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EDITORIAL

Round Fourteen: and Counting

Dentistry has long been recognized as a noble profession, not only because it serves humanity but because it has worked so diligently to put itself out of business. In recent years many dentists have experienced a "busyness" problem and most newly graduated dentists have found it difficult to enter into a solo private practice as a result of two significant changes: (1) a marked decrease in dental caries experience of the younger generation and (2) a significant increase in the number of dentists graduating from dental school.

These factors coupled with the recent economic recession have led many to vocalize "doom and gloom" concerns about the future of the profession. Can it be true that dentistry will soon be dead, or are we in round 14 of a 15-round fight? To make an educated guess and "crystal ball" future needs for dentistry we must assess the reduction of dental caries, new evidence concerning caries and periodontal disease rates in the adult population, and the status of reduced dental school enrollments. The real question is: Does dentistry still have a future?

As a profession, dentistry is young, having come into its own with the era of G V Black when he elevated dentistry to a true scientific discipline. For over 100 years the professional has looked forward to the day when the ravages of dental decay would be eradicated. Although not totally eliminated, the effects of dental decay have been significantly reduced. Numerous studies have demonstrated that caries is at historically low levels, yet 20% of children present a relatively high caries rate. The specialty of pedodontics is struggling to stay alive as the youth of today are growing up with few if any carious lesions. Without caries, these young patients will not have the need for replacement restorations and treatment of fractured teeth resulting from removal of tooth structure for restorative purposes.

Fluoride and other preventive means have made a significant impact on the profession's lofty goal of self-elimination. Fluoride has proven to be most effective in the prevention of smooth surface dental caries. The concept of acid etching and the use of pit-and-fissure sealants can virtually assure most patients a caries-free dentition through their childhood years. Of course, patients must be seeking care if they are to receive this benefit.

For many years we have been led to believe that a caries vaccine was just around the corner. We are now told that such a vaccine is all but a reality. With the introduction of a true vaccine to eliminate dental decay, those individuals which now comprise the 20% of the population that is experiencing 75–80% of the decay will have the potential for decreasing their caries rate. With this in mind: Is the fight now over?

Elimination of caries from the young will have a big impact on the profession in years to come. We must remember that there is a large population of adults that has experienced a great deal of restorative dentistry in the past. The maintenance of these dentitions will keep the profession occupied well into the 21st century. Sufficient data is available to lead us to believe that the restorative dental care required now will keep today's dentists sufficiently busy, maintaining the existing restored teeth and teeth that otherwise need repair as a result of trauma, occlusal wear, or demands for cosmetic restorative care. So maybe the fight is not yet over.

There has been a substantial cutback in the number of students being admitted to dental schools. In part this is a result of the reduced numbers of candidates applying for admission and, to keep the standards high, schools must decrease the numbers they accept. Also fiscal problems have required many schools to cut back. We have seen the announced closure of two schools and a general decrease in first-year acceptances in most of the other schools. First-year enrollments that were at an all-time high of 6,335 in 1978 have now decreased to 4,300 first-year positions in 1986. Projections show further reductions in the numbers of first-year entrants of either 3,300 or 2,900 by 1990. As we prepare to enter the 21st century, should we not be able to look forward to a continued busy and fruitful practice of dentistry or will we be faced with further reductions?

A long-term study conducted by the National Institute of Dental Research, as yet unpublished, has evaluated the caries and periodontal status of our adult population age 18-65 and age 65 and over. This study will undoubtedly set our professional world into another tailspin as it becomes aware of the data. A brief summary of some of that data was presented at the recent American Dental Association meeting in Miami, Florida, in October. A four-hour presentation of the data is to be given in conjunction with the IADR meeting in Chicago this March. It appears the population sampled has considerably less caries and periodontal disease than was anticipated. What a stir this information is going to make! Is the fight over?

Already comments are being heard from some educators that we certainly can eliminate the time allocated to operative procedures as we now know that the adults don't have a significant caries problem. It looks like we are going to be fighting the same battles of a few years ago all over again. Even if the demand as well as the need for restorative procedures may decrease, it is imperative that dental schools not curtail time allocated for restorative procedures. If the dentist of tomorrow were to spend only minimal time performing restorative procedures, those procedures must be done at a level of excellence. To teach excellence, educators must have the time.

We really are at a crossroads, and now is the time for serious planning and drastic actions. If indeed our younger generation is to be relatively free of dental disease, our adult population age 20 and beyond already has significant dental restorations in place which need maintenance. The time required for this will be great; however, we should recognize that as this population ages over the next 40 to 50 years the time required for such maintenance will be greatly reduced. Eventually this population will age and pass away. Then what is the dentist to do? Surely it doesn't take a mental giant to ascertain that we eventually must do one of two things: (1) find alternative treatments for the dentist to provide and (2) program a reduction of class sizes and numbers of existing dental schools.

It seems unrealistic to try finding other forms of treatment for the dentist to deliver. To suggest that we more closely ally with the medical profession is not a viable suggestion. The medical profession today faces its own problems of overtraining and the graduation of an excessive number of physicians, and is in no position to cope with the problems of the dental profession — these are our problems! Nor is the concept that we can find more and new forms of dental treatment to maintain the present dentist/patient ratio a viable suggestion. That leaves us one workable alternative: Plan now for the future. We should anticipate the reduction of a large number of schools as we approach the 21st century. We should plan to reduce the number of care providers in the profession in an orderly manner so that there will be neither feast nor famine, but a logical transition into the new era which is bound to come.

Dentistry has made tremendous strides towards putting itself out of business, but it has not won as yet. Those who tell us that mechanical dentistry is dead and is not needed in the curriculum must be countered. We cannot allow these people to prevent the maintenance of quality in our technical procedures. The fight is not over, it is only round 14 of a 15-round championship fight, and we are still counting!

DAVID J BALES
University of Washington
School of Dentistry, SM-56
Seattle, WA 98195

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ORIGINAL ARTICLES

Flexural Strength of Repaired High-copper Amalgam

K B BROWN • M P MOLVAR • V A DEMAREST
T K HASEGAWA JR • P N HEINECKE

Summary

Four high-copper amalgams were tested for flexural strength after early repair. Rectangular bars of amalgam were condensed in a mold. Control specimens were allowed to set without disturbance. Test samples were sectioned by carving or fracturing to half their original length at 7 or 12 minutes following trituration. New increments of amalgam were condensed against the fractured or carved surfaces and tested 24 hours later. The mean force required to break the test samples was 13 to 44% lower than the controls at 7 minutes, 13 to 48% lower at 12 minutes for carved samples, and 35 to 59% lower at 12 minutes for fractured samples.

University of Nebraska Medical Center, College of Dentistry, Department of Adult Restorative Dentistry, Lincoln, NE 68583-0740, USA

K BIRGITTA BROWN, DMD, assistant professor

MICHAEL P MOLVAR, DDS, MS, assistant professor

VICTORIA DEMAREST, MS, graduate student, Northwestern University

THOMAS K HASEGAWA, JR, DDS, MA, assistant professor, Baylor University

PHILIP N HEINECKE, DDS, general practice resident, University of Florida

Introduction

Amalgam restorations sometimes fracture soon after condensation. When the restoration is complex, repair of the restoration might be considered rather than complete replacement. Earlier studies on bond strength of amalgam repair have reported variable results. Terkla, Mahler and Mitchem (1961) evaluated low-copper amalgams repaired at 15 minutes and 7 days and demonstrated bond strengths of less than half that of controls. Berge (1982), using both conventional and high-copper amalgam repaired after 7 days, and Consani, Ruhnke and Stolf (1977), using conventional silver amalgam repaired after 72 hours, showed drastic reduction in bond strengths. Kirk (1962), and Jørgensen and Saito (1968) in their study of True Dentalloy, indicated that good bond strength of repairs could be achieved after 48 to 72 hours, but only after certain specific surface treatments.

One recent study of repairs by Walker and Reese (1983), using a high-copper amalgam (Tytin), appears to confirm that the bond strength of repaired amalgam is inferior to that of intact samples even when the repair is done as soon as 5 minutes after the end of the con-

Flexural Strengths of Control and Repaired Specimens (MPa)

Material		Control	Treatment: 7 Min Carved	12 Min Carved	12 Min Fractured	Overall F-Test
Dispersalloy	Mean	81	70	62	33	
	SD	14.4	14.7	18.5	8.8	F = 18.809
	n	10	7	8	9	$P < 0.05$
	P-values for pairwise *t*-test vs control		NS	$P < 0.05$	$P < 0.01$	
Tytin	Mean	100	56	52	43	
	SD	16.8	20.8	20.4	10.5	F = 21.012
	n	10	9	10	10	$P < 0.05$
	t-test vs control		$P < 0.01$	$P < 0.01$	$P < 0.01$	
Sybraloy	Mean	71	60	62	46	
	SD	20.1	17.1	25.2	9.6	F = 2.735
	n	10	7	6	8	NS
	t-test vs control		NS	NS	$P < 0.05$	
Contour	Mean	68	51	40	42	
	SD	16.4	11.2	17.9	12.6	F = 7.323
	n	10	10	8	10	$P < 0.05$
	t-test vs control		$P < 0.05$	$P < 0.01$	$P < 0.01$	

densation. Conversely, Scott and Grisius (1969) showed fairly good bond strengths at the earlier intervals. This study compares the bond strength of four high-copper amalgams repaired at two intervals soon after condensation, comparing specimens which were fractured and those separated by carving.

Methods

Control and test samples were made using regular set Dispersalloy (Johnson & Johnson, East Windsor, NJ 08520), Tytin (S S White, Philadelphia, PA 19102), Sybraloy and Contour (Kerr, Romulus, MI 48174). The precapsulated (double spill) amalgams were triturated at manufacturers' recommended speeds and times. The samples were condensed by hand in a silicone-lined stainless steel mold creating rectangular bars 12 mm x 4 mm x 2 mm (Fig 1). Condensation force was approximately 4 pounds, with a Hartzell #3 rectangular condenser, resulting in a force of about 92 kg cm^{-2} at the face of the condenser point.

