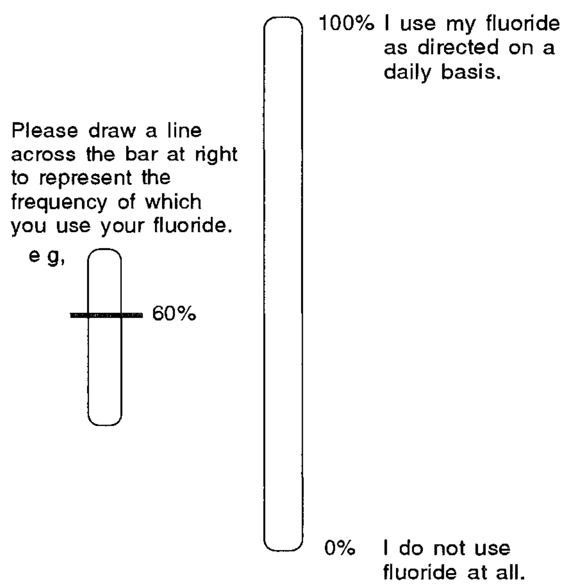


Figure 1. *Visual analog scale for patients to depict their frequency of fluoride use. Each patient was asked to draw a line across the bar depicting their fluoride use. This was then checked against pharmacy records to verify truthful answers.*

was completed.

Analysis was based on a direct comparison of the number of failed glass-ionomer restorations versus the number of failed amalgam restorations. The null hypothesis was: Glass-ionomer restorations in class 5 restorations do not fail any more frequently than class 5 amalgam restorations when examined over a two-year period. Specific comparisons made included determining the mean and standard deviation (SD) for scores of marginal adaptation of the restoration (MAS) for both glass-ionomer cement restorations and amalgam restorations. In addition, anatomical form (AFS) and caries on adjacent tooth structure (ACS) were similarly handled.

RESULTS

There were 54 pairs of restorations placed in 36 patients. One patient died prior to completion of the study, and one patient moved and was lost to follow-up. Surprisingly, restorations of both types failed early in the course of reviewing these patients. The mean time for failure for all restorations was 8.5 months (SD = 4.4). The mean time for failure for the glass-ionomer cement restorations that failed was 8.52 months (SD = 3.4), and those amalgams that failed did so with a mean time of 8.4 months (SD = 5.4). There was no significant difference between the two types of restorations in this regard.

The six-month peripheral softening score, marginal adaptation score, anatomical form score, and adjacent caries scores are expressed in Table 3. Glass-ionomer cements performed significantly more poorly when compared to amalgam restorations overall.

In patients who were fluoride users

Table 2. Method of Restoration Evaluation at Each Six-Month Follow-up Appointment

Section 1. Scoring criteria for marginal adaptation of the restoration to the cavity preparation (MAS)

1. The restoration appears to adapt closely to the tooth along its periphery, with no crevice formation. An explorer did not catch on being drawn across the margin, or if it did catch, then only in one direction. A numerical score of 0 was awarded.

2. A sharp explorer did catch in both directions, and there was visible evidence of early crevice formation into which the explorer penetrated. Dentin and lining were not visible. A numerical score of 1 was awarded.

3. A blunted explorer penetrated or caught in both directions, and there was visible evidence of early crevice formation into which the explorer penetrated. Dentin and lining were not visible. A numerical score of 2 was awarded.

4. An explorer penetrated into the crevice to sufficient depth that the dentin or lining was exposed. The restoration required replacement. A numerical score of 3 was awarded.

5. The restoration is fractured or lost. A numerical score of 4 will be awarded.

Section 2. Scoring criteria for anatomical form (AFS)

1. The restoration was continuous with the existing anatomy of the tooth. A numerical score of 0 was awarded.

2. The restoration was not in continuity with the existing anatomy of the tooth, but the discontinuity was insufficient to expose dentin or lining material, and hence the restoration was clinically acceptable. A numerical score of 1 was awarded.

3. The restoration was not in continuity with the existing anatomy of the tooth; the discontinuity was sufficient to expose dentin or lining, hence the restoration required replacement. A numerical score of 2 was awarded.

Section 3. Caries on adjacent tooth structure (ACS)

1. Another carious lesion is present within 3 mm of the border of the restoration.

2. Another carious lesion is not present within 3 mm of the border of the restoration.

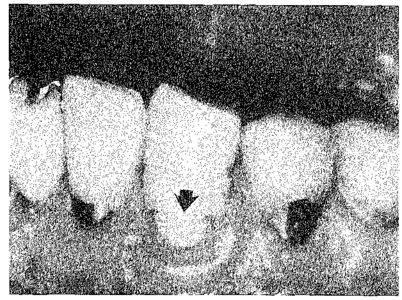
(fluoride use greater than 50%), 35 pairs of restorations were evaluated as a subset. Failure was defined as presence of adjacent caries or an MAS score of 4 or an AFS score of 3. Photographic representations of typical glass-ionomer and amalgam failures are depicted in Figure 2. In the fluoride-using group, glass-ionomer cements failed 32 times and were clinically adequate in three instances. There were no amalgam restorations that failed in this group; they were clinically acceptable 35 times (chi-square > 1052.4, $P < 0.0001$).

Paradoxically, in nonfluoride users (fluoride use < 50% and in most cases no fluoride use) glass-ionomer cements were clinically adequate in eight instances with no failures. Amalgam restorations failed in six patients and were clinically adequate in two (chi square = 17.14, $P < 0.0001$). Fluoride use correlated strongly with glass-ionomer restoration failure (correlation coefficient 0.9, R ^ 2 = 0.88). Fluoride use was negatively related to amalgam failure (correlation coefficient = -0.7, R ^ 2 = 0.4).

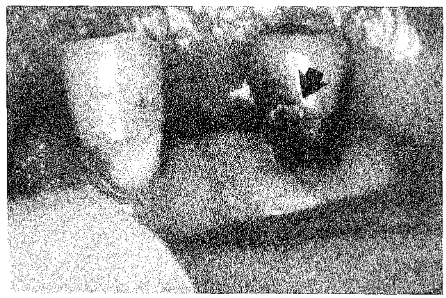
Xerostomia was related to the time required for restorations to fail. There was a total of 36 patients in the study: 25 had severe xerostomia, six had moderate xerostomia, and five had mild xerostomia. The degree of xerostomia correlated with the time required for a restoration to fail (correlation coefficient=-0.6, R ^ 2 = 0.353). The more xerostomic a patient was, the faster any restoration failed.

DISCUSSION

The rapid dissolution of the glass-ionomer restorations during the early months of this clinical trial was severe and unexpected. As this erosion was atypical of routine clinical experience with this material, it was apparent that the causative factor or factors were unique to this group of patients. Possibilities included the xerostomia itself or the concomitant regular home usage of topical fluoride gel. During the latter part of the study it became apparent that a probable correlation existed between fluoride compliance and cement dissolution. Analysis of the sodium fluoride gel showed it to be mildly acidic (pH 5.8). Prepared according to



a.



b.

Figure 2. *Typical photographic examples of restoration failure for glass-ionomer cement (a) and amalgam (b). Arrows show the failed restorations. The glass-ionomer restoration that failed (a) has been reduced in size but remains adherent to the underlying tooth material even though it has dissolved past the region of the retention grooves. The amalgam restoration that has failed (b) has a large carious lesion just to the mesial aspect. The glass-ionomer cement in this case is intact.*

the formula given by Daly in the 1973 *Textbook of Radiotherapy*, this 1% sodium fluoride gel has been in use at our institution for 10 years with excellent clinical results and no noted clinical detriment to silver amalgam or composite resin restorations.

Based on erosion testing in vitro, Walls, McCabe, and Murray (1988) reported that commercial glass-ionomer restorative materials tested, including Ketac-fil, resist erosion at normal physiological pH levels between 6 and 8. Only at a low level of pH 4 was erosion measurable. Interestingly, the hand-mixed version of the same material, Chelon, was less susceptible to this acid erosion than its mechanically mixed counterpart, Ketac-fil. This in vitro erosion study utilized sodium lactate/lactic acid buffers at pH 4 and 6. Kent, Lewis, and Wilson (1973) reported that glass-ionomer cements are greatly superior to silicate cements in their resistance to erosion by lactic acid. However, in this clinical study the cement dissolution was profound. The sodium fluoride gel used contains citric acid, probably as a preservative. Citric acid is a strong chelating agent, which even buffered to a relatively high pH of 5.8 has had an excessively detrimental effect on the polysalt matrix of the glass ionomer used. An in vitro study is necessary to study the effect of different acids on various polyalkenoate formulations. Knowledge of pH effects alone may not be sufficient, as different acids of the same pH behave differently.

