OPERATIVE DENTISTRY

july-august 1990 • volume 15 • number 4 • 121-160

(ISSN 0361-7734)

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JULY-AUGUST 1990 • VOLUME 15 • NUMBER 4 • 121-160

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, $45.00; other countries, $55.00 (sent air mail); dental students, $25.00 in USA and Canada; other countries, $34.00; single copy in USA and Canada, $13.00; other countries, $16.00. 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.

Contributions
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.

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EDITORIAL

On Predicting the Future of Dentistry

"The Changing Faces of Dentistry," a videotape funded in part by the American Fund for Dental Education, attempts to predict the future of dentistry.

The tape begins by depicting dentistry through old movie clips which portray the dentist as almost sadistic. The pain of toothache and the treatment provided by dentists in the past is panned. "Key" extraction forceps used by a fledgling profession many years ago are shown and made light of as terrible instruments once used.

Is it reasonable to put our profession down just to make a point about where we are going in the future? Why is the American Dental Association supporting a portrayal which makes dentists look foolish and sadistic? It is true that 125 years ago dentistry was rather crude and knowledge was very limited; however, the same is true of almost any other profession. Take a moment to reflect on the quality of care in medicine at that time in history: little or no anesthesia, crude instruments, and little training. One cannot help but wonder if the American Medical Association would show physicians in the Civil War as cruel, sadistic, unknowing and uncaring providers of care. I suspect not. I believe they would make their doctors out to be caring professionals using the best of their skills, without adequate technology, and under adverse conditions, which would make them the heroes of the day. Why does our professional leadership take such pride in putting down anyone who does "dentistry"?

Dentistry is rapidly changing; in fact, most of us find it difficult to keep up with the changes. With the decline in graduates from dental schools and the increasing demand for dental care, many are predicting a shortage of dentists during the 1990s. Let's face it, in spite of the increased workload of today's dentists, there will be a day when all of the patients with existing restorations requiring maintenance as well as those patients still experiencing dental decay will eventually pass on and we will have a new population to contend with. But just because the scope of dentistry may change, is there reason to believe that dentistry will disappear?

Dr Harold Löe of the National Institute of Dental Research states in the videotape that dentists of the future will be known as physicians of the mouth; they must begin to treat the real diseases of the oral cavity such as cancer. If indeed dentistry were to be totally eliminated at some time in the mythical future, why should we find new tasks for dentists? Why not close down the schools? After all, there is an overabundance of MD's in practice today who could take over the medicine aspect of dentistry. Why are our governmental agencies and the American Dental Association trying so hard to eliminate dentistry as it now exists, when it will always be needed, albeit to a much lesser degree? Why encroach on other areas such as general medicine for self-perpetuation?

As predictors of our future, I say these agencies are full of baloney. Dentistry will undoubtedly change and we will see a decline in the need for the quantity of services we see today. In this case, we should look carefully at the timing of these events and eventually scale down the profession so that patients in the mid-21st century will be assured the competent, quality care that only dentistry can provide. There will always be a need for traditional dentistry. Patients will continue to need treatment of their dentition and supporting structures when damaged by trauma or disease. Caries will continue to afflict a segment of the population. Patients will continue to need surgical procedures, both periodontal and oral surgery. Implants will continue to improve and their use will be more widespread. Fractured teeth and teeth requiring esthetic needs will be with us for a long time. Endodontics, like other areas, will diminish but not be eliminated.

To all those false prophets who want us to believe that dentistry is dead and that we need to find another profession within dentistry to survive, I say, Bah, humbug! We do not care to give up!

David J Bales
Editor

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ORIGINAL ARTICLES

Sealing Efficacy of Therapeutic Varnishes Used with Silver Amalgam Restorations

D MCCOMB • A BEN-AMAR • J BROWN

Summary

The sealing abilities of three therapeutic varnishes were compared with that of a conventional copal varnish in vitro under Tytin silver amalgam restorations. The therapeutic varnishes comprised two commercial fluoride varnishes and one experimental chlorhexidine-containing varnish. Leakage was traced using a basic fuchsin dye and was found to be considerable, particularly on root surfaces. The therapeutic varnishes performed as well as, and in some cases better than, the control. It is suggested that the use of preventive therapeutic varnishes in operative dentistry merits attention and further study.

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Introduction

Recurrent decay at the margins of restorations is a common clinical problem and in adults the proportion of secondary caries predominates over primary caries (Klausner, Green & Charbeneau, 1987). Ninety-three percent of this recurrence occurs at gingival margins of silver amalgam restorations (Mjör, 1985). Additionally, the problem of new carious lesions occurring

on the exposed roots of teeth has been identified as a growing problem in older adults (Banting, 1984). Clinicians note that the root-surface lesion is often extremely difficult to restore and that secondary marginal caries is a frequent occurrence (Jordan & Sumney, 1973).

Dental restorative materials can affect the acid solubility of enamel and dentin. Glass-ionomer restorative materials that provide long-term release of significant levels of fluoride play an important role in the treatment of root caries, particularly in aesthetic areas (Billings, Brown & Kaster, 1985). In less accessible locations silver amalgam is often the restorative material of choice due to its greater strength and ease of adaptation, contouring, and polishing (Battock, Rhoades & Lund, 1979). Unlike glass ionomer, however, silver amalgam contains no therapeutic agent for caries prevention and attempts to incorporate fluoride have not been universally successful (Shannon & Miller, 1980). Although release of fluoride has been demonstrated, fluoridated amalgams showed increased susceptibility to corrosion (Hurst & von Fraunhofer, 1978). Others have reported substantial decreases in compressive strength (Fazzi, Vieira & Zucas, 1977). More recent work by Tveit and others (1987) showed good fluoride uptake by cavity walls from fluoridated amalgam and acceptable clinical marginal integrity over a two-year period (Skartveil & others, 1986). The literature is therefore equivocal on the use of fluoridated amalgam.

Utilizing cavity varnishes internal to amalgam restorations to minimize early microleakage (Ben-Amar & others, 1986) and postoperative sensitivity is normal clinical practice. Ultimately, with time in the oral environment, the intermediate varnish is replaced by, or provides a matrix for, corrosion products from the amalgam. This self-sealing mechanism is well-documented and occurs at a slower rate around modern high-copper amalgams (Andrews & Hembree, 1980). It is possible that clinical treatment may be improved by the incorporation of therapeutic agents such as fluoride or chlorhexidine into the varnish.

Secondary caries lesions occur as two separate entities, outer tooth surface lesions and cavity wall lesions (Kidd, 1981). Microleakage of acid into the cavity wall around amalgam restorations is probably a prerequisite for the formation of wall lesions (Hals & Simonsen, 1972). Topical application of fluoride can inhibit the development of outer surface lesions but has little effect on wall lesions. Cavity wall fluoride uptake from topical application of fluoride varnish (Duraphat, now called Duraflor) placed external to silver amalgam restorations was investigated but was inhibited by the presence of the conventional cavity varnish (Tveit, 1980). A two-minute topical application of 2% NaF solution to cavities, besides being time-consuming, resulted in very little fluoride uptake in cavity walls (Tveit & others, 1987). Incorporation of fluoride into a cavity liner was suggested by Söremark, Hedin, and Röjmyr in 1969 and a significant reduction in the acid solubility of the dentin was found; however, liners, unlike varnishes, contain highly soluble constituents such as calcium hydroxide and zinc oxide, which can ultimately increase the long-term leakage if placed on cavity walls. Commercial copal ether varnishes that contain fluoride are available, but they are not in widespread clinical use, and compared to the preventive topical fluoride varnishes, there is a paucity of documented evidence demonstrating their efficacy. A recent review of commercially available fluoride varnishes developed for preventive usage concluded that such varnishes possess excellent cariostatic properties, including fluoride uptake by the dental tissues, demineralization inhibition, and caries prevention (de Bruyn & Arends, 1987).