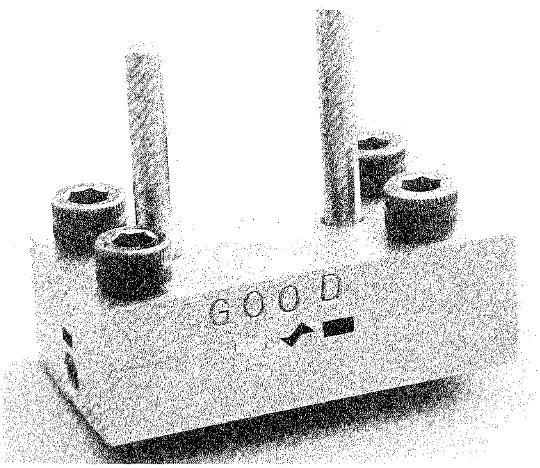

FIG 1. *Sample condensed in left opening of steel mold*

Control specimens were left in the mold for 15 minutes before removal. Test samples were fractured by hand or carved with a hand instrument to half the original length at 7 or 12 minutes after completion of trituration of the initial sample. The 7-minute specimens were all carved while 12-minute samples were carved or fractured. Test samples were then immediately repaired with fresh amalgam of the same brand. The repair was accomplished by placing the specimen to be repaired back into the steel mold in which the original specimen was made, and condensing a new mix of amalgam against the repair site in the same direction as the initial portion. Samples were stored in artificial saliva for 24 hours at 37 °C. The flexural strength was determined using a four-point testing device in an Instron Universal Testing Machine (Instron Corp, Quincy, MA 02021) at a crosshead speed of 1 mm/min at room temperature (Fig 2). The specimens did not always fracture at the joint between old and new amalgam, but only those that did are

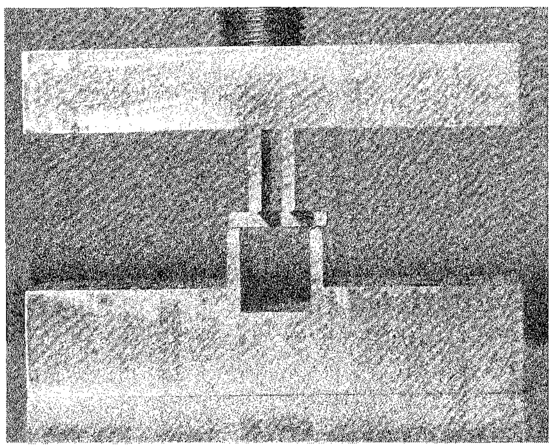

FIG 2. *Sample in the four-point testing device*

included in this study. Fractures at sites other than the repair sites were not considered relevant to repair bond strengths. The flexural strength was calculated using the following formula:

$$\text{Flexural strength} = \frac{3PA}{BH^2}$$

where P = load, A = distance between outside support and first pressure point, B = width, and H = thickness of sample.

Statistical evaluation was done with analysis of variance followed by multiple comparisons using Newman-Keul's test.

Results

The mean 24-hour flexural strengths of the specimens are shown in the table. None of the repaired specimens reached the mean strength of the control samples. However, the reduction was only significant for Tytin and Contour at 7 minutes and Dispersalloy, Tytin, and Contour at 12 minutes for the carved specimens. The flexural strengths of the 12-minute fractured and repaired specimens were significantly reduced for all brands of amalgam. The 12-minute specimens in general demonstrated lower flexural strengths than the 7-minute specimens with the exception of Sybraloy. However, these differences were not statistically significant. With the exception of Contour, all of the 12-minute carved and repaired specimens showed greater flexural strength than the fractured specimens. This difference was significant for Dispersalloy ($P < 0.01$).

Discussion

Different strengths of repaired amalgam were observed for different brands of amalgam for the same time period and surface treatment. Apparent contradictions in earlier studies may be partially explained by the difference in type of alloys used. Walker and Reese (1983), in their study of Tytin alone, demonstrated bond strengths of less than 50% when compared with intact samples after 5 and 15 minutes. Tytin in this study demonstrated a 43% loss of flexural strength after repair at 7 minutes. This might be related to the very early set of this amalgam. The percentage reductions in flexural strength of repaired specimens in our study were not as great as in the Walker and Reese study because our control specimens had only half the flexural strength recorded in that study. The difference in strength of intact specimens is possibly due to the fact that in this study the specimens were hand condensed at less than one-tenth the force used in their study. Hand condensation is also a possible reason for variability in flexural strengths within the same group. Hand condensation was used to simulate conditions under which these materials are used clinically. Berge (1982) also noted such inconsistency between specimens of the same amalgam.

Scott and Grisius (1969) demonstrated that good bond strengths could be achieved with a spherical alloy (Kerr Spheraloy). Their results were very similar to this study for Sybraloy (a high-copper spherical amalgam). In their study there was a 30% reduction at 15 minutes for Spheraloy, while in this study Sybraloy had the least flexural strength reduction, 13% at 12 minutes.

However, Tytin (a high-copper spherical amalgam) had the greatest reduction in flexural strength. Dispersalloy and Contour (admixed high-copper amalgams) were intermediate in bond strength. The data seem to indicate that generalizations cannot be made about the level of bond strengths of repairs of different types or brands of amalgam.

This study clearly indicates that reduction in flexural strength can be expected for all the amalgams tested if repair is done as early as 7 minutes after the end of trituration. Moreover, there were reductions in mean bond strengths between 7 and 12 minutes, though these were not statistically significant. A test of specimens repaired after 24 hours was attempted but abandoned because of difficulty in handling the specimens without breaking the very weak bonds. For the amalgams tested, if repair is contemplated it is advisable to do the repairs as early as possible.

Differences in mean flexural strengths were also observed between 12-minute specimens prepared by fracture as opposed to carving prior to the repair. The fractured specimens generally exhibited lower values with the exception of Contour. Such a result might be attributed to differences in surface texture or in the amount of mercury available to react with unconsumed gamma particles, as suggested by Walker and Reese (1983). Further research is indicated to seek an answer to this difference between carved and fractured specimens and its relevance to clinical application.

Conclusions

For the regular set high-copper amalgams tested:

- The mean flexural strength of all repaired specimens decreased relative to control specimens. The extent of the reduction varied greatly with the brand of amalgam used.
- The mean flexural strength of the repaired

specimens of Contour, Dispersalloy, and Tytin decreased more for the 12-minute specimens than for the 7-minute specimens. This difference was not statistically significant.

- For 12-minute specimens, carved surfaces resulted in a stronger bond than the fractured surfaces for Dispersalloy, Sybraloy, and Tytin. This difference was significant for Dispersalloy.

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Clinical Predictability of Caries Beneath Restorations

E J DESCHEPPER • S L WENDT
T H ALMS

Summary

This predictive study was conducted to determine the extent to which presence or absence of caries could accurately be predicted through clinical means prior to removing the base.

Despite considerable variation in the results of the two examiners, attesting to subjectivity factors in the methods used for clinical detection of residual caries, results generally indicate that, when both radiographic and digital interpretation are used simultaneously, errors in predicting the incomplete removal of caries were much lower.

University of Missouri-Kansas City School of Dentistry, 650 E 25th Street, Kansas City, MO 64108

EDWARD J DESCHEPPER, DDS, assistant professor of operative dentistry

STANLEY L WENDT, JR, DDS, assistant professor, Division of Biomaterials, University of Tennessee-Memphis College of Dentistry

THOMAS H ALMS, PhD, professor of microbiology

Introduction

Residual caries refers to caries left in a cavity preparation, either by oversight or purposely, in an effort to avoid unnecessary exposure of the pulp. Residual caries may not be as easy to detect as recurrent caries, which occurs at or near the margins, since residual caries is usually blocked from visual and digital detection by the restoration. To make a diagnosis of residual caries beneath a restoration, one must rely mostly upon radiographs, which can be difficult to interpret. Studies by Franco and Kelsey (1981), Zander (1940), Charbeneau and others (1981), Craig (1959), and Anderson and Charbeneau (1985) indicate that a clinically reliable guide on which a dentist may base a decision regarding complete caries removal may not exist.

The purpose of this predictive study was to determine the accuracy of predictions made through the use of radiographic and digital means about the presence or absence of caries beneath a base or restoration prior to removing the restoration and its base.

Materials and Methods

Forty-eight amalgams were selected from patients currently under treatment at University of Missouri-Kansas City School of Dentistry. The amalgams were scheduled to be replaced for various reasons (recurrent decay, fractures, or open margins) and had radiographic evidence of the presence of a base. Those restorations with gross caries or gross amounts of missing amalgam and/or tooth structure were not selected.

Before any procedures were begun, the following determinations were made and recorded: approximate age of the restoration (from patient interview), radiographic evidence of decay beneath the base, and evidence of decay at the margin of the restoration. Two operators conducted the study, verbally agreeing upon criteria for predictions and procedures to be used. Each operator examined a separate set of samples.

The following clinical procedures were employed, sterile technique being the main objective. The tooth selected was isolated with a rubber dam. The subject tooth in most cases was the only one isolated and the dam was checked for leakage. The subject tooth and surrounding dam were swabbed with a 10% Betadine solution (Betadine, Purdue Frederick Company, 50 Washington St, Norwalk, CT 06856, USA) and left for one minute. The area was flushed with sterile water from a sterile bulb syringe. The tooth and surrounding dam were again swabbed with Betadine. The handpiece and bur were swabbed with Betadine and run dry with sterile water irrigation from a sterile bulb syringe. During the procedure all instruments were either autoclaved or the working ends were rendered sterile by placing the ends in a salt sterilizer for 10 seconds, or both.

The amalgam was removed to ideal depth (approximately 0.5 - 1 mm pulpal to the dentino-enamel junction) and a sharp EX 3CH explorer (Hu Friedy, 3232 N Rockwell St, Chicago, IL 60618, USA) was used to check for caries around the remaining amalgam or base. At this point a prediction was made as to the presence or absence of caries around the amalgam or base. Decisions were then made by radiographic interpretation or by digital examination with the EX 3CH explorer in predicting the presence or absence of caries before the removal of the base. If the explorer engaged soft dentin, or encountered resistance to removal, it was considered to have engaged caries and the appropriate prediction was entered on the data card. Radiolucencies beneath the base were interpreted as caries unless the radiolucency was obviously representing pulpal tissue. This information was also transferred to the data card.

After making predictions about the presence or absence of caries, the remaining amalgam and base were completely removed and the underlying dentin checked for caries. Two tests were used to determine the actual presence or absence of caries following the removal of the amalgam or base. For caries to be considered present, the tooth had to display a "stick" with the EX 3CH explorer or allow the removal of soft dentin with a sharp discoid excavator and have a positive culture for caries-producing bacteria. If either of these criteria were not met, then caries were not considered to be present.

The first test included visual inspection and sticking with a sharp EX 3CH explorer or scraping soft dentin with a spoon excavator. A clinical determination of the presence or absence of caries was made at this time and the information transferred to the data card.

The second test involved culturing material that had been removed with the excavator. The dentin removed from the pulpal floor was transferred via the excavator to glucose ascites broth.

Each specimen was incubated in glucose ascites broth at 37 °C and observed daily for growth. When turbidity was observed, the culture was incubated an additional 24 hours to allow for sufficient growth for subculturing and identification. Most specimens required 48 hours of incubation before subculturing. Specimens not showing growth at 48 hours were incubated one week. If they still showed no growth, they were considered sterile.

After gram staining, each glucose ascites specimen was subcultured onto two brain-heart infusion agar plates (BHIA) with 5% sheep blood. One plate was incubated anaerobically at 37 °C for 24 and 48 hours, respectively. Based upon the colony morphology and gram stain, each type of bacterium was inoculated to selective/differential media for identification as to genus and species.

Results

Data were collected on 39 amalgams. Cultures were either not taken or rejected on 9 of the original 48 specimens due to obvious contamination (leaking dam) or pulp exposure upon complete removal of base. Two pulp exposures were discovered upon removal of the base.