Treatments containing fluoride ions have also been implicated in the dissolution of glass-ionomer cements. Although the detrimental effect of acidulated phosphate-fluoride and stannous fluoride rinses on dental cements is not disputed, the effect of 2% neutral sodium fluoride solutions has been debated. Akselsen and others (1987) found that of three commercial glass-ionomer cements, Ketac-fil was the only one hardly affected after 24 hours' exposure. In a repeat study using neutral sodium fluoride, Billington and others (1987) disputed Akselsen's results. Billington, Williams, and Pearson (1991) have recently stated that the erosion of maleic-acrylic acid co-polymer-based glass-ionomer cements such as Ketac-fil has been shown to be worse both in vitro and in vivo (Setchell, Teo & Khun, 1985; Ibbetson, Setchell & Amy, 1985). Indeed Wilson and others (1986) demonstrated, with an impinging jet method of measuring acid erosion of dental cements, that erosion of Ketac-fil was similar to that of some dental silicate cements. Certainly the loss of glass-ionomer cement restorations was extreme and unacceptable in this clinical study. Total disintegration of the complete restoration was seen in all instances where fluoride patient compliance was high. The operating dentists instilled high motivation in patients to avoid radiation caries. Patients were directed to use the fluoride gel at night before retiring and with no final water rinse. The xerostomic patient would allow abnormally long persistence of the gel in the oral cavity due to lack of salivary dilution. The unanticipated detrimental effect of the citric acid containing fluoride gel on the commercial cement used was thus magnified. Some patients, anxious to preserve their dentitions, chose to carry out the gel treatment more frequently than once per day. This compounded the problem. The abrasive effect of regular toothbrushing, progressively removing the eroded surface layer of cement, exposing the next layer, may explain the ongoing nature of the process.

As expected, the patients who did not carry out the home fluoride treatment showed more typical behavior of glass-ionomer cements with full presence of restorations and excellent inhibition of recurrent peripheral decay, despite xerostomia. This was not significant in this study due to the high fluoride compliance and associated problems. The concept of using preventive restorative materials containing fluoride is still advantageous where low compliance is anticipated.

Although the results of this clinical study were disappointing, it is cautionary to note that the results may only be applicable to the materials evaluated here, and it may be inappropriate to use these results to assess the performance of glass-polyalkenoate cements in general used under differing fluoride conditions.

Amalgam restorations performed admirably in those patients who used fluoride and poorly in those patients who did not. This causes a dilemma in selecting a suitable restorative material for an individual patient. The authors know of no way in which to predict whether a patient is going to comply with fluoride use. If a patient is an obvious noncompliant type with respect to fluoride use, then perhaps glass-ionomer cements are the material of choice. In compliant patients, amalgam restorative material is the best material to use of those tested in this investigation.

CONCLUSIONS

1. Glass-ionomer cements are damaged by concentrated daily fluoride application of

the type most commonly used in prevention of postradiation caries when it is applied topically. When patients use daily topical fluoride applications of the type used in this investigation, glass-ionomer cement restorations should be avoided.

2. Amalgam restorations fail in those patients who elect not to use daily fluoride applications.

3. Further in vitro and in vivo testing is required to deduce which fluorides are safe to use with glass-ionomer cements. In these instances any new fluoride formulation would have to be proven to be equally effective in its radiation caries-preventative properties.

(Received 20 February 1992)

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Microhardness and Porosity of Class 2 Light-cured Composite Restorations Cured with a Transparent Cone Attached to the Light-curing Wand

M VON BEETZEN • J LI
I NICANDER • F SUNDSTRÖM

Clinical Relevance
A technique of light-curing with more complete resin curing is described.

SUMMARY

A new technique for curing class 2 composite fillings was investigated with respect to microhardness and porosity in the cervical part of the restorations. The technique is based on a plastic transparent cone that is attached to the curing wand. Before polymerizing the cervical portion, the cone is pressed down into the material in the direction of the floor of the approximal box. When the light is activated, it concentrates in the tip of the cone, from where it is distributed into the composite material.

In order to compare this technique with conventional curing, standardized class 2 cavity preparations were made in brass blocks. Four different composite materials were used for 20 restorations each: Heliomolar, Herculite XR, Occlusin, and P-50. Ten restorations of each material were cured using the conventional technique (in two portions), and in the remaining 10 restorations the cervical portion was cured with the transparent cone. The irradiation time was 60 seconds in all instances. The Vickers hardness of the cervical approximal surfaces was measured after one and 24 hours. The surfaces were photographed in a stereomicroscope, and the numbers of porosities were counted on black-and-white prints.

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Using the new technique, a significant increase in microhardness was obtained in all four materials. The increase ranged from 19% to 57%. Regardless of curing technique, there were considerable differences in microhardness among the materials. For two of the materials a significant correlation was found between the use of the cone and a decreased number of porosities.

INTRODUCTION

In order to obtain good curing with a high conversion rate in light-curing composites, every part of the composite material has to be sufficiently irradiated by light in the proper wavelength range (Ruyter & Øysaed, 1982; Cook & Standish, 1983; Viohl, 1982; Swartz, Phillips & Rhodes, 1983; Atmadja & Bryant, 1990). The depth of cure is limited by the reduction in light intensity as it is attenuated by filling materials, tooth substance, and matrix systems (Tirtha & others, 1982; McCabe & Carrick, 1989). Incomplete polymerization of the material may reduce the durability of the filling because of increased solubility and sorption (Pearson & Longman, 1989). The biological compatibility of the material may also be affected due to release of unreacted resin (Braden & Clarke, 1984).

Good curing is particularly difficult to achieve in the cervical area of the approximal box of class 2 composite restorations (Kays, Sneed & Nuckles, 1991). Several methods have been proposed in order to solve this polymerization problem. These include application and curing of the composite in small increments (Hassan & others, 1987), curing from buccal and lingual directions through part of the enamel (Swartz & others, 1983), use of translucent matrix bands and light-conducting wedges (Lutz, Krejci & Oldenburg, 1986), and use of mirror matrix bands (Kays & others, 1991).

In this investigation, a transparent cone attached to the end of the curing wand (Ericson, 1987) was used to improve the curing of the cervical area of the approximal restoration. The light from the curing wand is concentrated in the tip of the cone, from where it is distributed in a hemispherical fashion. In clinical use the cone is pressed down into the composite material, approaching the floor of the approximal box (Figures 1 & 2). At the same time, the matrix band is pressed towards the neighboring tooth, thus establishing good contact, and the curing light is activated. After curing, the cone is removed and the rest of the cavity is filled with a new portion of composite, which is cured in the conventional way (Figure 3).

Using the same technique, Ericson and Dérand (1991) obtained a considerable reduction in the cervical gap between the restoration and the cavity wall. Since the plastic

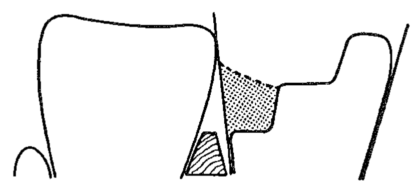

Figure 1. *Section of premolar with class 2 cavity. Composite material is inserted into approximal box.*

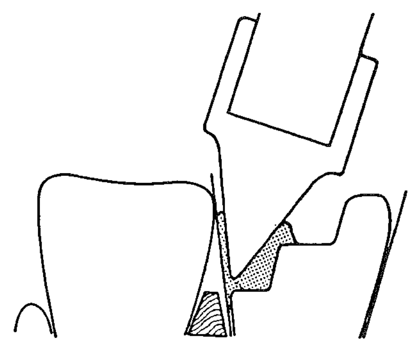

Figure 2. *The transparent cone pressed into material before curing*

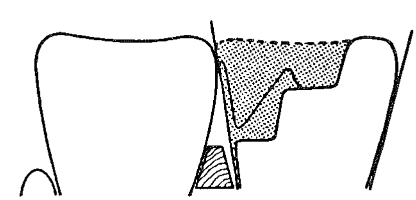

Figure 3. *After curing the first portion, the tip is removed and the rest of the restoration is built up and cured.*

cone directs more light into the cervical area of the composite, it can also be expected to improve the curing in this region.

The hardness test has been the most frequently used method for assessing the depth of cure of dental composites (DeWald & Ferracane, 1987). These authors compared four methods of evaluating depth of cure of light-activated composites and concluded that infrared spectroscopy analysis of the degree of conversion was the most accurate indicator of depth of cure, despite the method being relatively complex in use. Hardness measurements were generally well correlated to the degree of conversion, while optical and scraping techniques overestimated depth of cure.

Another factor potentially influenced by the curing technique is the amount of porosities in composite materials. Restorations made from two paste systems generally contain more porosities than those generated by light-cured composites (Reinhardt & others, 1982; Gotfredsen, Hörsted & Kragstrup, 1983). Porosity of light-activated composites is affected by the insertion methods and by application of pressure during the curing procedure (Medlock & others, 1985; van Dijken, Ruyter & Holland, 1986). Consequently the pressure applied to the composite while curing with the transparent cone may also influence the amount of porosities.