Another problem exists in operative dentistry, and that is the role played by infection, both residual and acquired, on the continued health of the pulp. Brännström and Nyborg (1971) identified bacterial infection as one of the major causes of pulpal inflammation, and this is well-corroborated by many others (Browne & others, 1983; Patterson & Watts, 1981). Currently the importance of the marginal seal of restorations is stressed in order to prevent acquiring bacteria by microleakage, and antibacterial treatment of prepared cavities is recommended by some (Brännström & Nyborg, 1974) to eliminate possible residual infection.

Chlorhexidine is, next to fluoride, the most intensely researched preventive agent in dentistry (Fardal & Turnbull, 1986). It is an antibacterial agent active against a wide range of gram-positive and gram-negative organisms, facultative anaerobes and aerobes. A 20% chlorhexidine varnish has been developed as a total-mouth treatment with the objective of eliminating

Streptococci mutans (Balanyk & Sandham, 1985). The varnish, composed of chlorhexidine acetate and tincture of benzoin, was found to release low but bactericidal levels of chlorhexidine continuously for up to 12 days in vitro.

The purpose of this paper was to compare the sealing abilities of three therapeutic varnishes with that of copal varnish under silver amalgam restorations. Two commercial fluoride varnishes and one experimental chlorhexidine varnish developed by Balanyk and Sandham (1985) were investigated.

Materials and Methods

Forty freshly extracted, sound, human third molars stored in tap water in a refrigerator were utilized. Two stylized class 5 cavity preparations were made on each tooth, one on the buccal surface and one on the lingual surface. Each cavity preparation measured approximately 3 x 2 x 1.5 mm and was prepared with a #330 non-cross-cut carbide high-speed bur using air-water spray. The gingival and occlusal cavosurface margins were placed equidistant from the cementoenamel junction, each having a 90° margin configuration. No hand instrumentation was used and all cavity preparations were carried out by one operator immediately prior to restoration.

One conventional and three treatment cavity varnishes were studied (Table 1). Duraflor varnish contains 5 wt % sodium fluoride or 2.26 wt % F^- in a neutral colophonium base. Fluorprotector is a polyurethane-based lacquer containing 0.7 wt % fluoride ion, as 5 wt % difluorosilane (de Bruyn & Arends, 1987). Duraflor varnish was originally marketed under the name Duraphat. The chlorhexidine varnish was provided by Dr James Sandham at the University of Toronto and contains 20% (w/v) chlorhexidine acetate and 40% (w/v) Sumatra benzoin in absolute alcohol (Balanyk & Sandham, 1985). A systematic method was used to divide the treatment varnishes into 20 samples each, rotating the pairing per tooth of each treatment and randomly assigning teeth and surfaces. Cavity preparations were washed and dried and two coats of varnish applied with a small sponge pellet in the conventional manner. After the first and second applications the surface was gently air-dried with an air syringe. The fluoride varnish Duraflor was noticeably thicker in application than the other varnishes used. The excess was gently air-thinned out of the cavity onto the tooth surface but no attempt was made to await complete drying of this varnish layer.

Table 1. Varnishes by Group

Group	Varnish	Manufacturer
1	Copalite	H J Bosworth Co, Skokie, IL 60076
2	Duraflor	Pharmascience Inc, Montreal, Canada
3	Fluorprotector	IVOCLAR/Vivadent, Liechtenstein (Vivadent USA, Inc, Tonawanda, NY 14150)
4	Chlorhexidine varnish	Experimental

Restoration was carried out using the spherical uni-composition silver amalgam alloy Tytin (Kerr/Sybron, Romulus, MI 48174). The alloy was manipulated according to the manufacturer's directions and condensed thoroughly with a large-diameter hand condenser. All restorations were performed by one operator. After placement to slight excess, restorations were carved using a sharp metal carving instrument. No attempt was made to burnish the carved restoration, nor was polishing carried out.

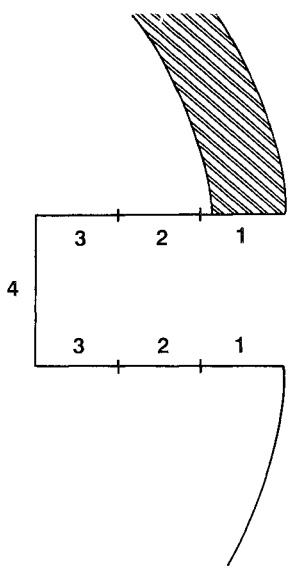
Following restoration the teeth were immersed in water at 37 °C for 24 hours followed by thermal cycling (10 °C - 50 °C) for 1000 cycles. Submergence time was six seconds at each temperature with a six-second delay at room temperature between each hot and cold bath. Teeth were then dried briefly, apices sealed with Duralay acrylic resin (Reliance Dental Mfg Co, Worth, IL 60402) and two coats of nail varnish applied over remaining surfaces to within 1 mm of the restoration margins. After 24 hours' immersion in a 0.1% basic fuchsin solution, the teeth were washed and sectioned inciso-gingivally twice through each restoration using an Accutom (Struers, Copenhagen, Denmark) with a rotating diamond cutting wheel. Restorations were thus divided into three approximately equal sections.

The microleakage evident on the sections was graded independently by two examiners, using

X2.5 magnification and the scoring system described in Table 2 and the figure. Separate scores for occlusal and gingival leakage were recorded. For one restoration it was found that the preparation was not into enamel, and therefore a result for occlusal leakage was not recorded. One tooth, containing two restorations, was lost during sectioning. After comparison of the independent data, minor differences in scoring were analyzed by re-examination of specific sections and consensus reached.

Table 2. Dye Penetration

Category	Dye Penetration
0	None
1	Less than 1/3 of cavity wall
2	Up to 2/3 of cavity wall
3	2/3 or more of cavity wall
4	Along cavity floor



DIAGRAMMATIC REPRESENTATION OF MICROLEAKAGE SCORING SYSTEM

Results

Average occlusal and gingival dye penetration scores for each varnish used are shown in Table 3. The distribution of leakage grades is shown in Table 4. Microleakage values along the occlusal (enamel) wall of the restoration were always less than those along the gingival wall for all treatment groups. Mean leakage for Duraflor varnish was the least in each category. These nonparametric data were submitted to Kruskal-Wallis testing to determine if any of the treatments differed significantly at the 5% level. The Wilcoxon statistical test was then performed, using normal approximation and a continuity correction, to determine which treatments differed, following the procedure recommended by Lehmann (1975). The results indicate that group 2 (Duraflor) provides a significantly better seal than the other

Table 3. Mean Dye Penetration Scores

Group	Material	Occlusal Wall	Gingival Wall
1	Copalite	1.06 (n = 18)	3.95 (n = 19)
2	Duraflor	0.21 (n = 19)	2.20 (n = 19)
3	Fluorprotector	1.85 (n = 20)	2.75 (n = 20)
4	Chlorhexidine varnish	1.45 (n = 20)	3.20 (n = 20)

Table 4. Distribution of Leakage Grades

Material	Occlusal Wall					Gingival Wall				
	0	1	2	3	4	0	1	2	3	4
Copalite	12	0	1	3	2	0	0	0	1	18
Duraflor	17	0	2	0	0	6	1	3	1	8
Fluorprotector	8	1	3	2	6	5	1	1	0	13
Chlorhexidine	5	2	12	1	0	3	0	1	2	14

groups for restorations which are in both enamel and root, when considering overall leakage. There is no significant difference among the other treatments when total leakage is considered. If leakage in root surface only is considered, group 1 (Copalite) performs the worst and there is no significant difference between the other three treatments. If we consider only occlusal leakage, group 2 (Duraflor) is better than groups 3 and 4, but not significantly better than the control (Copalite) and there is no significant difference between groups 1, 3, and 4.