The range in age of the restorations at the time of removal was between 2½-15 years. Some restorations may have been present longer but could not be determined with accuracy because of the patient's inability to remember time of placement. Obviously, the longer the restoration had been in the mouth the more difficult it became for the patient to remember the time of placement.

Before totally removing the amalgam or base, considering radiographic criteria alone, caries was predicted in 20 of the 39 samples; using digital criteria alone, caries was predicted in 7 of the 39 samples.

Following removal of the amalgam or base, softened dentin was found digitally in 18 of the 39 teeth cultured. Caries-producing bacteria were found in 26 of the 39 specimens sampled. Those organisms considered to be cariogenic included *Streptococcus viridans* and *mutans* and *Lactobacillus acidophilus*. Other organisms were cultured from some specimens, but were not considered to be cariogenic. These included *Staphylococcus aureus, Staphylococcus epidermis,* micrococci, *Corynebacterium* species and diphtheroids. Sterile cultures were obtained in 6 of the 39 teeth cultured.

Fifteen of the 39 specimens displayed both digital and microbiologic evidence of caries after removal of the remaining amalgam or base. Of the 15 teeth that displayed caries according to digital and microbiologic criteria, 6 were not predicted to have caries radiographically or digitally before removing the base. Ten specimens showed clinical or radiographic evidence of caries, but cultures were either sterile or had no cariogenic bacteria. Only 4 of 39 specimens met all criteria — radiographic, digital, and microbiologic — for the presence or absence of caries beneath the base.

Discussion

The purpose of this study was to determine how accurately the presence or absence of caries beneath a base could be predicted before removal of an entire restoration, with hopes of shedding new light on the accuracy of diagnosing residual caries. One rationale for testing the accuracy of these predictions was to determine the feasibility of incomplete removal of intact bases when replacing restorations to avoid unnecessary injury to the pulp or pulp exposure in deep restorations.

The procedure involves removing the old restoration and/or base to the ideal pulpal and axial depth. Only those portions of the restoration adjacent to the pulp (axial or pulpal wall) are left intact. At this point, the remaining base and/or restoration is checked at its margins for caries. If the dentin surrounding the remaining base or restoration is sound as determined by digital examination with an explorer and radiographs show no evidence of caries beneath the alloy or base, the new restoration is placed over it. If accurate predictions can be made there is no reason to remove the entire base.

However, from the results it became obvious that two types of errors in prediction were possible. Errors in which no caries was predicted but was actually found were labeled E_1. Errors in which caries was predicted but not actually found were labeled E_2. If one were to practice the incomplete removal of bases and amalgams when replacing them, then only type E_1 errors would result in leaving residual caries under a restoration. Results of the two types of errors are found in Table 1.

Table 1. Percentage Error by Type

Type of Error	Total Number of Samples	Number of Prediction Errors	Error %
Radiographic Prediction Errors			
E_1	39	9	23.1
E_2	39	14	35.9
Digital Prediction Errors			
E_1	39	11	28.2
E_2	39	3	7.6
Prediction Errors Using Digital and Radiographic Means			
E_1	39	6	15.4
E_2	39	15	38.5

E_1 = caries not predicted but found
E_2 = caries predicted but not found

When using radiographs alone to make predictions, the two examiners made the correct prediction 76.9% of the time when stating that no caries was present under a base. This means that caries was present in 23.1% of the cases, but was not detected before the removal of the base. When using radiographic criteria alone, the two examiners were correct 64.1% in predicting that there was caries under the base. This means that in 35.9% of the cases caries was thought to be present but actually was not. This type of error may have been due to the radiolucent bases present under amalgams.

Using digital criteria alone, the two examiners made the correct prediction that no caries was present under the base in 71.8% of the cases, representing a 28.2% error type E_1. The examiners were correct in predicting the presence of caries under the base using digital means alone in 92.4% of the cases representing a 7.6% error (type E_2).

The above data indicated error when radiographic and digital predictions were considered separately. However, when diagnosing, most operators use both digital and radiographic means to detect caries. During the detection process, a positive indication of caries *either* radiographically or digitally would indicate the presence of caries and necessitate removal of an entire restoration. Thus residual caries would have been left in only 6 of the 39 samples in this study. This translates to a 15.4% error when using radiographic *and* digital means to make predictions (type E_1, Table 1).

Table 2 indicates that this type E_1 error ranged from 6.7% - 20.8%, depending upon the operator. The percent error varied considerably

Table 2. Percentage Error

Type of Prediction	Type of Error	Total Number of Samples	Number of Prediction Errors	Error %
		Examiner I		
Radiographic	E_1	15	1	6.7
	E_2	15	10	66.7
Digital	E_1	15	5	33.3
	E_2	15	1	6.7
Radiographic and digital combined	E_1	15	1	6.7
	E_2	15	10	66.7
		Examiner II		
Radiographic	E_1	24	8	33.3
	E_2	24	4	16.7
Digital	E_1	24	6	25.0
	E_2	24	2	8.3
Radiographic and digital combined	E_1	24	5	20.8
	E_2	24	4	16.6

E_1 = caries not predicted but found
E_2 = caries predicted but not found

between examiners with both radiographic and digital means of detecting caries. The caries detection process remains subjective and the above results indicate the difficulty of diagnosing residual caries.

If one were to practice the procedure of incomplete removal of restoration based upon predictions made using digital or radiographic criteria, it would become apparent that residual caries could be left inadvertently in a significant number of cases (6.7% - 20.8% of the time in this study).

A question remains, however, as to the significance of leaving "small" amounts of residual caries in a sealed environment. It is assumed that the presence of viable caries-producing bacteria is necessary for the progression of caries. Therefore, previous studies dealing with the effects of leaving cariogenic bacteria within a cavity preparation have tested the ability of bacteria to survive in various sealed environments.

Inconsistencies in the literature are apparent. For example, Fisher (1977) claimed sterility under amalgams based with Dycal (L C Caulk Co, Milford, DE 19963, USA). As a result of this study, Dycal was thought to be bacteriocidal and thus responsible for rendering cavities sterile, preventing progression of residual caries. However, Cotton (1974) some years earlier found colonies of bacteria growing directly on $Ca(OH)_2$ in pulp cap studies in rats. Leung, Loesche and Charbeneau (1980) found similar results that showed that bacteria could survive under Dycal; however, the bacteria were reduced in number over time. This raises a question of the efficacy of $Ca(OH)_2$ or Dycal to render cavities sterile and suggests some other reason for the results that Fisher (1977) obtained.

In contrast to Fisher's study, Besic (1943) showed that lactobacilli could live for long periods of time (up to 19 months) under sealed restorations. Schouboe and MacDonald (1962), McCloskey (1978), Hawes, DiMaggio and Sayegh (1964), King, Crawford and Lindahl (1965), and Fairbourn, Charbeneau and Loesche (1980) have all verified that bacteria can survive under sealed restorations, which suggests that merely sealing bacteria within restorations does not totally eliminate them.

If bacteria can survive under sealed restoration, as suggested by this literature, there must be a supply of nutrients to the bacteria. Bergman and Lindén (1965) describe ionic exchange between pulp and saliva, suggesting flow through enamel as well as dentin. This could be a supply of nutrients to bacteria in sealed restorations. Bacteria may also be obtaining nutrients via dentinal tubules and quite possibly from microleakage.

This literature combined with the results of this study would, at first glance, strongly discourage the incomplete removal of amalgams and bases when replacing restoration. Prediction errors suggest that residual decay may be inadvertently left when using digital and radiographic means to make predictions. The literature also suggests that bacteria can survive in sealed environments, indicating the possibility of the progression of residual decay. However, one question still remains, and that is whether or not the bacteria can survive in sufficient numbers to allow residual caries to progress in a sealed environment.

Some literature suggests that they cannot. A pit-and-fissure sealant study by Handelman, Washburn and Wopperer (1976) claimed a 2,000-fold decrease in the number of viable organisms sealed under pit-and-fissure sealants. Similarly, a study by Mertz-Fairhurst and others (1979) suggests that pit-and-fissure sealants alone slowed the progress of decay in enamel. What needs to be determined is whether the sealing of bacteria from outside nutrients caused this phenomenon or whether the sealant itself has some bacteriostatic effect. If sealing alone could prevent the progression of decay, not by killing all bacteria but reducing the number sufficiently to prevent disease, one could theorize that "small" amounts of residual caries left may be of no significance as long as the restoration is sealed from outside nutrients. Indirect pulp caps are at least partially based upon the theory that when small amounts of residual caries are left, they will not progress under restorations. In fact, Dumsha and Hovland (1985) have described a method of sealing indirect pulp caps with a final restoration without re-entering the tooth to remove residual softened dentin. The rational for this procedure, as in the procedure described in this study, is to prevent unnecessary insult to the pulp. What remains to be determined is how much is a "safe" amount of residual caries that may be left without fear of progression of decay.

Massler (1967) and Fusayama (1980) describe two layers of carious dentin: an inner affected dentin which is relatively less bacteria-laden, and an outer infected layer. Fusayama (1980) advocates that only the outer layer need be removed. However, these two layers of carious dentin are difficult to discern clinically. Fusayama (1980), Iwaku and others (1983), Shimizu and others (1983), Anderson and Charbeneau (1985), and Anderson, Loesche and Charbeneau (1985) have all advocated the use of a dye, either 1% acid red in propylene glycol or 0.5% basic fuchsin in propylene glycol, to indicate infected dentin that must be removed to insure complete carious dentin removal. These studies indicate that the dye is quite accurate in this regard. However, none of the studies mentioned the use of the dye to predict the presence of caries under intact bases prior to removal.

If the dye proved to be as accurate in predicting caries beneath restorations before complete removal, it might be used to prevent injury to the pulp by unnecessary removal of bases when residual caries are not present.

From the results of this study, however, it must be remembered that two pulp exposures were discovered only after the bases were removed. These exposures were not detected prior to removal of the amalgam and one of the exposures revealed a totally necrotic pulp.

The diagnosis of residual caries under restorations remains a difficult problem for dentistry and further research in the area is needed.

Conclusions

Completely accurate prediction of the presence or absence of caries beneath intact bases proved not to be possible. However, prediction errors were lowest when the two operators used both radiographic and digital interpretation despite a rather wide variation (6.7% - 20.8%), due to subjectivity factors, between them.

Acknowledgment

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Effectiveness of Direct Restorative Materials in Repairing Cast Restorations

T J CARLSON • M A COCHRAN • M R LUND

Summary

Based on SEM analysis, this study presents a criteria for choice of restorative material when the decision is to repair rather than replace a cast restoration. If conditions are not favorable to direct filling gold — amalgam is the best alternative choice for sealing ability — amalgam is an acceptable though less permanent alternative. Restorative resins are unacceptable, since there is no bond between resin and metal.