The aim of this investigation was to study the effect of using the new transparent cone curing technique on the microhardness and surface porosity in the cervical area of light-cured class 2 composite restorations.

METHODS AND MATERIALS

Standardized class 2 cavities were formed in brass blocks. The size and form of those corresponded to a Black cavity in a premolar (Figure 4). The depth of the occlusal preparation was 2.5 mm, and the approximal box extended a further 2.5 mm, giving a total depth in the approximal box of 5.0 mm. A strip of plastic matrix band was held in place with a brass cover and two screws. Three hybrid composites, Herculite XR (Sybron/Kerr, Romulus, MI 48174, batch number 03319), Occlusin (ICI Dental, Macclesfield, Cheshire, England, batch number LOT LM 60), and P-50 (3M Dental Products, St Paul, MN 55144, batch number ODC 3R), and one microfilled composite, Heliomolar radiopaque (Vivadent, FL-9494 Schaan, Liechtenstein, batch number 260490) were used in a series of 20 restorations each, all in universal colors. These were cured with a Luxor model 4000 (ICI Dental) curing lamp. The light intensity was checked at intervals of five restorations with a curing radiometer (CL-tester, Dendema AB, S-182 05 Djursholm, Sweden). During the experimental period the readings were consistently at the same point on the scale, indicating good curing capacity. In 10 brass blocks with the cover in place, the approximal box was filled with carefully packed composite up to the level of the floor of the occlusal box. The composite was cured for 60 seconds with the curing wand at the level of the "occlusal surface." The remaining part of the cavity was then filled in one portion, which was also cured for 60 seconds.

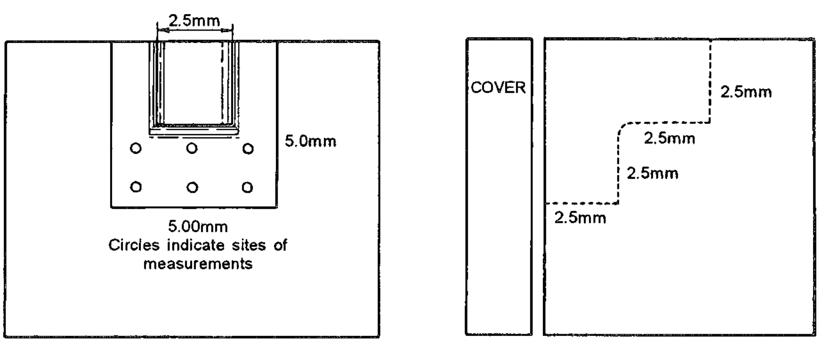

Figure 4. *Standardized class 2 cavity milled in brass block*

After curing, the plastic band and the cover were removed and the samples were placed in distilled water at 37 °C. In the remaining 10 blocks from each different resin series, the approximal box was filled in the same way. Before curing, a transparent cone, Light-tip (Dendema AB), attached to the curing wand was pressed down into the composite until the tip was 1 mm from the floor of the box. The side of the cone was pressed towards the approximal cover. At the same time the cone was brought in to a three-point contact with the upper edges of the brass mold. This ensured a fixed position of the cone in different molds and samples. The curing light was then activated for 60 seconds. The cone was removed and the remaining part of the cavity was filled in one portion, which was cured for 60 seconds using the conventional technique. After curing, the plastic band and the cover were removed, and the samples were placed in distilled water at 37 °C.

The Vickers hardness of the approximal composite surfaces was measured with a Shimadzu microhardness meter (Shimadzu Corp, Kyoto, Japan) at a load of 100 g for 15 seconds, after one hour, and after 24 hours. Six measurements were made each time at predetermined, regularly distributed sites in the cervical area of the approximal surface (Figure 4).

A stereo microscope with camera attachment (Olympus SZH, Olympus Optical Co, Ltd, Tokyo, Japan) was used to obtain black-and-white photographs with standardized illumination of all samples. Fifteen-fold magnification allowed the whole sample to fill the photographic frame. Prints of all samples (127 x 178 mm) were produced, and visible porosities were counted in the area corresponding to the cervical 2.5 mm part of the approximal surface.

The mean values and standard deviations of hardness and porosity were calculated for each composite material cured with and without the transparent cone, and the common *t*-test was used for statistical analysis of the results. The accepted level of significance was set at $P \leq 0.01$.

RESULTS

The results of the microhardness measurements are listed in Tables 1 and 2. For all

Table 1. Mean Values of Vickers Hardness Number after 1 Hour (Load 100 g)

Material	Heliomolar		Herculite XR		Occlusin		P-50	
	M	SD	M	SD	M	SD	M	SD
Cured without the cone	21.4	4.5	44.0	7.3	54.6	10.5	60.5	14.5
Cured with the cone	25.9*	5.0	59.8*	6.3	66.9*	10.2	83.0*	16.0

* indicates significant difference from cured without cone value.
N for all materials = 60.

Table 2. Mean Values of Vickers Hardness Number after 24 Hours (Load 100 g)

Material	Heliomolar		Herculite XR		Occlusin		P-50	
	M	SD	M	SD	M	SD	M	SD
Cured without the cone	21.4	4.0	45.5	7.0	56.5	10.6	53.5	12.8
Cured with the cone	27.7*	5.2	65.3*	7.1	67.3*	12.5	83.8*	6.0

* indicates significant difference from cured without cone value.
N for all materials = 60.

materials investigated, and at both time intervals, there was a strong correlation between increased microhardness in the cervical area of the approximal surfaces and the use of the transparent cone ($P < 0.001$). The relative improvement in microhardness obtained after 24 hours was for P-50 57%, for Herculite XR 44%, Heliomolar 30%, and Occlusin 19%. Regardless of curing technique, there were considerable differences in microhardness of the measured area among the four composites. In order of hardness the rank was P-50, Occlusin, Herculite XR, and Heliomolar. A slight, general increase in microhardness between the measurements at one hour and 24 hours was noted. There was a statistically significant correlation between the use of the transparent cone and a decreased number of porosities for Herculite XR and Heliomolar ($0.001 < P < 0.01$). For Occlusin and P-50 a slight decrease in porosities was noted, but the correlation was not significant (Table 3).

DISCUSSION

Microhardness

A statistically significant increase in microhardness of 19% to 57% was obtained in the cervical area of class 2 composite restorations by curing with a transparent cone. For dental restorative composites there appears to be a good correlation between hardness and degree of conversion (Asmussen, 1982; Ferracane, 1985; DeWald & Ferracane, 1987). There is also a correlation between the curing light intensity and the depth of cure (Watts, Amer & Combe, 1984). The increased microhardness in the cervical composites found in this investigation could therefore be explained as a result of a higher degree of conversion and crosslinking in the resin. This is probably a consequence of improved light irradiation into the deep cervical part of the restoration. Measurements of the degree of conversion with infrared multiple internal reflection spectroscopy are planned.

The effect of the cone varied considerably among the materials studied. This is probably due to differences in the resin as well as in the filler systems of the composites. The highest improvement in percentages after 24 hours was obtained with P-50 (57%), followed by Herculite XR (44%).

Regardless of the techniques used, there were apparent differences among the four composites. Chung and Greener (1990) reported a significant correlation between the hardness of the composite material and the volume fraction of filler. In a pilot study with Heliomolar, Herculite XR, Occlusin, and P-50, the percentages by weight of filler were analyzed. The values were found to have a positive correlation to the values of hardness obtained in this study. In the case of Heliomolar, besides a low volume fraction of filler, other factors such as the increased light-scattering phenomenon reported for microfilled materials (Ruyter & Øysaed, 1982) may contribute to the low values of hardness obtained. The microhardness of the cervical surfaces cured with the conventional two-step technique was unexpectedly low, in spite of the relatively long exposure time (60 seconds). However, the effect of a further

Table 3. Mean Total Number of Porosities in the Cervical Area 12.5 mm² of Approximal Surfaces

Material	Heliomolar		Herculite XR		Occlusin		P-50	
	M	SD	M	SD	M	SD	M	SD
Cured without the cone	170	72	76	20	207	48	17	8
Cured with the cone	99*	30	35*	25	179	31	13	7

* indicates significant difference from cured without cone value.

increased exposure time is probably limited, as the depth of cure is dependent on the luminous flux and the logarithm of the irradiation time (Watts & others, 1984). The slight increase in microhardness between one and 24 hours observed in the present study is in accordance with findings by other investigators (Leung, Fan & Johnston, 1983; Swartz & others, 1983; Atmadja & Bryant, 1990), who showed that resin materials continue to polymerize to some extent after removal of the light source. This effect, however, seems marginal in comparison with the improvement brought about by optimizing the initial light irradiation.

In the experimental set-up of this investigation, the impression of the transparent cone in the cured first portion of the composite and the occlusal part of the cavity were filled in one step, cured from the occlusal surface. Since the tip of the cone reached 4 mm below the occlusal level, this may lead to incomplete curing in the deep part of the portion (as indicated by the findings with conventional two-step technique). In the clinical situation this can be avoided by filling the impression of the cone separately and curing again with the transparent cone applied to moderate depth in this portion.