Discussion

This study agrees with the results of others that have shown the high degree of difficulty in fully sealing freshly placed silver amalgam restorations. Use of a conventional cavity varnish and a fluoride-containing liner by Grieve (1973) produced similar leakage reduction levels in wall lesions compared to unlined cavities. They did not completely prevent the occurrence of wall lesions, however, and his work demonstrated the relative ease with which hydrogen ions will defuse around dental restorations. The marginal seal of restorations is of considerable importance in the reduction of recurrent decay. Given that conventional cavity varnishes do not seal amalgam restorations completely, the presence of anticariogenic and/or antibacterial elements in therapeutic varnishes would seem to be beneficial. The literature on preventive fluoride varnishes emphasizes the advantage of prolonged contact between fluoride source and the tooth surface, thus enabling a higher level of fluoride uptake (Yanover, 1982). This would be particularly likely in the restoration wall where the varnish would be undisturbed for long periods of time.

The increased leakage found on root surfaces compared to enamel walls in this study was unexpected. This phenomenon is a common microleakage pattern for composite resin restorations. This is due to the inherent difficulties in bonding composite resin to dentin surfaces combined with polymerization shrinkage. The only suggestion that can be made for such behavior in amalgam restorations is that the junction between enamel and amalgam may be more thermally stable than that between amalgam and root surfaces.

Duraflor varnish provided a significantly better seal overall than other varnishes in this study, considering enamel and root surfaces together. This varnish differed physically from the others used in two respects: the varnish was noticeably thicker and took considerable time to dry. The method used included careful air thinning of the varnish, but complete drying had not occurred prior to amalgam condensation. It is possible that condensation of amalgam into this layer helped seal voids often left along the cavity walls during placement. This probably explains the ranking of Duraflor in this report. Duraflor varnish provides a higher concentration of fluoride ion (de Bruyn & Arends, 1987) and also greater depth of dentinal fluoride uptake. Comparing the two commercial fluoride varnishes used in this study, analysis of dentinal fluoride uptake after a single application (Tveit & others, 1985) showed that the varnishes had deposited large amounts of fluoride, far greater than that from NaF topical application. In addition, the fluoride ion had permeated much more deeply. Increased F- concentration could be detected to a depth of 13 ± 5 μm with NaF solution but the extent of increased fluoride content was 139 ± 73 μm and 67 ± 42 μm for Duraphat- and Fluorprotector-treated surfaces respectively.

While the most important factors in the prevention of secondary caries undoubtedly are total removal of the initial lesion, careful finishing of cavity walls, and meticulous restoration insertion, any procedure likely to minimize the occurrence of recurrent decay merits attention, particularly in the treatment of root decay. In a comprehensive review of the literature de Bruyn and Arends (1987) state that fluoride varnishes are safe and efficient topical agents with excellent caries preventive properties that have even shown promise as dentin-desensitizing agents. They contain fluoride in high concentration, remain in position for long periods, are well-researched, and provide high levels of fluoride, to significant depth, in enamel and dentin.

Varnishes can also provide sustained release of chlorhexidine, which may be of value in cavity disinfection. The sealing ability of the experimental varnish used in this study is similar to that of conventional copal varnish if overall leakage is considered and better than copal on root surfaces. Schaeken, Van der Hoeven and Hendriks (1989) have developed different chlorhexidine varnishes with the viscosity of Duraflor varnish. They found that a single treatment with such a

40%-chlorhexidine varnish was effective in suppressing *Streptococcus mutans* in non-carious occlusal fissures for a period of 22 weeks. It is interesting to note that they suggest high-concentration chlorhexidine varnishes for chemotherapy of caries-prone sites of the dentition and prevention of root-surface caries.

This study and others have shown that no varnish can totally eliminate early silver amalgam microleakage. It is suggested therefore that therapeutic varnishes may be of benefit to improve operative clinical treatment. As early as 1973 Brännström and Nyborg suggested the use of solutions that contained both fluoride and microbicidal agents for cavities prior to restorations. Varnishes can provide improved therapeutics due to their sealing potential and sustained release.

Conclusion

The results of this study in vitro indicate that certain therapeutic varnishes can seal silver amalgam restorations as well as or better than a conventional copal varnish. They therefore merit further study as to their therapeutic use under amalgam restorations.

(Received 29 August 1989)

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A Comparison of Accuracy in Seating and Gap Formation for Three Inlay/Onlay Techniques

A PEUTZFELDT • E ASMUSSEN

Summary

The accuracy (fit) of MOD inlays of three brands of composite resin was determined by measuring the axial discrepancy (marginal opening in the approximal area). The axial discrepancy varied between 17 and 121 μm. Directly manufactured inlays were more accurate (axial discrepancy: 17-26 μm) than indirectly manufactured inlays (axial discrepancy: 40-121 μm). Inlays of a microfilled resin, SR-Isosit, were less accurate than inlays of two hybrid materials, Brilliant and Estilux Posterior C VS (axial discrepancy: 121 μm vs 44 and 41 μm respectively). There was a tendency for 24-hour-old inlays to be less accurate than 10-minute-old inlays. The formation of marginal gaps due to contraction of the resin cement was assessed in a light microscope on cemented single-surfaced inlays. Gaps were not formed when enamel margins were etched or dentin margins treated with a dentin-bonding agent of high efficacy. Gaps (2.4-5.6 μm) were formed, however, at untreated dentin margins and at margins treated with dentin-bonding agents of low efficacy.

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INTRODUCTION

Recently, composite resins have been introduced as inlay/onlay systems. The additional extraoral cure of these inlay/onlays has been reported to provide improved mechanical properties (Lutz, Krejci & Mormann, 1987; Kullmann, 1988) because of a decrease in remaining double bonds.

As the major part of the polymerization

contraction of the composite resins takes place prior to cementation, another observed advantage of inlay/onlays is reduced gap formation (Lutz & others, 1987; Schaller, Götze & Bertram, 1988). Only gaps due to contraction of the relatively thin layer of resin cement are possible, but this contraction has been reported to be negligible (Lutz & others, 1987; Schaller & others, 1988). On the other hand, Feilzer, De Gee and Davidson (1989) found increased wall-to-wall polymerization contraction in thin, bonded resin layers. If gaps were formed at inlay/onlays of composite resins, one of the reasons for producing these more time-consuming, more expensive, and less tooth-sparing restorations as compared to fillings of composite resins, would not be present.

Curing contraction taking place extraorally may, however, constitute a disadvantage, especially for MOD inlay/onlays. A consequence of the contraction is that inlay/onlays will not seat properly in the cavities. This will increase the risk of gap formation after cementation, and make the procedure of obtaining a perfect occlusion time-consuming.