Indiana University School of Dentistry, Department of Operative Dentistry, 1121 West Michigan Street, Indianapolis, IN 46202

T J CARLSON, DDS, MSD, assistant professor

M A COCHRAN, DDS, MSD, professor

M R LUND, DMD, MS, professor and chairman

INTRODUCTION

The cast restoration is generally considered to be a stable and reliable option in restorative dentistry; however, it may become defective if caries develops at a margin or if the occlusal surface is perforated for an endodontic access. When the defect is not extensive, consideration is frequently given to repair rather than replacement of the casting. This is particularly true if the restoration is an abutment for an existing fixed or removable prosthesis.

Three factors having the greatest influence on the success of a casting repair are: access to the area, ability to attain adequate isolation, and the choice of restorative material. Perhaps the most perplexing and controversial of these has been the repair material itself. Research on the interface leakage of direct restorative materials (Martin, 1981; Hormati & Chan, 1980; Taylor & others, 1959) has generally indicated that direct gold restorations offer superior margin adaptation when properly manipulated. While amalgam and composite resins are widely used for casting repair, their sealing ability and compatibility with gold alloys have been questioned.

The purpose of this study was to utilize scanning electron microscopy to present visual evidence of the integrity of margin interfaces between gold castings and the three commonly used direct repair materials: composite resin, high-copper amalgam, and direct filling gold.

MATERIALS AND METHODS

Fifteen caries-free human canines were selected which had been stored in water immediately following their extraction. All teeth selected were visually free from fractures or craze lines, and were cleaned with a white webbed prophy cup and slurry of pumice.

A one-surface inlay preparation was cut on the facial of each tooth. A #56 bur was used in a high-speed handpiece with an air-water spray coolant. Burs were used for five teeth and then replaced. The preparations were cut 1.5 mm deep and 2 mm x 4 mm in outline. All margins were cut in enamel, and a 45° bevel was placed on the mesial, distal, and incisal margins. The preparations were lubricated, direct wax patterns made, and the teeth replaced in water. All patterns were cast with type III gold.

Just prior to cementation of the inlays, the teeth were dried and two coats of cavity varnish were applied to each preparation. The inlays were cemented with zinc phosphate cement and, following a 30-minute delay, were again placed in water for storage.

At a subsequent time, preparations were cut at the cervical margin of each inlay to simulate a clinical margin repair (Fig 1). The instrumentation was similar to that of the initial preparation. Retentive features were added cervically and incisally to each of the preparations, and all margins except those against the inlays were kept in enamel. Five of the preparations were modified with rounded internal line angles; two layers of cavity varnish applied, and these preparations restored with amalgam (Dispersalloy, Johnson & Johnson Dental Products, East Windsor, NJ 08520, USA) (Fig 2). Five of the preparations had sharpened internal line angles and were restored with direct gold (Goldent, Williams Gold, Buffalo, NY 14214). The remaining five were restored with composite resin (Silar, 3-M Co, St Paul, MN 55144, USA), and the enamel margins were etched with 37% phosphoric acid for 60 seconds and washed with water for 20 seconds. The preparations were then air dried and coated with a thin coat of bonding agent prior to restoration.

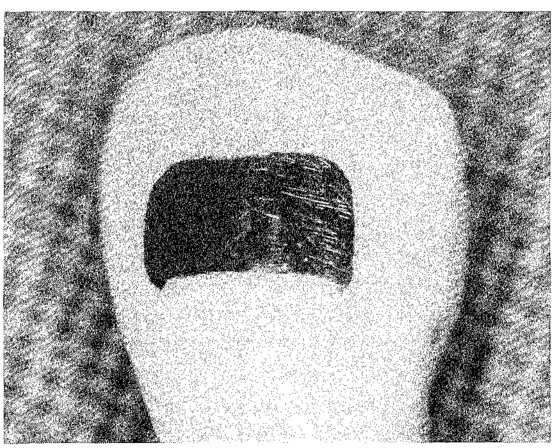

FIG 1. *Typical gold inlay used in this investigation. The cervical margin has been prepared.*

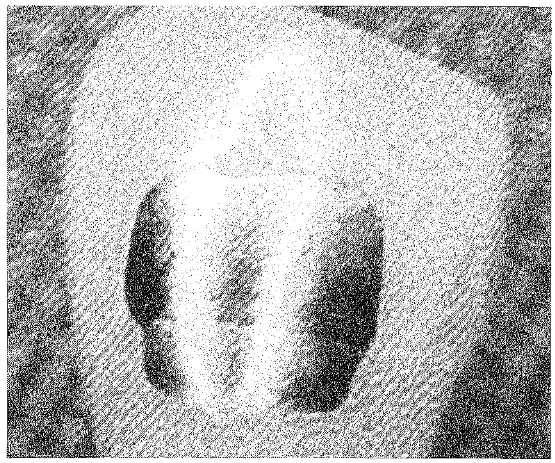

FIG 2. *The same specimen after an amalgam repair has been placed at the cervical margin. The specimen has been polished, but not yet thermocycled.*

All specimens were thermocycled for 3500 cycles at temperatures of 10 and 50 °C. Replicas were made and viewed under a scanning electron microscope at various magnifications to compare their micromorphology and margin adaptation.

RESULTS

Restorations within each category exhibited the same micromorphology and characteristics of adaptation. Figure 3 shows a typical inlay/resin margin; Figure 4, inlay/amalgam; and Figure 5, inlay/direct gold. In all photographs, the cast gold is at the top and the repair material is toward the bottom. The direct gold repairs consistently showed a lack of any visible interface (Fig 5).

FIG 3. *Typical gap formed between the casting (top) and resin.*

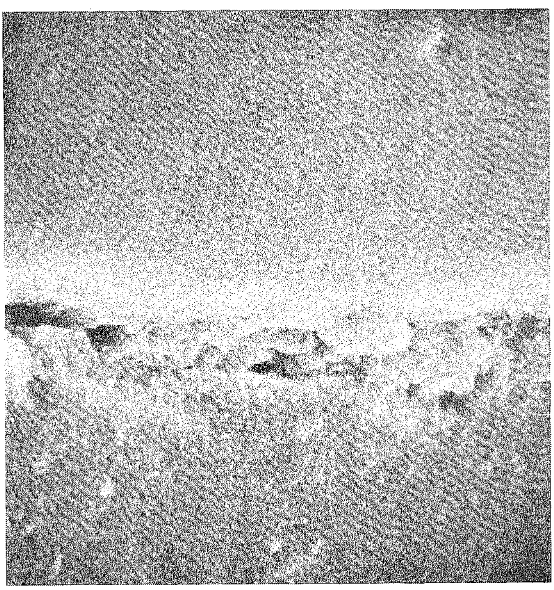

FIG 4. *Casting–amalgam interface. A gap is formed, but is filled with corrosion products.*

DISCUSSION

Resin

All of the margins between cast gold and resin demonstrated lack of bonding and all specimens exhibited a gap between the resin and the gold after thermocycling. As expected, the resin bonded with the etched enamel. This pattern would indicate that resin is not an acceptable repair material for cast restorations, since the lack of bonding and resultant open interface between the resin and gold would lead to microleakage and the likelihood of caries.

Amalgam

The amalgam restorations also showed marginal discrepancies after thermocycling, but

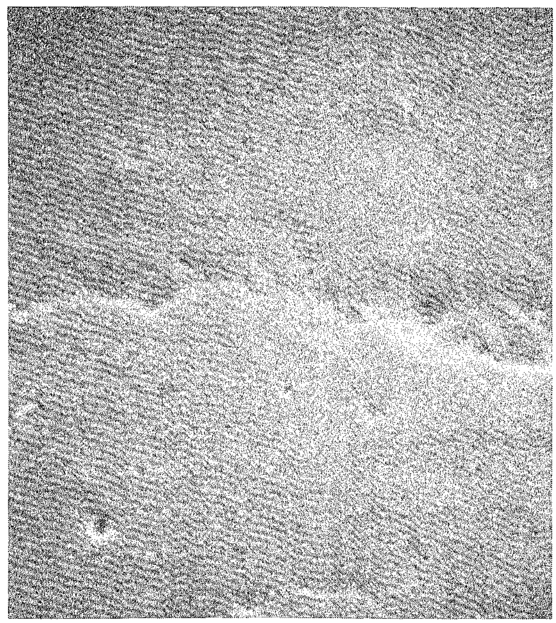

FIG 5. *Casting–direct gold interface. This junction was generally not visible even under high magnification. A rough margin is used to highlight the capability of direct gold.*

FIGS 3-5. *Above: Scanning electron micrographs of typical gap, casting–amalgam interface, and casting–direct gold interface. X800 (original magnifications X1000)* these areas were filled with corrosion products which would certainly reduce or eliminate leakage at the repair interface. However, this initially helpful situation actually presents another problem. The dissimilarity between the two metals results in a galvanic reaction that produces excessive corrosion and breakdown in both materials. Although amalgam would provide a better repair than resin, the longevity of the material would be considerably shortened in the corrosive environment of the dissimilar metal interface (Fig 6).

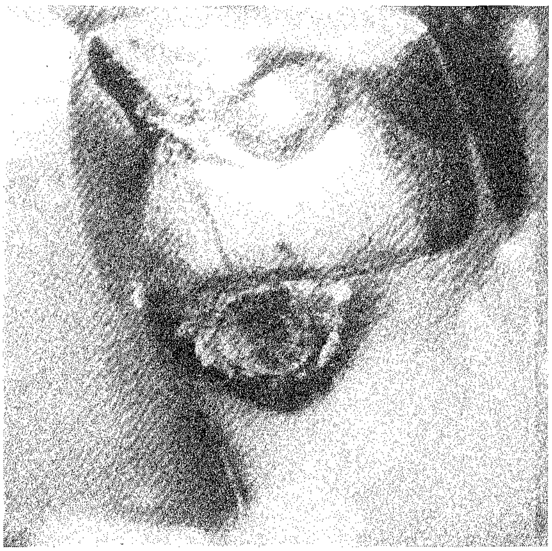

FIG 6. *Although amalgam seals well clinically, this photo illustrates the rapid corrosion from contact with gold.*

Direct Gold

The cast gold/direct gold interface demonstrated the best adaptation of all the repair materials. The compatibility of the materials was obvious under all magnifications, in that the interface was generally undetectable even after thermocycling. Naturally, the use of direct gold requires good isolation, access, and a familiarity with the handling of the material. However, when these conditions are met, direct gold provides the best possible repair material for cast gold restorations.

CONCLUSIONS

Based on SEM analysis of micromorphology and margin adaptation, the recommendations on the selection of a direct repair material for cast gold restorations are:

- Where access and isolation allow, direct gold is the material of choice because of its adaptability and similar composition.

- If conditions exist that are unfavorable to the placement of direct gold, amalgam would be an acceptable alternative since its corrosion products would provide protection against microleakage. However, the patient should be informed that the longevity of such a repair is limited and that the casting will probably require replacement in the future.

- Restorative resins are unacceptable as a repair material for cast restorations since there is no bond between the resin and metal.