From the results of the present study, it appears that the use of the transparent cone offers a significant improvement in curing of the cervical part of light-cured class 2 restorations. In addition, the reported reduction in the cervical gap (Ericson & Dérand, 1991) is another advantageous consequence. Potential benefits from these improvements could be an increased resistance to surface degradation and secondary caries in the clinical situation. Another potential advantage of the method is the establishment of an improved approximal contact between the restoration and the neighboring tooth. Consequently a considerable increase in quality can be expected when class 2 composite restorations are performed using this technique.

Surface Porosity

The number of surface porosities in the cervical part of the cavity was reduced in all four materials when the transparent cone was used. The effect on the reduction differed between the materials, and for Herculite and Heliomolar it was statistically significant. It is likely that the reduction in surface porosity is due to the increased pressure exerted by the plastic cone during polymerization. The occurrence of such effects was reported by van Dijken and others (1986). Why the number of porosities was significantly reduced in only two of the materials is unknown. Similar material-related variations in the effect of the insertion technique were also observed by van Dijken and others (1986). The standard deviation values indicate apparent variations in surface porosity between separate restorations of the same material. This may be a consequence of unavoidable variations in the manual insertion and packing procedures. It is likely that the presence of porosities in the surface of composite material will increase the abrasion in class 1 restorations (Jørgensen, 1980; Jørgensen & Hisamitsu, 1983), but it is still unknown to what extent porosities located on approximal surfaces of class 2 composite restorations can influence the durability of the material. According to Skjörland and others (1982), there is no correlation between porosity and bacterial adhesion. However, a high amount of porosities on approximal surfaces decreases the wear resistance and contributes to chemical degradation of the material due to increased water diffusion.

CONCLUSIONS

An increase of microhardness of from 19% to 57% for the different composite materials tested was obtained in the cervical part of class 2 restorations by curing with the transparent cone. The levels of microhardness obtained in the composites investigated is also different. For all the composites a reduction of surface porosity was obtained by the use of the cone. For two of the materials the reduction was significant.

Acknowledgment

We thank Mr G Olof Ekberg for assistance with the figures.

(Received 18 March 1992)

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Use of a Caries-disclosing Agent to Improve Dental Residents' Ability to Detect Caries

C B STARR • W R LANGENDERFER

Clinical Relevance
A dye improves caries recognition and aids in teaching caries removal.

SUMMARY

Clinicians often have difficulty determining which dentin should be removed during cavity preparation. Caries-disclosing agents have proven to be useful in the identification of carious dentin that requires removal. Recent dental school graduates are able to improve caries identification and removal when a caries-disclosing dye is used to check their attempts at complete caries removal.

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INTRODUCTION

The complete removal of dental caries prior to the placement of restorations is a well-established, long-standing goal of restorative dentistry (Baum & McCoy, 1984; Baum, Phillips & Lund, 1985; Gilmore & others, 1982; Sturdevant, 1984; Charbeneau, 1988). Carious dentin may be left inside the cavity preparation without adverse effects if certain conditions exist (Massler, 1972). If nutritional substrates are not available, the bacteria will not increase in number (Paterson, 1974). If bactericidal medicaments such as calcium hydroxide or eugenol are applied to the carious dentin, the number of viable bacteria will be reduced and caries will not progress (King, Crawford & Lindahl, 1965; Fisher, 1977; Fairbourn, Charbeneau & Loesche, 1980; Leung, Loesche & Charbeneau, 1980). These two conditions can and do occur in deep caries progressing in a pulpal direction, forming the rationale for the indirect pulp capping procedure.

Decay often spreads along the dentino-enamel junction (DEJ), and incomplete caries removal at this area is particularly likely to cause caries progression. Since medicaments are not applied to the DEJ, bactericidal agents are not available to stop the caries process in this area. The marginal microleakage that occurs around many restorations offers a plentiful, nearby source of nutrients for bacteria remaining at the DEJ. Kidd and others (1989) and Franco and Kelsey (1981) have proposed that recurrent caries is often really the result of residual decay left inside the cavity preparation in the area of the DEJ.

The carious process in enamel and dentin has been well described (Fusayama, 1979; Featherstone, 1990). Fusayama (1979) identified two layers of softened dentin. Infected dentin contains bacteria, is irreversibly demineralized, and should be removed. Affected dentin is reversibly demineralized and should be allowed to remain, particularly if its removal would result in a pulpal exposure.

Caries-disclosing agents have proven to be useful in the identification and removal of carious dentin (Shimizu & others, 1983). Fusayama (1979) found that a dentin disclosing agent made from basic fuchsin in a propylene glycol base reliably stains only the dentin that is infected with bacteria and irreversibly demineralized. Affected dentin does not stain. Therefore, the presence of stain reliably determines which dentin to remove and which to leave. Draheim and Re (1981) found that a caries-disclosing agent made from acid red in a propylene glycol base is as reliable as one made from basic fuchsin. Kidd and others (1989) also found that acid red disclosant can accurately determine dentin status. Anderson, Loesche, and Charbeneau (1985a) found a large difference in the quantity of bacteria present in stained versus unstained dentin. Stained dentin contains an average of 550,000 CFU/mg. Unstained dentin contains less than 10,000 CFU/mg.

The mechanism by which caries-disclosing agents selectively stain only carious, irreversibly demineralized dentin has been determined. It was originally thought that the solutions were staining bacteria directly. It is now known that the stain is instead the result of bacterial demineralization. Both basic fuchsin and acid red stain the collagen fibers exposed by the bacteria-caused dentin demimeralization process (Fusayama, 1980; Fusayama, 1988).

Clinicians often have difficulty determining which dentin should be removed during cavity preparation. Historically, hardness and color have been used as the two criteria to judge whether dentin is decayed, requiring removal, or sound, and therefore retainable. Unfortunately neither hardness nor color can be used to reliably determine whether dentin is infected or affected. Studies (Franco & Kelsey, 1981; Anderson, Loesche & Charbeneau, 1985b; Kidd & others, 1989) have demonstrated that clinicians, dental students, and dental school instructors all failed to determine dentin status correctly when using color and hardness as the criteria. Anderson and others (1985b) found residual decay at the DEJ in 59% of cavity preparations completed by dental students and checked by faculty. Kidd and others (1989) found that 57% of teeth had residual decay at the DEJ in a similar clinical study involving dental students and faculty. In a laboratory study (Kidd & others, 1989) caries removal was completed on extracted teeth with the aid of X4 magnifying loops; residual decay was at the DEJ in all 11 teeth examined.

This study was undertaken to determine if recent dental school graduates in a one-year advanced education in general dentistry (AEGD) residency could improve their ability to identify gross caries with the aid of a caries-disclosing solution.

METHODS AND MATERIALS

The subjects in the study ranged in age from 25-37, had graduated from accredited dental schools within the last three months, and were enrolled in a one-year postdoctoral education program. The study was divided into four intervals. Each interval consisted of four restorative dentistry clinical sessions.

The first interval was designed to evaluate each resident's initial ability to distinguish sound from carious dentin. During the first four clinical sessions, each resident completed cavity preparations and attempted complete caries removal. After local anesthesia was obtained, the rubber dam was applied, defective restorations were removed if present, caries were excavated, and the cavity preparations were completed. The resident then left the treatment room while the investigator used a caries-disclosing agent (Caries Finder, Danville Engineering, Danville, CA 94526) to determine if caries removal was complete or if residual decay remained. The disclosing agent, a 1% solution of acid red in propylene glycol, was applied to the cavity preparation for 10 seconds, rinsed with water for 30 seconds, and dried with the air syringe for 10 seconds. The presence or absence of stained dentin was noted. If stained dentin was present, its location was also noted (pulpal wall, DEJ, or both). The investigator then removed all the carious dentin and modified the preparation (if necessary) before the dental resident returned to the treatment room. This was done in an attempt to prevent the resident from observing the staining process during this initial evaluation period.

Intervals two through four were designed to teach the residents how to properly identify grossly carious dentin and how to distinguish between dentin that could remain and that which required removal. During the next 12 clinical sessions, each resident isolated and prepared the teeth as before. The investigator then reviewed the preparations with each resident to point out areas where gross decay remained. The preparations were then stained with caries-disclosing agent to confirm that decay was still present. The residents performed the decay removal process themselves, restaining and removing stained dentin until decay removal was completed.

RESULTS

The results obtained for each resident are listed in Table 1. The combined results for all residents, including the rate of incomplete caries removal and the standard deviation, are listed in Table 2. Caries removal was considered to be incomplete if caries-disclosing agent applied for 10 seconds stained any of the remaining dentin. During the four-session baseline evaluation period, incomplete caries removal for all residents occurred in 18 of 28 teeth treated. During the second treatment interval, residual decay was identified in 12 of 25 teeth treated. The rate decreased to five of 27 teeth for interval three and three of 28 teeth for interval four. The rate of incomplete caries removal for each resident ranged from 40% to 80% for the first interval, 33% to 57% for the second interval, 13% to 25% for the third, and 0% to 20% for the fourth.