It was the purpose of the present investigation to measure 1) accuracy and 2) gap formation associated with three different composite resin systems. The study involved direct as well as indirect techniques.

MATERIALS AND METHODS

Accuracy

Accuracy was expressed by means of axial discrepancy of inlays. A large axial discrepancy means a poor seating, and thus a low degree of accuracy.

For measuring axial discrepancy, inlays were fabricated on a standard MOD cavity milled in brass and shown in Fig 1 (diameter, 9.0 mm; occlusal depth, 2.5 mm; approximal depth, 5.0 mm; occlusal width, 3.0 mm; total taper, 10°). The procedures for each of the three inlay/onlay systems are described in the following.

BRILLIANT

In a room at 37 °C and after application of Separator (Coltene AG, Altstätten, Switzerland) onto the MOD cavity, composite resin (Brilliant, Coltene), was applied directly and polymerized for four 60-second periods with a Translux CL polymerization unit (Kulzer & Co, Wehrheim, West Germany). The inlay was removed from the brass model, transferred to room temperature and cured for seven minutes in a DI-500 light/heat curing oven (Coltene). At 37 °C the inlay was seated on the brass model and the axial discrepancy measured by aid of a stereo

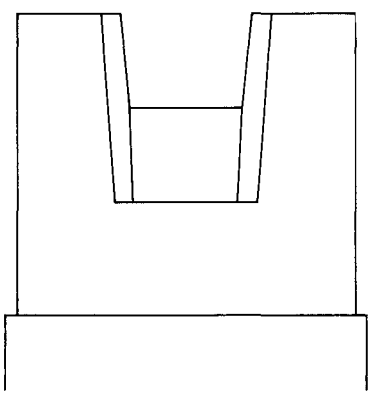

FIG 1A. *Approximal aspect of MOD cavity*

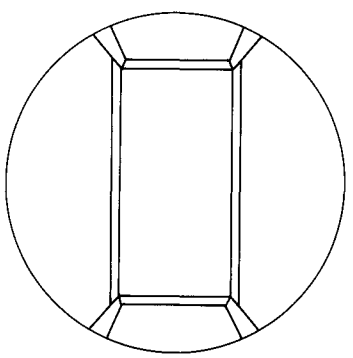

FIG 1B. *Occlusal aspect of MOD cavity*

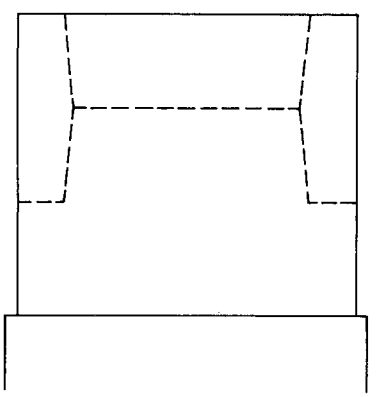

FIG 1C. *Buccal aspect of MOD cavity*

FIG 1. *Line drawing of MOD cavity milled in a brass cylinder with a diameter of 9.0 mm. MOD cavity: occlusal depth = 2.5 mm, approximal depth = 5.0 mm, occlusal width = 3.0 mm, and total taper = 10°.*

microscope. This was done by measuring the marginal opening at three sites along the cervical margin of each approximal box (Fig 2). Of the six measurements the mean value and standard deviation was computed to give an initial value (T_0) of axial discrepancy. The inlay was removed and kept at 23 °C. After 24 hours the inlay was reseated at 37 °C and the axial discrepancy (T_{24}) measured once more.

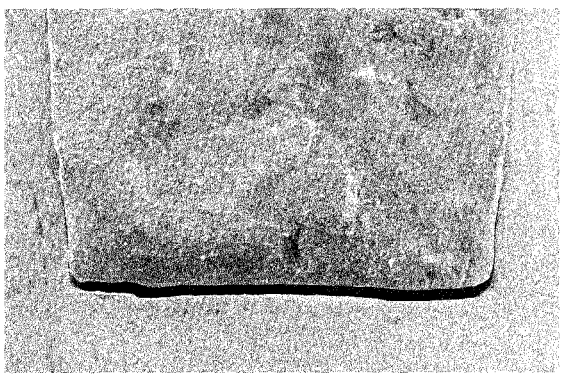

FIG 2. *Approximal aspect of composite resin inlay seated in MOD cavity of brass model. Axial discrepancy (marginal opening) of approximately 100 μm. Original magnification X20.*

In another series, inlays were produced indirectly as follows. Impressions (Deguflex, Degussa AG, Frankfurt, West Germany) were taken of the brass MOD cavity at 37 °C. Immediately after set, the impressions were poured with Type II Stone (Vel-Mix die stone, Kerr/Sybron, Romulus, MI 48174) at 23 °C and after one hour separated from the dies. Still at 23 °C and following another 24 hours, the dies were coated with separating medium and inlays fabricated. The inlays were subsequently evaluated in the same manner as the directly fabricated inlays.

ESTILUX POSTERIOR C VS

For the direct technique, the brass model was covered with a separating medium, ADS-Gel (Kulzer), at 37 °C. The pulpal half of the cavity was filled with XR1 (radiopaque composite resin, Kulzer) which was polymerized for four 20-second periods. Material A 20 was applied in the occlusal half of the cavity and polymerized for two 20-second periods. After removal of the inlay from the brass model, it was transferred to room temperature and cured in a Dentacolor XS unit (Kulzer) for six minutes. The axial discrepancy was determined as described above. As with the Brilliant system, a series of inlays was produced also by indirect technique.

SR-ISOSIT

The composite resin of this system (SR-Isosit, Ivoclar AG, Schaan, Liechtenstein) is cured by heat and pressure, allowing inlays to be made by indirect technique only.

At room temperature, the stone dies manufactured as previously described were treated with Separating Fluid and SR-Isosit-N-Fluid (Ivoclar). SR-Isosit-Dentin (Ivoclar) was applied into the cavity and covered with a thin layer of SR-Isosit-N-Fluid. The inlay was transferred to an Ivomat IP3 polymerization apparatus (Ivoclar) and cured for 10 minutes at six bar (1 bar = 10^6 dyn/cm^2 = 1 atmospheric pressure) and 120 °C. After removal of the inlay from the die, the axial discrepancy was recorded immediately and after 24 hours.

Each of the five series consisted of five inlays.

Gap Formation

Teeth that were kept in 1% chloramine since extraction were embedded in epoxy resin (Epofix, Struers, Copenhagen, Denmark) and left for 24 hours for the resin to polymerize. The teeth were ground on carborundum paper No 1000 until a flat enamel or dentin surface appeared. On each tooth, one suitable surface was used. Standard cavities (depth = 2.15 mm; diameter at top = 3.50 mm; taper = 10°; Fig 3), either totally in

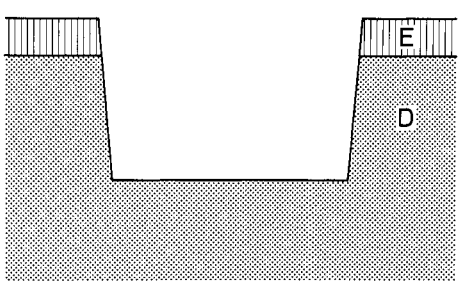

FIG 3. *Standard cavity used for measuring gap formation. Depth = 2.15 mm, diameter at top = 3.50 mm, and total taper = 10°. E = enamel, D = dentin.*

dentin or with enamel margin, were prepared with burs mounted in a Clou 10 B drilling machine (Clou, Copenhagen, Denmark). Inlays were modelled and cemented as follows.