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Influence of Dentin Surface Treatments on the Bond Strengths of Dentin-lining Cements

KO HINOURA • B KEITH MOORE
RALPH W PHILLIPS

Summary

Various dentin surface treatments combined with the placement technique used did not improve the bond strengths of glass-ionomer and polycarboxylate cements to dentin. However, improved adhesion was obtained when pressure was applied to cement, as compared to bulk-applied material, particularly when treated with polyacrylic acid.

After seven days storage, followed by thermocycling, bond strengths did not decrease significantly for glass-ionomer and carboxylate cements, but did decrease for Silux/Scotchbond. At 24 hours Silux/Scotchbond had twice the bond strength of Durelon, but the values fell into the same range as the cements after seven days of storage and thermocycling, and none of the surface treatments increased bond strength to dentin at either 24 hours or seven days.

Indiana University School of Dentistry, Department of Dental Materials, 1121 West Michigan Street, Indianapolis, IN 46202

KO HINOURA, DDS, DDSc, visiting professor of dental materials; junior instructor of operative dentistry, Nihon University School of Dentistry, Tokyo, Japan

B KEITH MOORE, PhD, professor

RALPH W PHILLIPS, MS, DSc, associate dean for research and professor of dental materials

Introduction

Resin bonding to enamel with the acid-etch technique is well accepted and forms the basis of many clinical procedures. The potential advantages of also bonding to dentin are well recognized (Phillips, 1976). Adequate bonding to both enamel and dentin would permit a more conservative cavity preparation and would reduce the potential for microleakage which results in bacterial invasion and thus pulpal irritation, secondary caries, and marginal stain of the restoration.

There is some evidence that glass-ionomer and polycarboxylate cements bond to tooth structure by chemical adhesion (Maldonado, Swartz & Phillips, 1978; Coury & others, 1982; Wilson, Prosser & Powis, 1983). Certain pretreatments of the dentin surface have been reported to enhance the bond strengths of some cements (Levine, Beech & Garton, 1977; Bowen, Cobb & Rapson, 1982; Causton & Johnson, 1982; Powis & others, 1982; Beech, Solomon & Bernier, 1985).

One such possibility involves acid etching of dentin. However, this presents a much more complex problem than the acid etching of enamel. Although a strong acid effectively removes surface debris when applied to freshly cut dentin, the tubules are opened (Retief, 1975) and could lead to an undesirable pulpal response (Stanley, Going & Chauncey, 1975; Brännström & Nordenvall, 1977; Gwinnett, 1977). Also acid treatment of the dentin may selectively remove elements responsible for the chemical bonding to the polyacrylate cements.

The purpose of this investigation was to study the effect of several biocompatible dentin cleansing agents on the bond strength of glass-ionomer and carboxylate cements. Since previous research in this field had investigated the effect of certain agents on the bond strengths when the cement was applied under pressure (Powis & others, 1982), in this study a nonpressure technique was used. Since cements were being evaluated for their use as a lining material, the test chosen was one that made use of a bulk of cement rather than a film.

Materials and Methods

The occlusal surfaces of human molars were ground on wet No 240 grit SiC paper mounted on a metallurgical grinder until approximately 1 mm remained coronal to the nearest pulp horn. The roots were removed, and each tooth was then mounted in cold-curing acrylic resin to expose the flattened area. Final finish was accomplished by grinding on wet No 400 grit SiC paper until a 4 mm diameter area of dentin was exposed. The surface was washed and dried with compressed air. The following surface treatments were applied:

(A) No treatment (smear layer intact).

(B) Dentin surface was etched with Durelon Liquid (ESPE-Premier Dental Products Co, Norristown, PA 19401, USA) (40% polyacrylic acid) for 15 seconds and washed with tap water for 20 seconds.

(C) Dentin surface was swabbed with 3% H_2O_2 for 30 seconds and washed with tap water for 20 seconds.

(D) Dentin surface was etched with 50% citric acid for 15 seconds and washed with tap water for 20 seconds.

(E) Dentin surface was cleaned with dry pumice (Whip-Mix Corporation, Louisville, KY 40217, USA), Grade No CL 125, using a rubber cup at low speed.

All specimens were then dried with compressed air.

A Delrin mold, 6 mm high and 4 mm in diameter, was used to form and hold the restorative materials. A 30-degree chamfer was machined at one end of each half of the mold in order to retain the materials during loading (Fig 1). A spring-wire clamp was used to hold the mold to the dentin while each material was inserted.

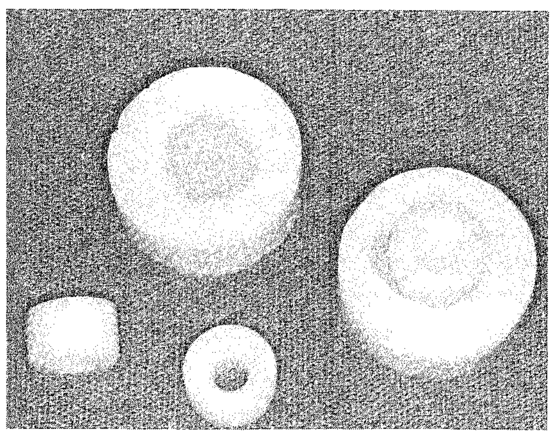


FIG 1. *Molds and mold attached to dentin surface*

Two glass-ionomer cements, a polycarboxylate cement, and a control of a composite resin were evaluated, as shown in Table 1. The GC Lining Cement, Fuji Ionomer Type II, and Durelon were mixed on the paper pad as recommended by the manufacturer. Those cements were condensed into the mold in one increment. As Silux/Scotchbond are light-cured, Scotchbond was placed with a small sponge and cured for 20 seconds using a Kerr Command Light (Kerr/Sybron, Romulus, MI 48174, USA). Silux was condensed into the mold in three increments, each of which was cured for 30 seconds.

Table 1. Materials Evaluated

Material	Manufacturer	Mixing Ratio Powder/Liquid
		g
GC Lining Cement	GC Japan	1.2 / 1.0
Fuji Ionomer Type II	GC Japan	2.3 / 1.0
Durelon	ESPE-Premier	1.0 / 1.0
Silux/ Scotchbond Universal Shade	3M	na

The finished specimens were allowed to set for 1 hour at room temperature, at which times all assembled specimens were transferred to distilled water and stored in 37 °C water for 24 hours or 7 days before testing. The 7-day specimens were subjected to 2500 thermocycles using a 40 °C temperature differential. Two temperature baths, one at 5 °C and the other at 45 °C, were used; the dwell time in each bath was 30 seconds.

At the appropriate time, the molds were screwed into the threaded caps by which they were attached to the testing machine (Fig 2). Tensile bond strengths of 10 specimens for each combination were determined using an Instron Testing Machine (Instron Corporation, Canton, MA 02021, USA) with a crosshead speed of 0.5 mm per minute.

In order to compare the results of this experiment with previously reported data (Powis & others, 1982), measurements were also made by bonding stainless steel lingual buttons, 5 mm in diameter, to dentin. The buttons were prepared before use by immersion in hot 50% nitric acid, followed by a water wash to remove the acid, abrasion with No 400 grit SiC paper, and a rinse with water and then acetone at 37 °C, as described by Powis and others (1982).

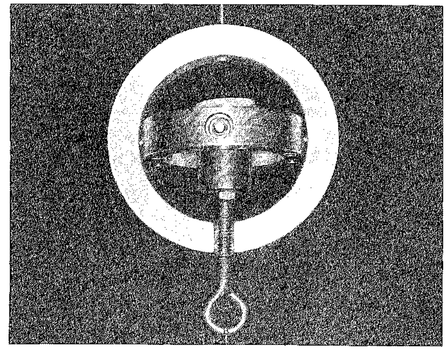
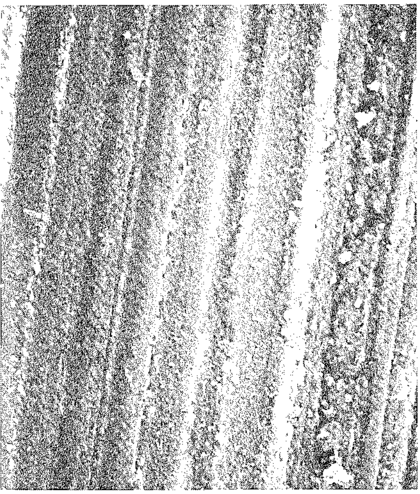


FIG 2. *The apparatus used to measure the tensile bond strength*

Dentin surface treatments A and B, as described previously, were used. Each button was coated with the freshly prepared cement mix and was positioned on the prepared dentin. GC Lining Cement was employed. One minute after placement of the cement a 38.2 g mm^{-2} load was applied vertically on the button for 10 minutes. Excess cement which had exuded around the edge of the button was carefully removed with an explorer. Those specimens were stored in 37 °C distilled water for 24 hours. After 24 hours, the specimens were screwed into the threaded fixtures and tensile bond strengths of 10 specimens for each group were determined using an Instron Testing Machine with a crosshead speed of 0.5 mm per minute.

Scanning electron micrographs were taken of the treated dentin surfaces to determine the topographical effects of the conditioning solution. After treatment, the dentin specimens were fixed in 2.5% gluteraldehyde + Millong's PO_4 Buffer (pH 7.3) and postfixed in 1.5% osmium tetroxide + PO_4 Buffer (pH 7.3). The specimens were then dehydrated in ethanol by means of the critical-point drying method. The dried specimens were sputter-coated with approximately 300A of gold/palladium and observed in a Hitachi S-450 scanning electron microscope (Hitachi, Tokyo) at 20 kV.



G 3a. *No treatment (smear layer intact)*

FIG 3b. *Etched with 40% polyacrylic acid*

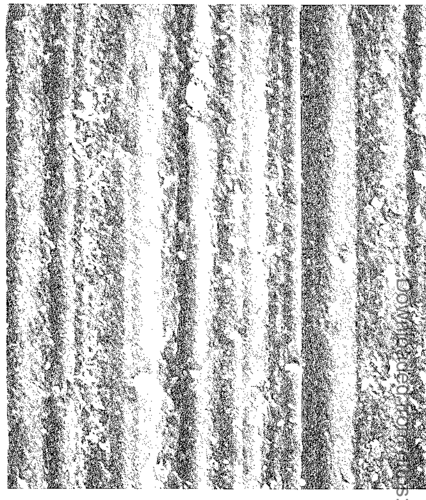


FIG 3c. *Swabbed with 3% (H_2O_2)*

FIGS 3a-3e. *Scanning electron micrographs show dentin surface after treatments. X1260 (original magnifications X2000)*

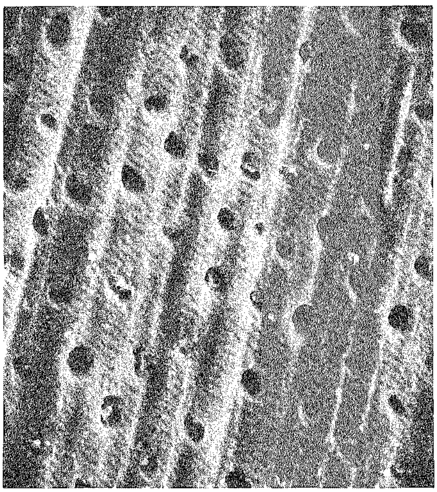


FIG 3d. *Etched with citric acid*

FIG 3e. *Cleaned with dry pumice*

Results

Scanning electron micrographs for the various dentin surface treatments are shown in Figure 3.