Figure 1 shows the rate of incomplete caries removal for the length of the study. The

Figure 1. *Incomplete caries removal (combined)*

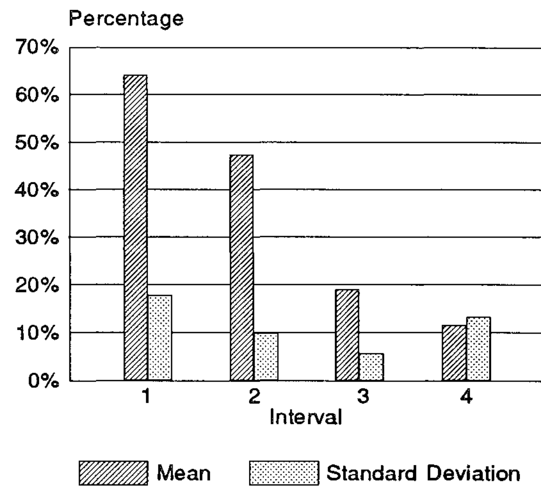

Table 1. Residual Decay Rate

Interval	Res 1	Res 2	Res 3	Res 4
1	50%	80%	71%	40%
2	50%	57%	50%	33%
3	25%	20%	20%	13%
4	20%	20%	0%	0%

Table 2. Overall Residual Decay Rate

Interval	Teeth	with Decay	Rate	SD
1	28	18	64%	18
2	25	12	48%	10
3	27	5	19%	5
4	28	3	11%	12

data were analyzed using analysis of variance for repeated measures. Each subject served as his/her own control, since each thought that caries removal was complete before the staining agent was applied. The decrease in the rate of incomplete caries removal from 64% to 11% was found to be statistically significant ($P < 0.01$). The Newman Keuls post-hoc test for individual comparisons found that the major decrease in incomplete caries removal occurred from intervals two to three ($P < 0.001$). Figure 2 shows the results for each resident.

Table 3 contains information on the residual decay left in cavity preparations classified by location and treatment interval. Some teeth had residual decay in more than one area. During the initial evaluation period, 13 of 28 teeth had residual decay on the axial wall while 14 of 28 teeth had residual decay at the DEJ. For the overall study, 23 of 108 teeth had decay left at the axial wall, and 28 of 108 teeth had decay remaining at the DEJ.

DISCUSSION

The caries removal process was monitored for a total of 16 clinical sessions divided into four intervals. The first four sessions were used to obtain baseline data on the residents' initial ability to identify and completely remove caries. Interval two contained data from the residents' initial experiences with the disclosing dye. Intervals three and four contained data from treatment sessions 9-16 and represent increasing levels of experience with caries removal substantiated with caries-disclosing dye. Each resident served as his/her own control, since the cavity preparations were not stained until the resident felt that decay removal was complete.

Initially, the residents were not accurately able to distinguish between sound and carious dentin. Many of the preparations thought to be caries free contained gross decay. The studies by Kidd and others (1989), Anderson and others (1985b), and Franco and Kelsey (1981) substantiate that clinicians, dental school students, and instructors may be unable to reliably distinguish between carious and noncarious dentin.

All residents demonstrated considerable improvement in the ability to remove grossly infected dentin when they were allowed to check the cavity preparation with an objective caries-disclosing agent. During the initial evaluation period, the residents left decay at the DEJ in 50% of the teeth treated. This is similar to the 59% found by Anderson and others (1985b) and the 57% found by Kidd and others (1989). With the use of disclosing stain as a teaching aid, the residents were able to lower the rate of residual decay at the DEJ to 11% (three of 28 teeth) by the last treatment interval. This clinically significant improvement would still result in residual decay at the DEJ in more than 10 of every

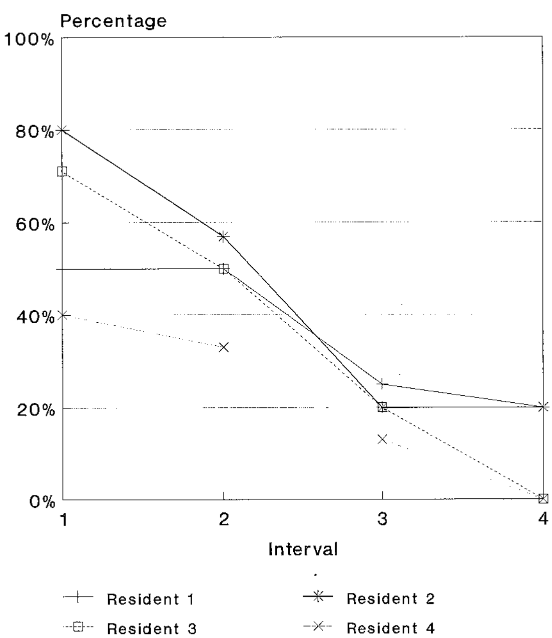

Figure 2. *Incomplete caries removal (individual)*

Table 3. Residual Decay Location

Interval	Total Teeth	Pulpal Stain (%)	DEJ Stain (%)
1	28	13 (46%)	14 (50%)
2	25	5 (20%)	8 (32%)
3	27	3 (11%)	3 (11%)
4	28	2 (7%)	3 (11%)

100 teeth treated. Although under certain conditions it may be clinically acceptable to leave some carious dentin axially, complete caries removal at the critical DEJ is always necessary. It is therefore recommended that all practitioners consider using caries-disclosing stain.

There was concern that residents would overprepare some teeth in their attempts to completely remove all of the stainable dentin. This was prevented with close supervision and frequent monitoring. Conservative tooth preparation was the goal, and no overprepared teeth were observed. The residents' improvement in caries removal appears to be the result of better identification of gross caries, not the overpreparation of teeth.

CONCLUSIONS

Cavity preparations completed by recent dental school graduates often contain residual decay. In certain situations it may be acceptable to leave carious dentin on the pulpal wall. However, caries near the DEJ must be removed completely if recurrent or residual decay is to be prevented. Caries-disclosing dye made from acid red has been proven capable of distinguishing between infected and affected dentin, thereby aiding the clinician in the caries removal process. This study demonstrates that clinicians are able to improve their gross caries identification and removal ability when they use a caries-disclosing dye to check their attempt at complete caries removal.

The opinions expressed herein are those of the authors and do not necessarily reflect the opinions of the DOD, the USAF, or of other federal agencies. The authors are responsible for the contents of this paper.

(Received 30 March 1992)

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How To Write A Clinical Article

MAXWELL H ANDERSON

Each year *Operative Dentistry* has a number of requests to publish more clinical articles. When I solicit clinicians to submit their table clinics or other techniques to *Operative Dentistry*, I am then asked for the guidelines for publishing a clinical article. This two-part article is intended to give the conceptual guidelines for a clinical article and an example of a clinical article. Dr Michael Cochran of the University of Indiana School of Dentistry was kind enough to provide the demonstration article. I sincerely hope that this will stimulate a number of our readers to submit their clinical techniques and tips so that we may all share the fruits of their experience.

A clinical article usually focuses on a procedure or a technique that the author(s) would like to share with others. The article should contain at least the following elements:

1. A clear statement of the problem, indication, or clinical situation the article or technique will address.

2. A clear, concise, step-by-step description of the technique(s) or procedure(s) the author(s) recommend to solve this situation. This section should contain a list of any materials required and any known pitfalls or potential problems with the individual steps or the overall technique.

3. Photographs to support the verbal description(s) where appropriate. Black-and-white glossy photographs, 5"x7", of the key steps should be provided. Where possible, these should be original black-and-white photographs rather than copies of color slides.

4. A brief summary statement to close the article that includes the advantages and any disadvantages of the technique compared to other techniques.

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Improving Casting Contours by Regaining Horizontal Space

MICHAEL A COCHRAN

A frequent clinical problem faced by the practitioner is the fabrication of a cast restoration for a posterior tooth that has experienced loss of horizontal space due to drifting/tipping of the adjacent dentition. This situation often results in a flattening of the casting's approximal form that may lead to difficulty in maintaining oral hygiene, with associated deterioration of the supporting tissues. In extreme situations (Figure 1), restoration may appear impossible due to cervical access limitations and the inability to create an acceptable path of insertion. While techniques such as stripping the approximal surface of the adjacent teeth may be helpful in cases of minimal space loss, they are not adequate for the more severe cases, and they are, at best, a compromise of the natural approximal contour and contact.

A viable and practical alternative is to regain the lost horizontal space through the judicious use of elastic orthodontic separators. These separators are normally applied to produce the space necessary for placement of orthodontic bands, but can provide the same action to regain space lost due to drifting/tipping. The author has used this technique for many years, and has found it to be relatively quick, easy, and consistently effective, with a limited armamentarium (Figure 2). Necessary materials include the following.