BRILLIANT

At 37 °C and after separation of the cavity, Brilliant composite resin was applied and polymerized for 60 seconds. The inlay was removed from the cavity and additionally cured in the DI-500 curing oven. Back at 37 °C, the cavity walls and inner surfaces of the inlay were smoothed with a 30 μm diamond bur. The enamel of the cavities with enamel margin was etched for 45 seconds, washed with water for 15 seconds and dried with an air blast. Chemically curing low viscous resin (Duo Bond, Coltene) was mixed for 10 seconds, brushed on the etched enamel, and thinned with compressed air. Duo Cement (Coltene) was mixed for 30 seconds and applied to the inner surfaces of the inlay. The inlay was then fixed in the cavity and the cement polymerized for 40 seconds.

Mixing of resin and cement took place at room temperature while application was performed at 37 °C.

In another series, inlays were produced indirectly by use of the above-mentioned impression-taking procedure.

ESTILUX POSTERIOR C VS

Cavities were covered with ADS-Gel. XR1 was applied in the pulpal half of the cavity and polymerized for 20 seconds. The occlusal half was filled with material A 20, which was polymerized for 20 seconds. After removal from the cavity, the inlay was covered with ADS-Gel and cured in the Dentacolor XS unit. At 37 °C, the ADS-Gel was removed from the inlay and the cavity with water spray, and the inner surfaces of the inlay smoothed with a 30 μm diamond bur. The enamel of the cavities with enamel margin was etched for 60 seconds, rinsed with water for 20 seconds, and dried with a jet of air. The cavity walls were covered with a thin layer of Dentin Adhesive (Kulzer). Low viscous resin (Estiseal LC, Kulzer) was brushed on to the cavity walls and inner surfaces of the inlay. A dual-cured resin cement, Microfill Pontic C (Kulzer), was mixed for 20 seconds at room temperature, applied to the inlay, and after cementation of the inlay at 37 °C polymerized for 40 seconds.

As with the Brilliant system, a series of inlays was produced by indirect technique.

SR-ISOSIT

SR-Isosit-Dentin was applied to the pulpal half of the cavity in the stone die, poured, and surface-treated as previously described. The occlusal half was filled with SR-Isosit-Incisal (Ivoclar), which was then covered with a thin layer of SR-Isosit-N-Fluid. Following polymerization, the inner surfaces of the inlay were sandblasted with aluminum oxide (grain size = 110 μm) at 2 bar. The inlay was etched for 30 seconds (Scotchbond Etching Gel, 3M Dental Products, St Paul, MN 55144), washed with water, and dried with a blast of air. At 37 °C, the cavity was rinsed with 4% H_2O_2, washed with water, and dried. The dentin was covered with Dentin Protector (Ivoclar) and dried lightly. Dentin Protector was removed from the enamel surfaces with a 30 μm diamond bur, the enamel was etched for 45 seconds (Scotchbond Etching Gel), washed with water for 15 seconds, and dried with an air jet. At room temperature, Dual Cement (Ivoclar) was mixed for 20 seconds and applied to the inlay. The inlay was then cemented at 37 °C and the cement photocured for 40 seconds.

For each of the three inlay/onlay systems, a series of specimens was prepared (by direct technique with Brilliant and Estilux Posterior C VS) and cemented in dentin cavities. Before cementation, the walls were treated in the following way. A solution of 0.5 M EDTA (pH adjusted to 7.4 by means of NaOH) was rubbed on to the dentin surfaces for 60 seconds with a cotton swab. The surfaces were rinsed with water for 15 seconds and dried with a jet of air. Gluma (an aqueous mixture containing 35% w/w of 2-hydroxy-ethyl methacrylate and 5% w/w glutaraldehyde) was then rubbed on to the dentin, left for 60 seconds, and the cavity dried with compressed air. The dentin surfaces were covered with low viscous resins belonging to the three respective inlay/onlay systems and the inlays cemented. When Gluma was used, application of Dentin Adhesive and Dentin Protector was omitted.

After cementation, the inlays were kept in water at 37 °C. Ten minutes after polymerization, a standardized method of gentle wet grinding and polishing was used for removal of approximately 0.1 mm of the free surface of tooth and inlay

(Hansen, 1982). The width of the maximum marginal contraction gap (M_1) was then measured by use of a light microscope (Leitz, Wetzlar, West Germany; 80 x 0.8 x 8) with a measuring ocular. The specimens were stored in water at 37 °C for one week before thermocycling.

Prior to and following thermocycling of the specimens between two water baths of 15 °C and 55 °C respectively for 900 cycles at 2 rpm, the maximum contraction gaps were determined again and designated M_2 and M_3.

Each of the 14 series consisted of five specimens.

RESULTS

The results are presented in Tables 1 and 2. The statistical treatment involved analyses of variance and Student *t*-tests (Hald, 1952).

Accuracy

The axial discrepancy varied between 17 μm and 121 μm (Table 1). Initially and after 24 hours no difference in axial discrepancy was found between Brilliant and Estilux inlays manufactured by direct technique ($P > 0.05$) nor between the indirectly produced inlays of these two brands ($P > 0.05$). For both brands, directly manufactured inlays initially showed less discrepancy than did inlays produced by indirect technique ($P < 0.025$).

Table 1. Axial Discrepancy (μm) of Composite Resin Inlays Measured Immediately after Manufacturing of the Inlays (T_0) and 24 Hours after Manufacturing (T_{24}) (Mean values and standard deviations)

Material	Technique	Axial Discrepancy (T_0) μm	Axial Discrepancy (T_{24}) μm
Brilliant	direct	17 ± 4	26 ± 5
Brilliant	indirect	40 ± 19	44 ± 26
Estilux	direct	18 ± 8	21 ± 2
Estilux	indirect	41 ± 10	41 ± 10
Isosit-D	indirect	109 ± 23	121 ± 22

After 24 hours, however, due to the large standard deviation, no difference was found in axial discrepancy between directly and indirectly manufactured Brilliant inlays ($P > 0.05$). T_0 and T_{24} for Isosit inlays were larger than T_0 and T_{24} for the other brands ($P < 0.001$). Only with regard to Brilliant inlays produced by direct technique and Isosit inlays was T_0 different from T_{24} ($P < 0.01$).

Gap Formation

Gaps only formed in dentin cavities and when Gluma had not been used (Table 2). The width of

Table 2. Contraction Gap (μm) of Composite Resin Inlays Measured 10 Minutes after Cementation (M_1), after One Week in Water at 37 °C (M_2), and after Thermocycling of the One-week-old Inlays (M_3) (Mean values and standard deviations)

Brand	Technique	Treatment of Dentin	Cavity	Maximal Contraction Gap (μm) M_1	M_2	M_3
Brilliant	indirect		E + D	0	0	0
Brilliant	direct		E + D	0	0	0
Brilliant	direct		D	3.0 ± 0.7	3.0 ± 0.7	2.4 ± 0.6
Brilliant	direct	Gluma	D	0	0	0
Estilux	indirect		E + D	0	0	0
Estilux	direct		E + D	0	0	0
Estilux	direct	Dentin Adhesive	D	5.2 ± 4.6	5.4 ± 5.0	5.6 ± 4.6
Estilux	direct	Gluma	D	0	0	0
Isosit-D+I	indirect		E + D	0	0	0
Isosit-D+I	indirect	Dentin Protector	D	3.0 ± 0.7	3.2 ± 0.8	2.8 ± 0.8
Isosit-D+I	indirect	Gluma	D	0	0	0

the maximum marginal contraction gaps varied between 2.4 μm and 5.6 μm. The size of the contraction gaps did not differ from brand to brand at any of the three measuring times (M_1, M_2, M_3) ($P > 0.05$), and neither storing for one week nor thermocycling changed the width of the contraction gap for any of the three brands ($P > 0.05$).