The results of the bond strength tests for various surface treatments are presented in Tables 2 through 5 and in Figures 4 and 5 for the 24-hour and 7-day tests, respectively. These results were analyzed with analysis of variance followed by Tukey's tests. Table 6 shows the statistical analysis between 24 hours and 7 days with 2500 thermal cycles.

The dentin bond strengths of GC Lining Cement were not significantly different when the surface treatments were compared to each other within the same time interval, as shown in Table 2. However, when comparing the effects of time on surface treatments, there were significant differences between the 24-hour and 7-day strengths with the polyacrylic acid and H_2O_2 specimens (Table 6).

For Fuji II, there were no differences in bond strengths seen between any of the surface treatments at 24 hours (Table 3). After 7 days, the polyacrylic acid treatment group was signifi-

Tables 2–5. Bond Strengths (kg cm^{-2})

Table 2. GC Lining Cement

After 24 Hours		After 7 Days*	
Citric	20.0	Citric	16.9
PAA	19.0	PAA	12.3
H_2O_2	15.3	None	11.2
Pumice	14.1	Pumice	10.7
None	13.5	H_2O_2	9.7

Table 3. Fuji Ionomer Type II

After 24 Hours		After 7 Days*	
PAA	15.9	PAA	17.4
H_2O_2	15.2	Citric	13.3
None	13.0	Pumice	12.4
Pumice	12.7	None	11.5
Citric	10.7	H_2O_2	11.4

Table 4. Durelon

After 24 Hours		After 7 Days*	
None	22.1	PAA	29.3
H_2O_2	22.0	H_2O_2	23.4
PAA	21.4	Citric	13.9
Pumice	19.3	None	13.6
Citric	17.7	Pumice	9.9

Table 5. Silux/Scotchbond

After 24 Hours		After 7 Days*	
None	45.5	None	30.4
H_2O_2	42.0	Citric	30.3
Citric	39.3	Pumice	17.6
Pumice	28.4	H_2O_2	16.8
PAA	24.1	PAA	6.1

*Followed by thermocycling

Values connected by vertical lines are not significantly different ($P \geq .05$)

cantly stronger than the other surface treatment groups. For any given surface treatment, no difference was noted between 24 hours and 7 days (Table 6). Failures were observed to be 90% cohesive with a very thin film of cement remaining on the dentin.

Table 6. Statistical Analysis between 24 Hours and 7 Days

Material	Surface Treatment				
	None	PAA	H_2O_2	Citric	Pumice
GC Lining		*	*		
Fuji II					
Durelon	*	*			*
Silux	*	*	*		*

*Significant difference ($P \leq .05$)

Table 4 indicates that at 24 hours none of the surface treatments had a significant effect on the bond strength of Durelon. However, the 7-day strengths fell into three groups. The polyacrylic acid group was the strongest, followed by the H_2O_2 group. The remaining treatments were weaker and grouped together. The smear layer and pumice groups had significantly lower strength values after 7 days while the polyacrylic acid group increased in bond strength (Table 6).

Table 5 shows the statistical analysis between various surface treatment with Silux/Scotchbond. The 24-hour bond strength values of Silux/Scotchbond fell into two groups: the smear layer and citric acid treatments were significantly stronger than the polyacrylic acid and pumice treatments, while the H_2O_2 treatment was intermediate in strength. After 7 days the bond strengths of the surface treatments separated into three groups: (1) smear layer and citric acid; (2) citric acid, pumice, and H_2O_2; and (3) polyacrylic acid. In essence, after 1 week there were significantly lower strengths evident with all surface treatments with the exception of citric acid.

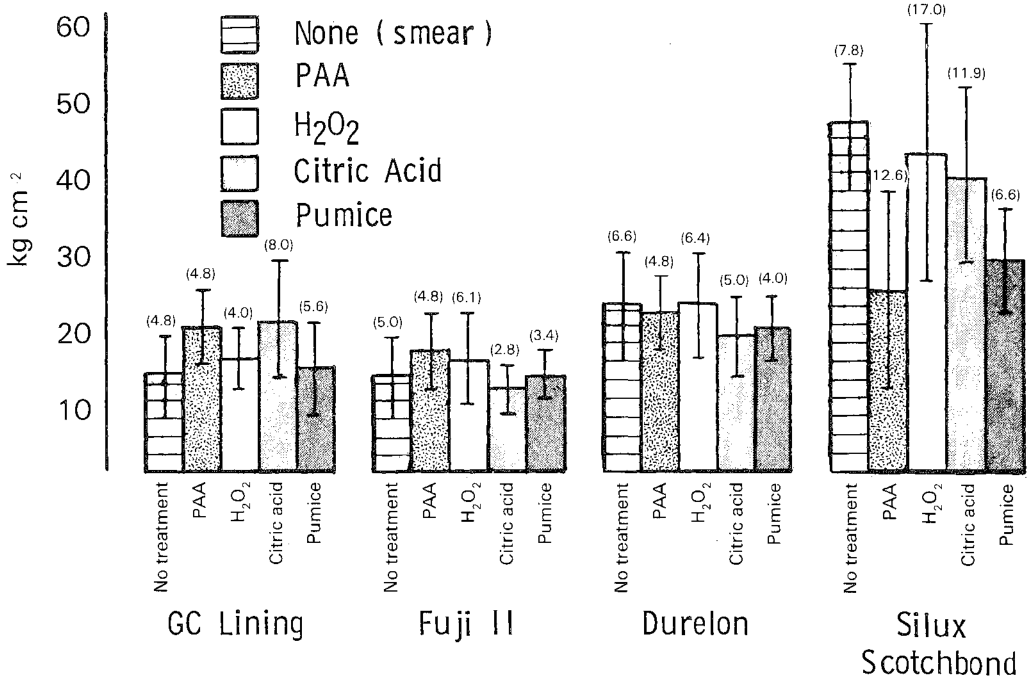


FIG 4. *Bond strengths between restorative materials and dentin with various surface treatments after 24 hours. Brackets indicate size of one standard deviation above the mean; sample size = 10.*

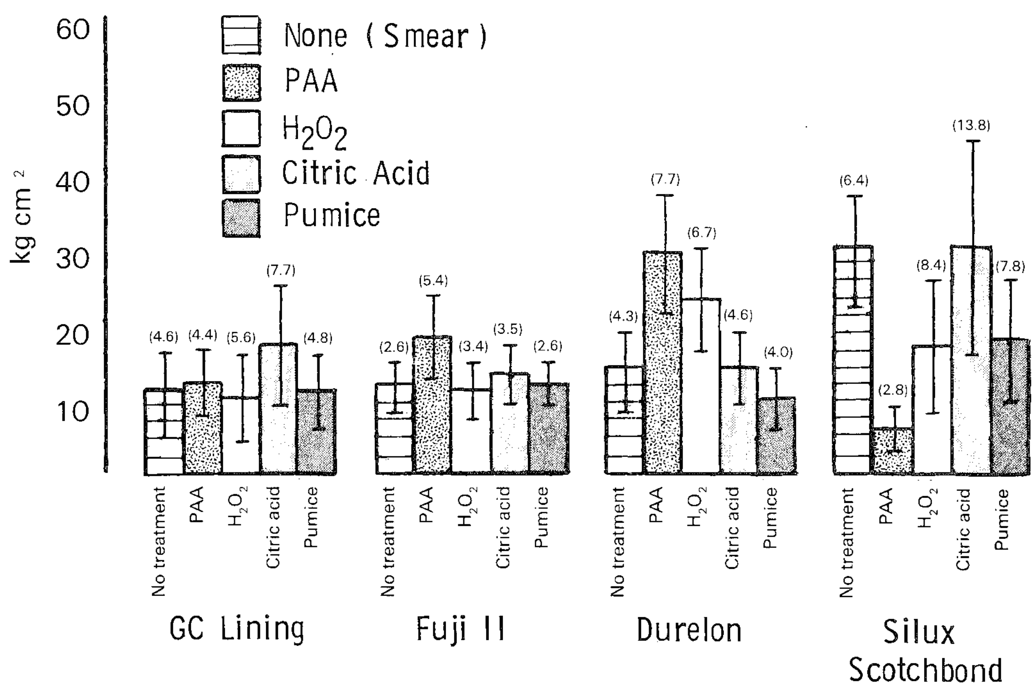


FIG 5. *Bond strengths between restorative materials and with various surface treatments of dentin after 7 days storage and 2500 thermocycles. Brackets indicate size of one standard deviation above the mean; sample size = 10.*

Table 7 shows the 24-hour bond strength of the lingual buttons cemented with GC Lining Cement. These data were analyzed by Student's t-test. When comparing the effects of polyacrylic acid treatments, significant differences ($P \leq .05$) were found between the group where the smear layer was present and the polyacrylic acid treatment groups cemented with the pressure technique. Failures were observed to be 80% cohesive.

Table 7. Dentin Cemented to Lingual Buttons

Treatment of Dentin	Bond Strength	
	kg cm^{-2}	SD
None	9.9	4.42
PAA	20.5	8.41

Discussion

It is interesting to note that none of the surface treatments had a significant effect on the 24-hour bond strength of GC Lining Cement, Fuji II, and Durelon when a nonpressure technique was used. Powis and others (1982) reported that the bond strength of a glass-ionomer cement to dentin treated with 25% polyacrylic acid for 30 seconds was 69.3 kg cm^{-2}, while the bond strength without treatment was 31.9 kg cm^{-2}. The obvious difference between Powis's study and this study can possibly be explained by considering the following points.

First, the cement employed was different. Powis and his coworkers used the ASPA IV (Laboratory of the Government Chemist, London, England). The cements used in this study were GC Lining Cement, Fuji II, and Durelon. Second, the cement thickness employed was different. While Powis's investigation used a film thickness such as that needed to produce a "coating" on a surface, this study employed bulk cement specimens formed in a mold 6 mm high and 4 mm in diameter. Third, Powis's test applied a load of 116.1 g mm^{-2} for 10 minutes to the assembly. It is possible that this load could increase the cement penetration into the rough dentin surface created by the polyacrylic treatment. In this study a nonpressure method was used. The cement was poured into the mold previously attached to the dentin surface.

In the bond tests employing the lingual buttons, the bond strength of GC Lining Cement to dentin treated with polyacrylic acid was 20.5 kg cm^{-2}, while the bond strength without treatment was 9.9 kg cm^{-2}. This indicates that applying pressure to the cement may produce improved adhesion. The cement may infiltrate the porosities and upon setting create retention tags at the interface, as was noted earlier. Powis and others (1982) reported that the bond strength to dentin treated with 25% polyacrylic acid bonded to the lingual buttons was 69.3 kg cm^{-2}, while the data from this study was 20.5 kg cm^{-2}. The obvious difference in the actual values might be explained by the different pressures used and the cements employed.