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Michael A Cochran, DDS, MSD, professor and chairman

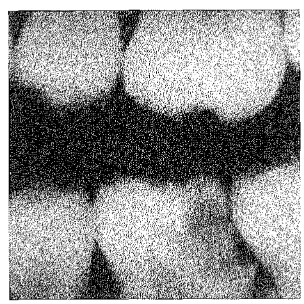


Figure 1. Radiograph showing a degree of horizontal space loss that makes adequate restoration impossible

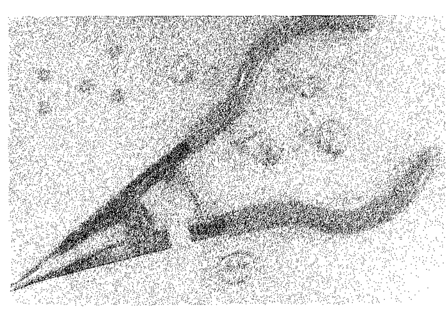


Figure 2. Armamentarium for regaining horizontal space

Provisional (Temporary) Crown Forms are available from a variety of sources. An example would be the anodized crown forms from 3M (3M Dental Division, P O Box C19597, 2111 McGaul Ave, Irvine, CA 92713).

The large-size Elastic Separators work best on posterior teeth and can be obtained from most orthodontic supply companies in packages of 100 or more. An example would be Sep-A-Rings elastic separators from T P Orthodontics, Inc (P O Box 73, LaPorte, IN 46350-0073).

Elastic Separator Pliers are used for placement of the elastic separators. As with the elastics, these can be obtained from most orthodontic supply companies. An example would be Orthopli Corporation's 018-A Elastic Separating Plier (Orthopli Corp, 10061 Sandmeyer Lane, Philadelphia, PA 19116).

CLINICAL TECHNIQUE

1. The tooth to be restored requires sufficient structure to retain a provisional (temporary) crown. This may mean a direct core build-up or the fabrication of a post and core prior to preparing the tooth to receive the provisional restoration.
2. A provisional crown is fabricated with good approximal contact and adequate approximal embrasure form (facial, lingual, occlusal, and cervical). NOTE: Cervical embrasure form is essential for placement of the separator. In some cases this will require positioning the cervical margin of the provisional axially to the prepared tooth margin (Figure 3).
3. The provisional is cemented and the elastic separator is stretched with the separator pliers. The cervical edge of the separator is passed through the approximal contact (Figure 4). Once the contact is cleared, the elastic is released so that it encircles the approximal contact area (Figure 5).
4. A properly placed provisional restoration and elastic will produce approximately 1 mm of separation within three to five days. Occasionally, minor occlusal equilibration is necessary if interference inhibits movement. At this point, a new provisional is fabricated with firm approximal contact to either hold the regained space until final casting delivery or to

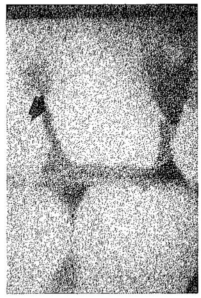


Figure 3. *Radiograph showing placement of provisional cervical margin axially to prepared tooth margin to create appropriate embrasure form for separator application*

Figure 4. *Placing elastic separator with orthodontic separator pliers*

Figure 5. *Elastic separator in place encircling approximal contact area*

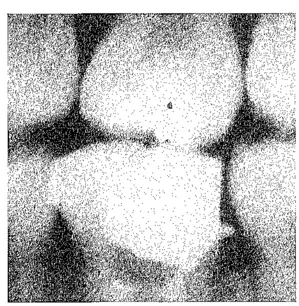


Figure 6a. *Radiograph of space regained with two separator applications*

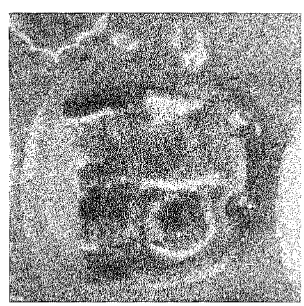


Figure 6b. *Clinical photograph of tooth ready for final restoration*

allow application of a second elastic separator (Figures 6a, 6b) to gain additional space (up to a total of 2+ mm within a two-week period, based on the author's experience).

5. Once the desired amount of horizontal space has been regained, the casting preparation is finalized, an impression is taken, and a new provisional is fabricated (Figure 7a) to hold the splice until the final restoration is placed (Figure 7b).

Horizontal space is most commonly lost when the tooth distal to a carious tooth tips mesially, following breakdown of the approximal contact area. However, mesial space can be lost as well, so this technique is applicable to regaining space on either or both approximals of a posterior tooth. Additions to the technique include placing a splice-holding acrylic stint if teeth anterior to the area of treatment are missing, and the use of alternate types of separators (twisted wire, elastic bands, etc).

The author has used this technique successfully up to the distal of first premolars.

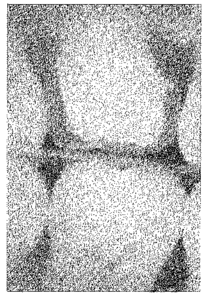


Figure 7a. Radiograph of final provisional in place

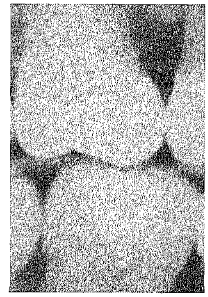


Figure 7b. Radiograph of final cast restoration

Using the separators anterior to this area may result in lateral displacement of the canine and such cases should be evaluated carefully, with orthodontic consultation suggested. This method of regaining horizontal space to allow fabrication of properly contoured castings is simple, effective, and inexpensive, and should have a place in the armamentarium of all restorative dental practices.

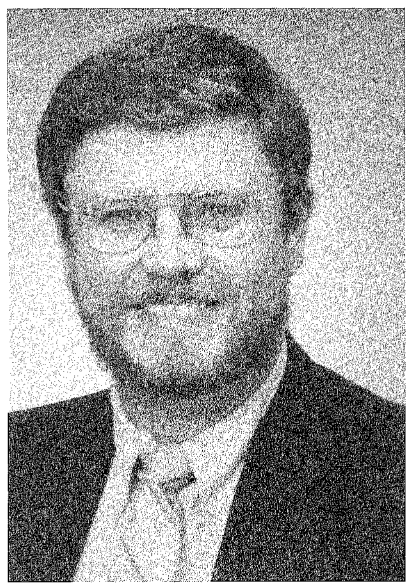
Clinician of the Year Award

The 1992 Clinician of the Year Award is being presented to Michael A Cochran.

Mike received his bachelor's degree in 1965 and his dental degree in 1969 from the University of Michigan. Immediately after dental school, he began military service in the Navy, where he served for 10 years, retiring as a commander in 1978. During his Navy years, Mike was sent to Indiana for operative training, receiving his master's degree in 1975.

Following Mike's Navy service, Dr Melvin Lund brought him to Indiana to direct the Undergraduate Operative Clinic. He has been an influential and respected member of the faculty, and begins his fifteenth year this fall, having risen to his present position as professor and chairman of the Department of Operative Dentistry.

Mike has received many awards over the years, including induction into the Omicron Kappa Upsilon dental honorary fraternity, multiple awards from graduating senior dental classes, and election to the American College of Dentists. He has remained a consultant to the Navy and has regularly been called on to provide continuing education courses in operative dentistry at several Navy programs. He recently received the Civism Award from the National Naval Dental Center in Bethesda in recognition for distinguished service and continuing contributions to the educational programs of the Navy Dental Corps and the Navy Dental School.

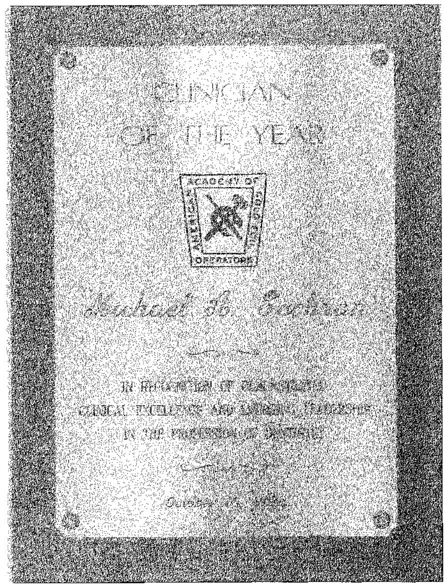


Michael A Cochran

One of Mike's most outstanding gifts is his ability to present enjoyable, informative lectures to dental audiences. He takes pride in quality presentations, whether he is speaking to 10 people at a local study club, or to a thousand at a national meeting. He has made literally hundreds of presentations to groups at all levels and on anything conceivably related to operative dentistry. Being an excellent artist, he creates all his own graphics and title slides. In recent years some dazzling effects were created at the keyboard of his favorite computer. I'm sure all of us who were there still remember his great presentation to this group in Puerto Rico entitled "Direct Gold in the Twenty-first Century."