DISCUSSION

Generally, inlays produced indirectly were less accurate than directly produced inlays. This may be explained by the more complex process of manufacturing involved for indirectly produced inlays, i e, the inaccuracies connected with the making and casting of impressions.

In two series, 24-hour-old inlays were significantly less accurate than 10-minute-old inlays. As to the remaining series, a tendency in the same direction was found, reflecting the fact that curing contraction of the composite resins proceeded beyond 10 minutes after start of polymerization.

Inlays produced of Isosit, a microfilled composite resin, were much less accurate than inlays of the two hybrid materials. This difference in accuracy was, most likely, the result of differences in coefficients in thermal expansion, microfilled composite resins having higher coefficients of thermal expansion than do macro- and minifilled materials (Raptis, Fan & Powers, 1979).

As an increase in axial discrepancy can be expected as a result of the presence of a cement, it seems advisable to reduce the inside of a MOD inlay prior to cementation to provide room for the cement and thereby avoid extensive occlusal adjustments.

The presence of an etched enamel margin proved effective in preventing marginal gap formation. The bond to the composite resin cement was strong enough to resist the stress created by the thermocycling procedure.

In cavities without an enamel margin, the use of the manufacturers' own dentin-bonding agents did not reduce gap formation compared to the inlay system not comprising a dentin-bonding agent. As the width of the marginal gaps did not increase following thermocycling, the expansions of the inlays supposedly equalized the contractions.

With Dentin Adhesive and Dentin Protector, Asmussen, de Araujo and Peutzfeldt (1989) measured bond strengths between dentin and composite resin of 0.5 MPa and 6.7 MPa after one day in water at 37 °C, and 0.0 MPa and 3.4 MPa after one year.

In the same study, the best results were obtained with Gluma, which gave rise to mean bond strengths of 9.8 MPa after one day and 10.7 MPa after one year. Thus, the stronger bond created between cement and dentin accounts for the absence of marginal gaps around inlays cemented in Gluma-treated dentin cavities. Moreover, the stress resulting from the thermocycling was not of sufficient magnitude to disrupt the bond and bring about gaps.

The layer of resin cement was generally less than 150 μm wide. Some inlays, however, had a cement layer of a maximum width of 400 μm. Even in these cases, gap formation was avoided by acid-etching of enamel or Gluma treatment of dentin.

The increased wall-to-wall polymerization contraction in thin resin layers reported by Feilzer & others (1989) did not turn out to be a problem in the present investigation, as gap formation could be totally avoided if enamel was acid-etched and dentin treated with Gluma. Thus, the use of a potent dentin-bonding agent is recommended at least when the cavity margin is situated in dentin.

The present authors (Peutzfeldt & Asmussen, 1990) found mechanical properties of composite resin inlay materials not to be outstanding as compared to conventional composite resins. Considering the incomplete marginal adaptation of composite fillings found in studies in vitro (Asmussen, 1977; Asmussen & Jorgensen, 1972) as well as in studies in vivo (Qvist, 1985), the principal advantage of composite resin inlays as compared to fillings would seem to be the possibility of establishing a perfect marginal adaptation.

(Received 8 December 1989)

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Microleakage of a New Cavity Varnish with a High-copper Spherical Amalgam Alloy

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A R SCARBROUGH • J H HEMBREE

Summary

In a study in vitro Copalite and Barrier cavity varnishes were applied to the walls of class 1 prepared cavities before placing Tytin, a high-copper amalgam. Tests with ^{45}Ca and autoradiographs showed that at six months only Copalite was effective in preventing microleakage. At one year neither Barrier nor Copalite was preventing leakage.

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Introduction

Cavity varnishes have been used for many years to prevent or minimize initial microleakage around amalgam restorations. Conventional amalgam has a tin mercury (gamma 2) phase which causes corrosion of these restorations. The corrosion products between the restoration and cavity preparation occur with time and reduced microleakage around the amalgam (Phillips, 1973). The most common corrosion products found with conventional (low-copper) amalgam alloys are oxides and chlorides of tin. These are found both at the tooth-alloy interface and penetrating the bulk of old alloy restorations. In the case of high-copper amalgams, corrosion products of copper are also seen, but the corrosion process is usually limited to the surfaces of the amalgam (Phillips, 1982). Several studies have shown that microleakage at the margins of conventional amalgam restorations diminished as the restoration aged (Going, Massler & Duke, 1960; Pickard & Gaylord, 1965). Another study showed that the contraction of dental amalgam on setting promoted microleakage, which could lead to tooth sensitivity, in the absence of an effective varnish (Yates, Murray &

Hembree, 1980). With conventional amalgam, varnishes are used to prevent early microleakage; however, as time passes, the varnish gradually breaks down in the oral fluids and is replaced by the degradation products derived from the gamma 2 phase of the amalgam alloy.

The introduction of high-copper-containing amalgams such as Tytin (S S White, Philadelphia, PA 19102) and Dispersalloy (Johnson & Johnson Dental Products Co, East Windsor, NJ 08520) overcame the problem of corrosion. This added copper has a greater affinity for tin than mercury does. The gamma 2 phase is partially or completely suppressed and a copper-tin phase develops instead of the normal tin-mercury phase. Amalgams made with increased concentrations of copper have a greater resistance to corrosion than conventional amalgams (Duperon, Neville & Kasloff, 1971; Gettleman & others, 1978). Amalgams of these high-copper alloys have higher compressive strength and lower static creep than conventional alloys (Eames & MacNamara, 1976); however, without the corrosion properties there may not be the sealing ability that occurs with conventional alloys with time. The accumulation of corrosion products is somewhat slower with the high-copper alloys, so the use of cavity varnish is even more essential with these newer systems (Phillips, 1982). Under simulated or accelerated electrolytical conditions, corrosion of high-copper amalgams by gamma 2 phase corrosion will not occur. Although possessing better corrosion resistance than the gamma 2 phase, the Cu_6Sn_5 (nu phase) will be the least resistant phase in the microstructure. If the copper from the nu phase becomes exhausted by corrosion, copper corrosion from the silver-copper and gamma particles may also follow. Freed by copper corrosion, tin also becomes corroded. Unlike low-copper amalgam, the interior of the high-copper amalgam is not likely to become affected by corrosion, because of the noninterconnection of any of the phases (*Metals Handbook*, 1987). The formation of the nu phase in high-copper amalgam systems are time-dependent and are dependent on the amalgam system. For fast-reacting amalgams, formation of the nu phase may be complete within hours, while for slower-reacting systems, nu may continue to form for months (Marshall & Marshall, 1987).