Powis and others (1982) also reported that citric acid cleansing did not produce improved adhesion compared to no treatment. Their report is in agreement with these data.

It is interesting to note that for Fuji II and Durelon the bond strengths of the groups treated with polyacrylic acid were significantly higher than any of the others after 7 days. Polyacrylic acid helps to remove the smear layer and to reveal the cut dentinal tubules, but does not open the tubules, as described by Duke, Phillips & Blumershine (1985) and as shown in Figure 3.

For Silux/Scotchbond, the polyacrylic acid treated group was significantly weaker than any others after both 24 hours and 7 days. A number of investigators have shown that adhesion of Scotchbond to dentin is greater when the smear layer is left intact (Erickson & Glasspoole, 1985; Retief & others, 1986). That is in agreement with the data presented here.

Although at 24 hours Silux/Scotchbond exhibited twice the bond strength to dentin as the polycarboxylate cement (Durelon), after thermocycling and 7 days storage the Silux/Scotchbond values fell into the same range as the cement. In general, the cements were much less affected by thermocycling and storage for 7 days than was Scotchbond. For light-cured material like Silux/Scotchbond, the curing starts from the surface in closest proximity to the light source and progresses to the rest of the material within the cavity. Therefore, the direction of polymerization shrinkage is toward the surface of the resin irradiated by light and the contraction and tensile stress appear at the bottom (Hansen, 1982). This could be a factor that contributes to lower strengths after thermocycling.

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CASE REPORT

Extensive Spread of Subcutaneous Emphysema Following an Operative Procedure

R S CHEN • T H CHEN

Summary

A case of subcutaneous emphysema of the face and neck following an operative procedure including use of an air-water syringe demonstrates the remarkable spread that is possible once tissue spaces have been penetrated, even from a site not normally considered susceptible to penetration. Potential complications of subcutaneous emphysema are discussed in order of severity. Although treatment is conservative and the prognosis is usually good, dentists should be aware of this uncommon dental complication and make every effort to prevent it.

National Taiwan University, School of Dentistry, Department of Operative Dentistry, Taipei, Taiwan, Republic of China

R S CHEN, DDS, associate professor

T H CHEN, DDS, resident in operative dentistry

Introduction

Subcutaneous emphysema is an uncommon clinical complication of dental treatment caused by the forcing of air into the loose connective tissue. The causes include operative procedures, endodontic treatment, periodontal therapy, and tooth extraction, and one case considered to be self-induced (Bavinger, 1982). Probably fewer than 10 cases related to operative dentistry have been documented (Bavinger, 1982; Schuman & others, 1983; Kaufman & others, 1984). Compressed air at 20-40 lbf in^{-2} used in association with operative procedures may force the air into the soft tissue. When air enters the interstices of the subcutaneous connective tissue, it causes swelling and crepitation. Infection may be a serious complication. Dental instruments that most commonly induce subcutaneous emphysema in these procedures are the high-speed air-turbine handpiece and the air-water syringe.

The extent of spread of the air within the soft tissues is variable. Air may remain near the site of penetration causing swelling and crepitation of the soft tissues. Further spread is possible along fascial planes and into fascial spaces. In extreme cases, air has been reported to pass via the masticator space into the lateral pharyngeal and retropharyngeal spaces and penetrate to the mediastinum (Marlette, 1963; Noble, 1972; Lloyd, 1975). If the air is contaminated with micro-organisms, serious infection may ensue. Auditory and swallowing disturbances have also been reported, as has air embolism (Quisling, Kangur & Jahrsdoerfer, 1977).

Case Report

The patient was a 58-year-old woman who had cervical abrasion of the facial surface of her lower right first premolar. Routine operative procedures, including cavity preparation, acid-etch technique, and resin filling, were performed by an undergraduate dental student. Immediately following the drying of the operating field with a compressed air stream, the patient complained of swelling of her right cheek and neck. The swelling extended from the infraorbital region to the neck. Palpation revealed crepitation and tenderness in both areas, extending down the neck as far as the clavicle. No color changes were observed in the overlying skin. The patient had no difficulty breathing or swallowing. No periodontal pocket was detected by periodontal probing (Fig 1). A periapical radiograph showed neither alveolar bone resorption nor other pathosis of this tooth (Fig 2).

The previous medical history of the patient included "left nodular goiter" and "bilateral chronic otitis externa" which were under medical control. She had also suffered from left temporomandibular joint pain accompanied by a clicking sound and trismus one year previously, and received occlusal splint therapy.

On the basis of the clinical findings, a diagnosis of subcutaneous emphysema was established. For preventing secondary infection and pain, a five-day dosage of oral penicillin and non-narcotic analgesics was prescribed. When the patient was seen 36 hours later, the swelling had subsided (Fig 3), but she still complained of tinnitus and tenderness of the neck (Fig 4). By the sixth day, the swelling had resolved completely as had all other signs and symptoms.

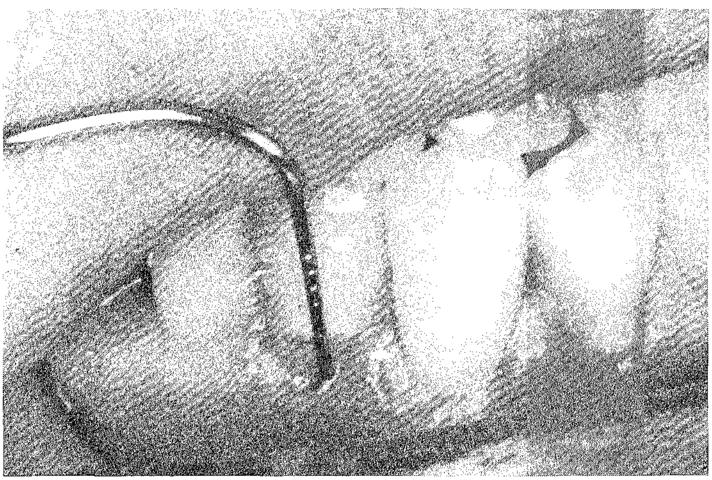

FIG 1. *Site of penetration of air into tissue spaces, via the facial gingival sulcus of the lower right first premolar. No periodontal pocketing was detected after the emphysema had been induced.*

FIG 2. *Periapical radiograph of the affected area. Alveolar crest height was close to the cementoenamel junction, and no evidence of pulpal-periapical pathosis or periodontal disease was apparent.*

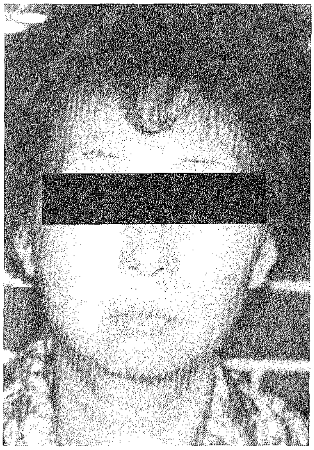

FIG 3. *Facial appearance of the patient after 36 hours. The swelling had largely subsided after this time interval.*

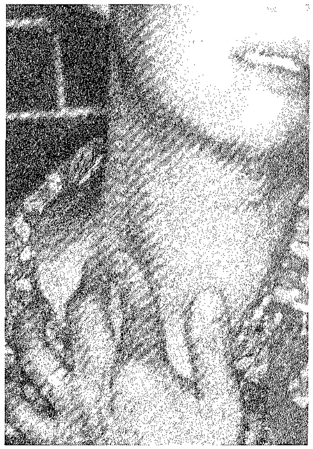

FIG 4. *Palpation of the neck. The emphysema was detectable as far inferiorly as the clavicle, and tenderness persisted in the area for several days, with tinnitus of the right ear.*

Discussion

Subcutaneous emphysema can occur following certain dental procedures. The mechanism of its occurrence can be explained as air being forced either directly through the gingival sulcus or elevated mucoperiosteum into soft tissue, or indirectly through the alveolar bone via root canals or extraction sockets into soft tissue. The air may remain subcutaneously or may migrate extensively, with reports of spread to the top of the head and as far down the thorax as the sixth rib via the fascial planes.

Based on the location of the penetration site in the present case, the extent of spread is quite remarkable. Spread from the facial gingiva of the mandibular premolar area to the infraorbital region and throughout the length of the neck involves extensive distribution through fascial spaces. The air presumably passed inferiorly and posteriorly to enter the buccal space. From there it could spread posteriorly to the lateral pharyngeal space and superiorly to reach the infraorbital area. Within the lateral pharyngeal space the air could also pass down the neck. The reported tinnitus also suggests spread to the retropharyngeal area.

Although considered innocuous in the majority of cases, subcutaneous emphysema has been sometimes reported to develop the following complications:

Swelling and pain: Swelling with crepitation on palpation is the most obvious sign of subcutaneous emphysema (Bavinger, 1982). Pain does not occur frequently, and can be readily controlled by analgesics.

Symptoms of the ear, nose, and throat: Quisling and others (1977) reported a case with otalgia and hearing loss, and interpreted the cause as inflammation and distention of the tissue around the Eustachian tube due to air entering into retropharyngeal and lateral pharyngeal spaces. In the case reported here, the patient complained of tinnitus, which might have occurred by the same mechanism, or perhaps was related to the history of chronic otitis externa. McGrannahan (1965) reported a case showing dysphagia, dysphonia, and a little dyspnea, which might also have been caused by the involvement of retropharyngeal and lateral pharyngeal spaces.

Infection: Feinstone (1971) described emphysema following the use of a water-jet spray device for home care after periodontal surgery, with developing infection. Moose (1974) has warned that septic material might be forced into soft tissues with air, resulting in a septic cellulitis and emphysema during endodontic treatment. Thus, prophylactic antibiotic coverage for five to seven days is recommended by most authors if subcutaneous emphysema occurs.

Mediastinal emphysema: Marlette (1963), McGrannahan (1965), and Noble (1972) reported cases developing mediastinal emphysema after tooth extraction; Lloyd (1975) reported the same complication after endodontic treatment and insertion of a preformed post. Mediastinal emphysema could be a disastrous situation and even lead to death.

Air embolism: Rickles and Joshi (1963) reported a case of surgical emphysema and air embolism after endodontic treatment that presumably caused the death of a patient. They demonstrated by animal studies that air under pressure can enter the circulatory system through vessels around the apexes of teeth and lead to death from air embolism to the right ventricle.

Treatment and Prognosis

The treatment of subcutaneous emphysema is supportive in nature and includes the following modalities:

- Antibiotic coverage to prevent infection and analgesics to relieve pain if necessary.
- Avoiding intraoral pressure such as sneezing, blowing a musical instrument, or expanding the mouth to relieve pain.
- Taking radiographs to rule out the more serious complication of mediastinal emphysema.

Close follow-up is necessary. In most cases, resolution of the swelling usually occurs uneventfully in five to seven days.