Mike has served this Academy admirably through the years, serving in all the traditional councilor and officer positions, including the office of president in 1990-1991. He, of course, has lectured and operated at our meetings and has served many years on the Research Committee, chairing the group that compiled the exhaustive Direct Gold References Listings, which is still being updated and is available from the secretary-treasurer.

Mike has always been an advocate of direct gold, especially promoting its widespread use in what he terms "practical applications" such as small pit defects and repair of castings; he has been trying to remove some of the mystique from the material to increase its appeal to a broader range of practitioners.



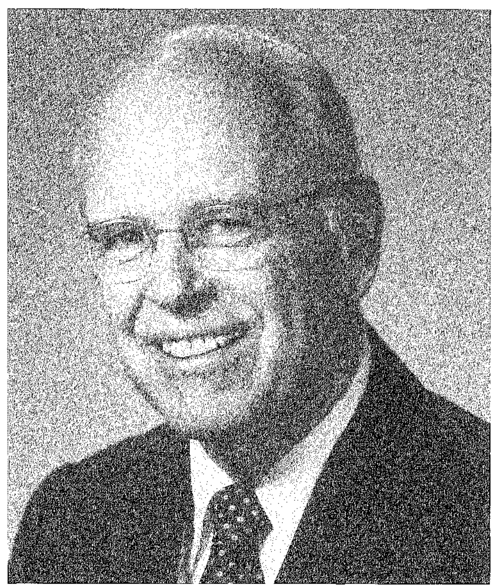
Clinician of the Year Award

In addition to his other abilities, Mike is an excellent clinician, a tireless supporter of the use of the rubber dam, and a promoter of excellence in dentistry. It gives me great pleasure to present this year's Clinician of the Year Award to Mike Cochran.

TIMOTHY J CARLSON

Distinguished Member Award

The American Academy of Gold Foil Operators proudly presents its Distinguished Member Award to Dr Nelson "Woody" Rupp. Woody graduated from Ohio State University School of Dentistry in 1943. After two years of private practice he joined the United States Navy, from which he retired in 1969 as a captain. During his career with the Navy, he worked in the National Bureau of Standards Dental and Medical Materials Group and received a master's degree in dental materials from Georgetown University. Dr Rupp joined the staff of the American Dental Association Health Foundation research group at the National Bureau of Standards in 1969, and prior to his retirement in 1987, he was associate director of the Bureau's Paffenbarger Research Center. He also served as national consultant to the Air Force Surgeon General. From the Paffenbarger Research Center, Woody made significant contributions to the development and improvement of denture base materials, amalgam, cements, composites, and adhesives. He is still active with the Paffenbarger Center, serving as training coordinator for new scientists.



Nelson Rupp

Woody served as president of the American Academy of Gold Foil Operators for the year 1986, when the annual meeting was held in Puerto Rico. He also served as president of the Academy of Operative Dentistry in 1979. Woody is a member of the American Academy of Restorative Dentistry, the International College of Dentists, the International and American Associations for Dental Research, and more. He has given lectures in many countries of the world and is constantly sought out for his opinions on all manner of topics.

Woody has received many awards and recognitions, including the Hollenback Memorial Prize from the Operative Academy, the

Callahan Memorial Award from the Ohio State Dental Association, the Wilmer Souder Award from the IADR, and in 1990 he was made an honorary member of the American College of Prosthodontists. He has a special interest in study club activity and has visited and contributed to many clubs throughout the United States and Canada. Woody is still active in the Navy Dental Study Club and often can be found operating and assisting with this group and with the George M Hollenback Study Club. His well-balanced perspectives on dental practice and science make his contributions very valuable to these groups.

We all salute a very fine gentleman and a role model, who is 1992's recipient of the Distinguished Member Award: Dr Nelson Rupp.

FREDERICK EICHMILLER

Distinguished Member Award

Award of Excellence

Thirty-eight years ago when I began my practice, the dentist from across the hall came in and said "Hi, I'm Paul Loflin, and I'm going to take care of you." He meant it, he did it, and he is still doing it. I suspect if you look around the room at the little smiles on some of the faces, you can tell who else got the same greeting and help. I might add that at the time I didn't know that this included golf, but it did, and he has really taken care of me since.

Paul Loflin was born in Mabscot, West Virginia, on 26 August 1924. Following graduation from Woodrow Wilson High School in Beckley, he attended Marshal College, now Marshal University. In 1944 he entered the Baltimore College of Dental Surgery, graduating in 1948. Immediately after graduation he went on active duty with the United States Navy, stationed at the Newport, Rhode Island Naval Station and on the USS *Thomas Jefferson.* In 1950 Paul began his practice in Beckley, but unfortunately, as happened to many, he was recalled to active duty in 1952. He returned to his practice in 1954. Since 1955, when I arrived on the scene, I have followed Paul in his many activities, and believe me, he is a tough act to follow.

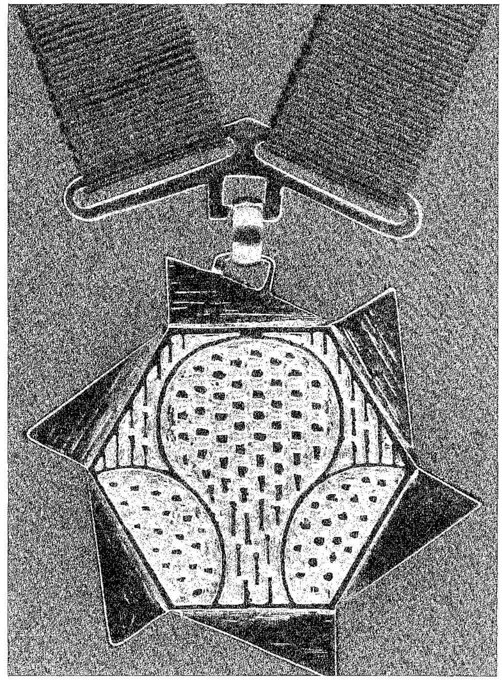
A true and hard-working leader, he has been president or chairman of virtually every organization in which he has been involved. The city of Beckley, Raleigh County, and the state of West Virginia know Paul well. Among many other activities, Paul has been involved with the Beckley-Raleigh County Board of Health, Raleigh County Health Council, and Beckley Common Council as an elected representative. He is a Paul Harris Fellow of the Beckley Rotary Club, a member of St Stephen's Episcopal Church, serving as a vestry member and senior warden many times, and he serves as a director of the Bank of Raleigh.

Paul H Loflin

Paul's introduction to the other side of dentistry began as vice-president of the New River Dental Society in 1954, and he shows no sign of slowing down in 1993. He has served in all of the offices of the New River Dental Society and the West Virginia Dental Association, including seven years as secretary. The American Dental Association also made good use of his talents during his eight years as a member of the House of Delegates. He was also appointed by the governor to the West Virginia Board of Dental Examiners. In this capacity he was a great influence on the fledgling Northeast Board of Dental Examiners and served many years as an examiner.

In 1962 Paul was a co-founder and charter member of the George M Hollenback Operative Dentistry Seminar. After 30 years, under the tutelage of José Medina, this is a still-growing group and a well-functioning study club. Paul is a very active member of the Academy of Gold Foil Operators and a charter member of the Operative Academy. He has served this Academy well with time, energy, and knowledge, and as its president. Presently he is chairman of the Founder's Committee. Of all the other organizations in which Paul has been involved, the International College is the premier group. From his induction in 1960 to being international president in 1989, he has worked diligently to promote dentistry. He has lectured internationally, in many countries, but probably his greatest input has been in South America. Along with his interpreter and confidant, José Medina, Paul has become known as the "*Queso Grande*," the "Big Cheese." As a result of his visits, a viable section has been added to the International College of Dentists.

Last year Paul was recognized by his fellow classmates and the alumni association, who presented him with the Distinguished Alumni Award of the Baltimore College of Dental Surgery.



Award of Excellence

Paul is still very active in dentistry and in his community, giving freely of his time and energy. I could continue at length, but it's tough to talk about someone who hasn't done anything.

To be excellent is to be eminently distinguished for goodness or ability. No one deserves the 1993 Award of Excellence for these qualities more than does Dr Paul Hurl Loflin.

DONALD E NEIL

DEPARTMENTS

Book Reviews

COLOR ATLAS OF OCCLUSION AND MALOCCLUSION

A P Howat, N J Caap, and N V J Barrett

Published by C V Mosby, St Louis, 1991. 240 pages, 766 illustrations. $99.00.

The *Color Atlas of Occlusion and Malocclusion* by Howat, Capp, and Barrett is a complete and indispensable guide for the general dentist and the specialist. The atlas is profusely illustrated with photographs and diagrams, and it covers all phases of occlusal diagnosis and rehabilitation. The authors have obviously gone to great lengths to create a manual that correlates anatomical, laboratory, and clinical data in a way that allows both the lab technician and the clinician to understand normal occlusion and malocclusion. The book is divided into three parts: Part I discusses mandibular movements and definitions; Part II deals with assessment of the occlusion; Part III concerns optimizing the occlusion.