In a study in vitro using Tytin and different cavity varnishes, Sneed and Hembree (1984) determined that leakage had stopped up to six months, after which leakage increased dramatically up to one year. They theorized that the space left between the amalgam and tooth structure where the varnish dissolved in the oral fluids was too large for the Tytin to seal itself. Other previous studies have indicated that marginal leakage of amalgams of conventional alloys and alloys with a high content of copper are essentially the same (Andrews & Hembree, 1975; Andrews & Hembree, 1978). In one of the studies (Andrews & Hembree, 1975) the earlier cessation of leakage may have occurred because the teeth were not thermocycled. In the other study (Andrews & Hembree, 1978), an animal study, the presence of proteinaceous material could possibly explain an earlier decrease in leakage. In a study in vitro (Andrews & Hembree, 1980) leakage around high-copper amalgam alloys did not subside as soon as that around amalgams of traditional alloy. Andrews and Hembree theorized that this was a result of high-copper-containing alloys corroding less.

The purpose of this study was to evaluate the effectiveness of two cavity varnishes, Copalite (H T Bosworth, Skokie, IL 60076) and Barrier (Teledyne Getz, Elk Grove Village, IL 60007), in reducing the early microleakage in vitro of a high-copper spherical-cut amalgam alloy.

Materials and Methods

Fifty-four class 1 occlusal cavities were prepared in sound, extracted human molars that had been stored in tap water. The teeth were then divided into three groups of 18 teeth. Two groups were treated with the two different cavity varnishes, Copalite and Barrier, and one group received amalgam without varnish to serve as a control. Two layers of each of the varnishes were applied to their respective groups of prepared cavities. All internal walls, including the cavosurface angle of the preparations, were well-covered.

After the varnishes had been applied, each tooth was restored with the silver amalgam alloy, Tytin, and the specimens were stored in tap water at 37 °C before testing. The size of the sample was 18 specimens for each cavity varnish and 18 specimens for a control group. Each group of 18 specimens was divided into three subgroups of six specimens. One subgroup of six specimens was then tested for leakage at

intervals of either one week, six months, or one year. Before testing, each specimen was cycled thermally by dipping alternately in water at 4 °C and 58 °C, one minute each for 100 cycles.

Marginal leakage was determined by the presence of a radioactive isotope, ^{45}Ca, between tooth and restoration as shown on an autoradiograph. Each specimen was soaked for two hours in a solution of $(^{45}Ca)Cl_2$ (concentration .1 mCi • $m1^{-1}$, Ph7). After removal from the isotope, the teeth were brushed with a detergent, mounted in a block of autopolymerizing resin and then sectioned longitudinally through the restorations by grinding wet on a wheel of aluminum oxide. The sectioned teeth were again brushed with a detergent, and the sectioned surface of the tooth was placed on an ultraspeed, bitewing x-ray film for 17 hours to produce an autoradiograph. The films were processed in an automatic developer. Leakage was evaluated on the following scale:

(None)	0--No evidence of the isotope between tooth and restorative material
(Slight)	1--Evidence of penetration of isotope between tooth and restorative material at the cavosurface angle
(Moderate)	2--Evidence of isotope along the lateral walls but no penetration to the pulpal floor
(Gross)	3--Evidence of penetration of isotope to the pulpal floor

Results

The results are shown in the table. The specimens with no varnish (amalgam only) demonstrated gross leakage after one week, six months, and 12 months with every sample. At one week Copalite and Barrier sealed effectively with no microleakage except for one Barrier sample exhibiting minimal microleakage. At six months the Barrier samples exhibited gross microleakage, whereas the Copalite samples exhibited only minimal microleakage. The 12-month samples of all groups exhibited gross leakage. The Barrier group had four of the six specimens showing gross microleakage with a score of 3. Copalite performed slightly better at 12 months with only two specimens exhibiting gross leakage with a score of 3; however, three Copalite specimens showed moderate microleakage at the 12-month interval. Typical six- and 12-month autoradiographs are shown in Figures 1 and 2.

Degree of Penetration of Isotope

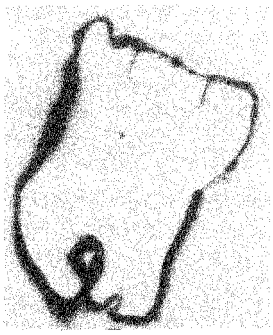
	0	1	2	3
Tytin only (no varnish) control				
1 week			3	3
6 months				6
12 months				6
Tytin and Copalite				
1 week	6			
6 months		5		1
12 months		1	3	2
Tytin and Barrier				
1 week	5	1		
6 months			1	5
12 months			2	4

Discussion

It is very difficult to compare the results of microleakage studies of dental materials when different techniques and procedures are used. The extent of the microleakage between the restoration and tooth interface is dependent on many factors. Some of these include: the material used, location of the restoration, technique for placement, method of thermocycling, and agent used in determining the microleakage. Going and others (1960) determined the reliability of two methods for microleakage using dyes and radioisotopes. They concluded that the radioisotope technique was more sensitive than the dye penetration method. Although the radioactive tracer technique was used in the present study, a limitation of this technique is the variability in the location of where the tooth is sectioned to determine the extent of the radioactive isotope penetration.

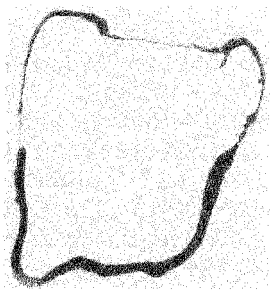
The results of this present study are in agreement with the study by Sneed, Hembree and Welsh (1984) concerning the excellent six-month sealing abililty of Copalite and Tytin. Also our results are similar to theirs in that Copalite and Tytin were exhibiting moderate microleakage at the one-year time interval. The Barrier varnish did not perform as well as Copalite, especially at the six-month interval.

Our results are also in agreement with other



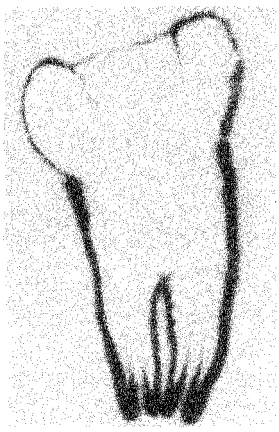
A. Tytin only (no varnish)

B. Tytin with Barrier

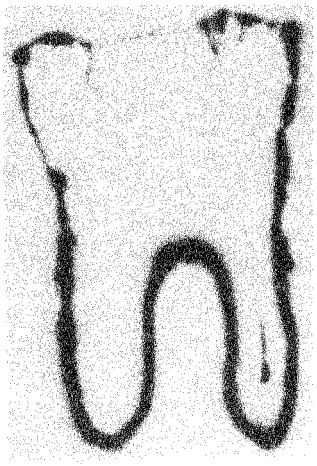


C. Tytin with Copalite

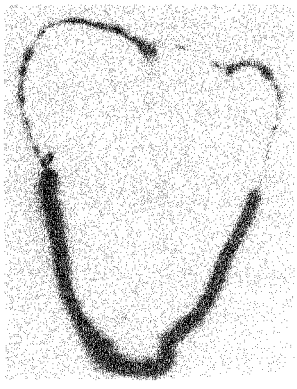
FIG 1. *Typical six-month autoradiographs*



A. Tytin only (no varnish)



B. Tytin with Barrier



C. Tytin with Copalite

FIG 2. *Typical 12-month autoradiographs*

studies concerning the gross leakage that occurs when high-copper amalgams are used without cavity varnish (Andrews & Hembree, 1980; Sneed & others, 1984; Andrews & Hembree, 1975).