Acknowledgment

The authors wish to thank Dr Harold H Messer, chairman, Department of Endodontics, School of Dentistry, University of Minnesota, for his valuable advice and review of this manuscript.

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POINT OF VIEW

Contributions always welcome

AIDS and Hepatitis Prevention: The Role of the Rubber Dam

W R FORREST • R S PEREZ

The rules of asepsis were promulgated many years ago for the prevention of cross contamination. At the same time, the use of the rubber dam was advocated and taught by every dental school to assure the basis for quality restorations.

We have been disappointed during the past 25 years as we observe the vast differences between doctrine and practice regarding both sterile technique and the use of the rubber dam. We are pleased, however, by more recent observations which reveal a much higher standard of asepsis as increased efforts are being made in dental practices to prevent cross contamination and the spread of dreaded communicable diseases.

Howard University College of Dentistry, Department of Endodontics, Washington, DC 20059

WILLIAM R FORREST, DDS, MS, MEd, associate professor, Department of Endodontics

RICHARD S PEREZ, DDS, MS, associate professor, Department of Restorative Dentistry

The use of the dental dam remains a technique advocated and taught in all dental schools, but the benefits are not yet fully appreciated. Most dentists are aware of the value of aseptic technique and the numerous benefits of the rubber dam in allowing for technical excellence, but few recognize the potential for health and safety provided by its routine use.

Less well known is the role of the dam in protecting the dentist and his staff against the ever-growing number of hepatitis and AIDS carriers.

Following the placement of the dam, we recommend the teeth be scrubbed with sodium hypochlorite for its bactericidal effects. Just as the use of drapes is a standard for surgical asepsis, the use of the dental dam will ultimately become an integral part of aseptic restorative technique.

DEPARTMENTS

Book Reviews

DENTAL LABORATORY PROCEDURES
Second Edition

Volume 2: Fixed Partial Dentures

John E Rhoads, Kenneth D Rudd, Robert M Morrow

Published by C V Mosby, St Louis, 1986. 520 pages, indexed. 1425 illustrations. $67.95

This revised second edition of a three-volume set providing a clinical approach to laboratory procedures is dedicated to the late Dr Harold Eissmann, first author of the first edition. Dr John E Rhoads, the new first author, has wisely retained without modification the entire text of Dr Eissmann's contributions to the previous edition. These sections address visual perception and tooth contour, axial tooth contours, marginal adaptation, and pontic design. The principles and concepts gathered from his precisely detailed lectures are restated in the preface: "first, in deference to his [Dr Eissmann's] memory and second because it was felt that no improvement could be made"—a fitting tribute to a great teacher and restorative dentist.

This volume on fixed prosthodontic laboratory procedures is composed of 18 chapters written by numerous contributing authors. Each chapter presents in varying writing styles a technique or philosophy regarding the clinical application and production of dental gypsum casts, diagnostic and working; metallic cast restorations, with a chapter on tooth morphology and a specific philosophy of occlusion; metal ceramic restorations, including the use of precision attachments, restorations in combination with removable prostheses, and methods for repairing restoration service failures.

New chapters have been added to this second edition as part of the authors' stated objectives of reorganization and update. These additions include coverage of these topics: color in dental ceramics presented with color illustration; provisional restoration fabrication; a castable ceramic material, DICOR; and dental equipment pertinent to fixed restorative procedures. However, the section on castable ceramics did not include the Cerestore or Cerapearl restorative materials nor did the chapter on equipment describing articulators include the availability of motion analog instruments produced by Panadent and Denar. This update of procedures might have also included acid etched-resin retained splint restorations and ceramic veneer production techniques.

This book presents the techniques and theory of laboratory procedures in a logical manner with a bibliography at the end of each chapter for further reference. The index is cross referenced with Volume 1 (removable partial dentures) and Volume 3 (complete dentures) by the same three authors. A list of problems with their attendant probable causes and possible solutions presented in many of the chapters provides assistance in troubleshooting for both the expert and novice.

Volume 2 of *Dental Laboratory Procedures* could serve as a useful text for the predoctoral dental student as a description of procedures and concepts that offer predictable clinical results. It could also serve as a reference source for practicing dentists and laboratory technicians seeking basic information in this arena of clinical dentistry.

DAVID G DRENNON, DDS, MS
Department of Restorative Dentistry SM-56
University of Washington
School of Dentistry
Seattle, WA 98195

ESTHETIC COMPOSITE BONDING

Technique and Materials

Ronald Jordan

Published by B C Decker Inc, Philadelphia, 1986. Distributed by C V Mosby, St Louis, Missouri. 352 pages, hundreds of color photographs, indexed. $68.00

Dr Jordan has assembled a comprehensive textbook devoted to the clinical use of composite resin materials. His purpose is to "provide clinical information on composite resin bonding techniques and materials as they relate to a wide variety of applications." To accomplish this end, he has compiled color photographs of clinical situations that demonstrate the possibilities of composite resins and describe in detail those techniques specific for composite resin application and finishing.

He directs his material to the general practitioner and to the undergraduate dental student. The material in this book is primarily organized according to techniques of restoration with chapters on materials, bonding systems, and the risk of eye damage.

The chapter on materials and methods defines the rationale for composite restorations: "The results of a failed composite restoration are easily reversed by conservative means, whereas failure of a full coverage restoration is difficult, if not impossible, to reverse by conservative treatment procedures." Having justified the use of composites, Drs Jordan and John Gwinnett explain the categories of composite resin according to particle size and suggest indications for different composite types. They review the basic chemistry of composites, self-cured versus light-cured resins, and the advantages and disadvantages of each system.

Separate chapters deal with the type of bonding possible with composite resins: resin dentin, resin resin, and resin metal. Clinical situations are used to detail the techniques. The resin enamel chapter covers indications for this bonding type which include labial veneers, composite crowns, mandibular incisal restorations, and other cosmetic procedures such as diastema closure and peg lateral build-up. The resin dentin chapter introduces the concept of "dentin bonding." Jordan discusses resin to dentin bonding, glass-ionomer to dentin bonding, and resin to glass-ionomer bonding. The discussion of the bond between resin and metal is included in the chapter "Bonding and Fixed Prosthodontics." Three types of retention between resin and metal are described: mechanical or perforated metal retention; etched metal retention; and macrosurface (mesh, beads) retention. Jordan briefly mentions resin resin bonding, describing the influencing factors and clinical technique.

The chapters dealing with special topics are mostly written by or in collaboration with clinicians who bring a special background to these subjects. Three chapters describe the difficulties encountered with direct veneers. Jordan and Dr Makoto Suzuki present alternatives to full coverage, with discussions about direct and indirect veneers (composite and porcelain) and bleaching. Drs Mark Friedman and Isaac Comfortes in their chapter, and Norman Feigenbaum and William Mopper in theirs deal with the coloring of direct veneers. They demonstrate the use of opaquers and tints, utilizing "opaque zoning" and "stratification" as methods to improve the natural appearance of the veneered tooth.

Jordan, in collaboration with Dr Leendert Boksman, deals with posterior composites, listing the many pitfalls encountered with these restorations. In a separate chapter, Jordan describes the technique for applying sealants.

Other chapters by contributing authors include "Bonding and Fixed Prosthodontics" by Dr Donald Gratton and "Potential for Damaging Effects of Light on the Eye" by Dr David Jordan. Dr Gratton thoroughly discusses bonding and the fixed bridge, with emphasis on the cast-metal prosthesis; he spends little time describing the all-resin bonded bridge. The case selection and prosthesis design are given much attention. Dr David Jordan, in his chapter dealing with eye damage, describes the potential for damage to the eye and makes recommendations to avoid problems.

This book has a number of pluses. Of most value is the detail in which the procedures are described. This is truly a how-to book, conveying enough information that the practicing dentist can read a section and then apply the new material directly to his practice. Subjects covered particularly well are the direct and indirect veneers, bleaching, cast metal bonded bridges, and sealants. Of interest especially for the dentist who has done a few composite restorations are the clinical recall photographs of successes and failures, both functional and esthetic. The author addresses the problems of "shine through," "halo," and stained margins, "white-line" margins, marginal ledges, discoloration, and excessive wear.

Each chapter concludes with a table of the products mentioned therein, their primary purpose, and the respective manufacturers with addresses — most helpful when comparing composite resins for their particle size and chemical activation characteristics.

The organization of the book presented the only significant problem. The arrangement at times led to redundancy as well as difficulty in retrieving information concerning particular procedures.

Overall, Dr Jordan has assembled an admirable book. Getting a book to print which is still current, about a topic as fast-changing as composite resins, is an accomplishment. The coverage of materials and techniques is comprehensive.

This book is highly recommended for the dentist who wants to improve or extend the use of composite resin in his/her practice. It is also recommended for the student as an excellent introduction to the possible uses of composite resin and as an excellent text of the techniques necessary for composite resin application.

L VIRGINIA POWELL, DMD
University of Washington
School of Dentistry
Department of Restorative Dentistry
Seattle, WA 98195

NOTICE OF MEETINGS

Academy of Operative Dentistry

Annual Meeting: 12 and 13 February 1987
Westin Hotel
Chicago, Illinois

American Academy of Gold Foil Operators

Annual Meeting: 7-9 October 1987
University of Colorado
School of Dentistry
Denver, Colorado

Announcements

NEWS OF THE ACADEMIES

American Academy of Gold Foil Operators

The 36th annual meeting was held 15-17 October 1986 at the University of Puerto Rico and the Condado Plaza hotel, San Juan. The board meeting on Wednesday was followed by a "Welcome Party" at poolside during the evening. On Thursday morning, clinical demonstrations were given, with 16 clinicians presenting a variety of procedures to an enthusiastic group.

During the afternoon, members and guests enjoyed activities of their choice, which included a tour of the Bacardi rum distillery, the rain forest, race track, or golf with Dean Carlos Suárez. The day concluded with a reception and banquet at the Condado Plaza hotel featuring entertainment of the Compagnia Folklorico Gibaro de Puerto Rico. The evening concluded with the presentation of the Distinguished Member Award for 1986 to Jose E Medina of Gainesville, Florida. The next morning, reports and essays were given on the theme "Direct Gold Restorations: Their Present and Future Usefulness."

This year's local arrangements committee and the Academies' hosts for the session deserve special mention, especially Dean Suárez, Dr Luis Marini, and Dr Raphael Aponte.

The officers of the academy for the forthcoming year are: president, Julian J Thomas; president elect, Allan G Osborn; immediate past president, Nelson W Rupp; vice president, Richard V Tucker; secretary-treasurer, Ralph A Boelsche; and councillors, William H Harris, Michael A Cochran, and Alfred C Heston.

Next year's annual meeting will be held in Denver, at the University of Colorado. Make your plans to attend!

Some problems are so difficult they can't be solved in a million years — unless someone thinks about them for five minutes.

—H L Mencken

OPERATIVE DENTISTRY

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OPERATIVE DENTISTRY

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

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I N D E X

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