The first section defining mandibular movements includes diagrams and clinical photos to outline the study of occlusion. Although this reviewer found the authors' use of the word "retruded" to be misleading in some diagrams, their overall description of the components and workings of the masticatory systems would be acceptable to both the Pankey-Dawson approach as well as the West Coast gnathological approach to occlusion. The middle section on assessments represents a thorough diagnostic guide with sections for the restorative dentist as well as the orthodontist and the prosthodontist. The last half of the book covers treatment considerations and represents a cookbook approach to optimizing the occlusion.

I have used this book frequently to train my staff and lab technicians. It is the first education guide I have used with patients that is complete enough to explain both the normal and the dysfunctional as well as treatment options.

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CURRENT CONTROVERSIES IN TEMPOROMANDIBULAR DISORDERS

Charles McNeill

Published by Quintessence Publishing Co, Inc, Chicago, 1992. 194 pages, 50 illustrations. $58.00.

This book presents the various, and at times conflicting, views of 14 internationally renowned experts regarding temporomandibular disorders (TMD) as presented at the Craniomandibular Institute's 10th Annual Squaw Valley Winter Seminar held in January 1991.

The book is divided into four main sections: 1) "Prevalence, Associations, and Diagnostic Classification of TMD"; 2) "Contributing Etiologic Factors to TMD"; 3) "Evaluation and Diagnosis of TMD"; 4) "Management of TMD." Each section is comprised of seven to nine short discussions on a topic of importance given by one of the experts. The majority of these presentations are three to five pages in length and written in a very understandable format with excellent current literature references. At the end of each section spirited panel discussions are presented. The information provided is of significant value in addressing many controversial topics that surfaced during the presentations. The panelists' statements with reasons documented greatly help the reader gain a clear understanding of agreements and disagreements of the issues.

The author's effort to present clearly understandable discussions of controversial issues plaguing the field of terminology, epidemiology, etiology, diagnoses, and management of TMD is expertly accomplished. Of particular interest is the description of how metabolic factors affect the TMJ, as is the panel discussion concerning different treatment modalities for management of TMD.

This book will not only be of interest to those working in the TMD field but will serve as an excellent guide for graduate program discussions as well as for general practitioners who would like to know the current status of the many important and controversial issues related to TMD.

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THE BRÅNEMARK SYSTEM OF ORAL RECONSTRUCTION—A CLINICAL ATLAS

Richard A Rasmussen, DDS

Published by Ishiyaku EuroAmerica, Inc, St Louis, 1992. 305 pages, 784 color illustrations. $175.00.

This book is a color atlas depicting the complete step-by-step procedures necessary for the diagnosis and treatment of patients with Brånemark implants. It is divided into seven chapters: Chapter 1) "The History of Evolution of Oral Implantology"; Chapter 2) "Diagnosis and Treatment Planning"; Chapter 3) "Surgical Protocol"; Chapter 4) "Stage I Surgery"; Chapter 5) "Stage II Surgery"; Chapter 6) "Restorative Management"; Chapter 7) "Maintenance."

The color atlas format is very applicable to the surgical through the maintenance chapters. The chapters on the history of implants and diagnosis and treatment planning are very thorough but do not lend themselves well to this format. The progression of treatment with dental implants from surgery through the final restoration is very well done. The surgical and restorative techniques are accurate and current with the state of the art in dental implantology utilizing the Brånemark system.

There are voluminous photographs (787) with the text directly opposite. The quality of the photographs is generally excellent; however, those that are duplicates rather than originals did not reprint well. The text opposite the photographs is very clear and concise.

The field of osseointegration is expanding rapidly. This book will give an excellent foundation for the surgeon, restorative dentist, and laboratory technician in the Brånemark System of Implantology.

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A COLLECTION OF CERAMIC WORKS: A Communication Tool for the Dental Office and Laboratory

Hitoshi Aoshima

Published by Quintessence Publishing Co, Inc, Chicago, 1992. 92 pages, 96 color illustrations. $60.00.

This is a collection of tooth ceramic arts. The characteristics in different types of teeth (young, middle-aged, and elderly) are demonstrated by the author. He has mastered the art of surface texturing, internal coloring, translucency, and other details of natural teeth.

It is an enjoyable book for communicating with the laboratory technician. Unfortunately, there is no mention of the technique used to achieve the effects he presents. In that sense, the book is limited to visual appreciation of dental ceramic arts, as the title implies.

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MINOR SURGERY IN ORTHODONTICS

Jean-Paul Schatz, Jean-Pierre Joho

Published by Quintessence Publishing Co, Inc, Chicago, 1992. 188 pages, 315 illustrations. $98.00.

After some puzzlement about the meaning of the title, closer inspection of the Table of Contents led me to believe that the authors wanted to distinguish orthognathic surgery and facial trauma from other aspects of surgery related to orthodontics. The authors have accomplished that successfully by covering topics ranging from radiologic assessment of pathologic conditions to principles of oral surgery. Chapters that would be of greatest interest to restorative dentists include: "Congenital Absence of Permanent Teeth," "Orthodontic Treatment Planning Considerations," "Orthodontic/Periodontal Considerations for Minor Periodontal Surgery," "Orthodontic Management of Traumatized Teeth," and "Autotransplantations and Orthodontic Treatment Planning."

The theme of the text is "the team," that is, the need for multidisciplinary care in the treatment of patients with complex problems. The authors advocate that high-quality dentistry be based on the integration of basic biological principles with mastery of new technologies. In that regard the book only lacks information on one of the more recent and exciting aspects of multidisciplinary care, implant dentistry. The book is amply illustrated; the quality of the figures is exceptional. Also the type face and page layouts make for a most readable text.

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INFLAMMATION: A REVIEW OF THE PROCESS
Fourth Edition

Henry O Trowbridge, Robert C Emling

Published by Quintessence Publishing Co, Inc, Chicago, 1993. 172 pages, 64 illustrations. $28.00, softbound.

This edition is a timely update of the third edition, copyrighted in 1989. The editors are well-known authorities in two different areas. Dr Trowbridge has long been involved in pulp biology research with an emphasis on inflammation and healing of the dental pulp. Dr Emling has a degree in education and has specialized in the professional and adult learner. The book is based on a self-study paradigm and effectively approaches the mechanisms of inflammation in seven chapters divided into four general topics loosely corresponding to the progression from injury to repair: 1) Acute Inflammatory Process; 2) Immunity; 3) Chronic Inflammation; and 4) Healing. Each chapter is further subdivided into important components related to its topic and contains many useful illustrations, summaries, and reviews of the material being discussed. The chapters are particularly effective in presenting potentially confusing and intricate information accurately and concisely. The many interrelated aspects of the inflammatory response are well described and linked. The overall format of *Inflammation: A Review of the Process,* with its concise text, informative illustrations, useful check points and reviews, and complete index lends itself well to both the student and established clinician interested in understanding the mechanisms related to inflammation. Although the text only lightly addresses the diagnosis and treatment of inflammation, it is very effective in discussing the process and how systemic factors affect it. This discussion easily leads the reader to a better understanding of diagnosis and treatment. Short, yet current, reference and additional reading lists at the end of each chapter further assist readers in expanding their knowledge of the topics. The authors have combined their expertise in a unique, enjoyable, and useful product that is very good at being an education tool, a concise overview, and a valuable reference.

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ENDODONTIC SURGERY

C R Stockdale

Published by Quintessence Publishing Co, Inc, Chicago, 1992. 122 pages, 66 illustrations. $48.00.

The author draws from over 30 years of experience in the practice and teaching of endodontic surgery in the writing of this book, which is directed primarily to general practitioners. He articulates a sound surgical philosophy and describes time-proven techniques. He correctly emphasizes throughout the work that surgery is indicated only after efforts to resolve endodontic problems with conventional therapy have failed. Illustrations are quite good and serve to reinforce the text. Most of the clinical photographs are in color, but some are not. The one of amalgam tattoo would be more meaningful had color film been used. The only inadequate illustration is the one of the suggested kit for endodontic surgery. It is so small that the reader will have difficulty in making out what all of the items are, and no legend is provided. No mention is made of the use of ultrasonic devices for preparation of retrograde cavities. The use of EBA cement and other alternates for amalgam as retrofilling materials is mentioned, but their current popularity over amalgam for many applications is not dealt with adequately. The chapter on medico-legal considerations provides broad concepts that are valid across jurisdictions. Although the book is not clearly superior to other recent publications that deal with endodontic surgery, it is adequately indexed and will be a valuable reference and guide for those in the target audience who purchase it.

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OPERATIVE DENTISTRY

MAY-JUNE 1993 • VOLUME 18 • NUMBER 3 • 81-128

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