Our study was done in vitro, therefore the effects of the oral environment such as the saliva, bacteria, and sugar interactions are absent and cannot be accounted for in the results. In a study comparing the microleakage of conventional amalgam in vivo and in vitro, the amalgam samples showed poor sealing qualities at 24 hours, but improvement followed. The only difference between the results in vitro and in vivo was that the microleakage of the restorations in vivo seemed to improve more rapidly than did the microleakage in the restorations in vitro (McCurdy & others, 1974).

Conclusions

Cavity varnish is extremely important when using a high-copper alloy such as Tytin to prevent early microleakage. When no varnish is used leakage can be expected to be immediate and long-standing. Copalite performed better than Barrier in this study at the six-month and 12-month intervals. After six months it appears that the space left after the dissolution of the varnish is too large for the high-copper amalgam Tytin to seal itself. More studies are necessary to determine the clinical significance of the gap that occurs when the cavity varnish washes out, and more studies in vivo are needed to determine the microleakage that occurs with the high-copper amalgams.

(Received 13 November 1989)

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An Evaluation of Marginal Leakage of Class 2 Combined Amalgam-Composite Restorations

E EIDELMAN • G HOLAN
S TANZER-SARNEH • A CHOSACK

Summary

Forty class 2 cavities were prepared in 20 permanent posterior teeth. In 20 cavities the gingival margin was placed in enamel and in the other 20 cavities in cementum. In every tooth one of the cavities was filled with composite and the other with a combined amalgam-composite restoration. Microleakage at the various interfaces was assessed by dye penetration. It was concluded that microleakage of the combined amalgam-composite restorations was significantly lower than that of the conventional composite restorations.

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INTRODUCTION

Defective gingival margins of class 2 composite restorations may cause microleakage into the gap created between the tooth and the restoration during the restorative procedure (Roulet, 1987; Trowbridge, 1987). Several methods to reduce leakage at the cervical margins of composite restorations have been suggested: bonding the composite material to a wide area of acid-etched enamel (Arends & others, 1985), filling the cavity by buccolingual increments (Asmussen & Munksgaard, 1985; Eakle & Ito, 1987), sealing the contraction gaps by reapplication of unfilled resin (impregnation) on the gaps after the filling has cured (Torstenson, Brännström & Mattsson, 1985; García-Godoy & Malone, 1985), the use of

dentin bonding agents (Dávila, Gwinnett & Robles, 1988), and the use of a "sandwich" technique employing a glass-ionomer material (Shortall & Asmussen, 1988). The problem of microleakage has not been totally eliminated, however. Cardash (1988) presented a method for class 2 restorations using a layer of amalgam at the cervical part of the box covered by composite material. He reported that microleakage was lower at the amalgam-cementum and amalgam-composite interface than at the composite-cementum interface. Another author (Kossa, 1987) evaluated class 5 combined amalgam-composite restorations and found that leakage at the amalgam-composite interface compared favorably with leakage at the amalgam-tooth and composite-tooth interface.

The aims of this study in vitro are: a) to evaluate (by direct observation and radiographs) the cervical margins of class 2 composite restorations, when the cervical part of the box is filled by amalgam followed by a composite material or when only a composite material is used, b) to assess the microleakage of the filling-tooth structure interface and at the amalgam-composite interface, and c) to evaluate by means of SEM the quality of the various interfaces.

MATERIALS AND METHODS

Cavity preparations

Twenty extracted permanent premolars kept in saline were used in this study. In each tooth, two separate conventional class 2 cavities (mesial and distal) were prepared, using a #331 carbide bur under coolant spray. In 10 teeth, randomly chosen, the gingival margins of the approximal box were placed in the enamel. In the other 10 teeth, the gingival margins were placed 1-2 mm gingivally to the cemento-enamel junction. A buccolingual retentive groove was prepared in the gingivo-axial line angle in one of two cavities in each tooth. The other cavity in each tooth remained conventional.

Restorative procedure

The following steps were undertaken in order to restore the cavities with the retentive grooves:

a) Copal varnish was placed on the gingival floor of the box. Excess varnish was removed with a small slow-speed bur.

b) A transparent celluloid matrix was used with a Tofflemire matrix holder, and held in a special device to imitate the function of a wedge (Fig 1).

c) A 3 mm-thick layer of Non-Gama-II amalgam (Silmet, Gyvatayim, Israel) was condensed into the box with a small amalgam condenser.

d) The enamel at the cavity walls, 1 mm of the enamel surrounding the cavity and also the surface of the amalgam were etched with 37% phosphoric acid for 30 seconds.

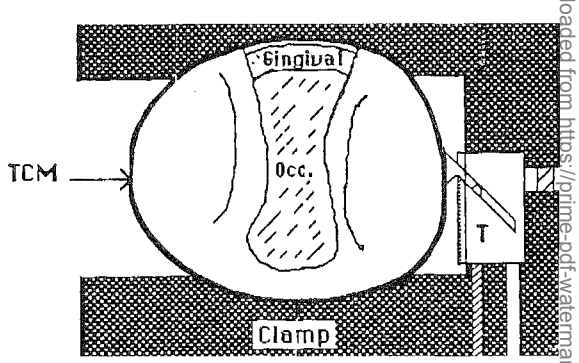

FIG 1. *Illustration of the clamp device showing the occlusal part of the cavity (OOC), the gingival part of the cavity (gingival), a transparent celluloid matrix band surrounding the tooth (TCM), a Tofflemire matrix holder (T), and the rubber clamp which imitates the function of a wedge*

e) The tooth was rinsed with water and dried with air.

f) Tenure dentin bonding agent (Den-Mat Corp, Santa Maria, CA 93456) was placed according to the manufacturer's instructions.

g) Marathon composite material (Den-Mat) was used in three buccolingual increments to fill the approximal box. Each increment was cured separately by exposure to a light source for 20 seconds. A fourth increment was used to complete the occlusal part of the restoration. A fine-fine finishing bur was used to smooth the approximal surface of the restoration.

The same steps, excluding steps a and c, were undertaken for the cavities prepared without retentive grooves, i e, restored with composite only. The teeth were randomly numbered for identification during evaluation. An example of the finished

restorations is presented in Figure 2.

Clinical evaluation

Marginal adaptation was evaluated with a probe by three independent examiners using USPHS criteria (Cvar & Ryge, 1971).

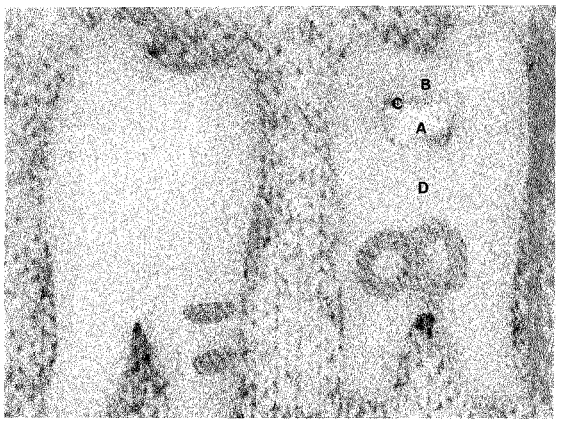

FIG 2. *Restorations with gingival margin in enamel. Tooth #8 showing amalgam-composite restoration; tooth #11 showing a composite restoration. A=amalgam; B=composite; C=amalgam-composite interface; D=cementoenamel junction.*

Radiographic evaluation

A radiograph of each tooth was taken in a buccolingual direction. The tooth numbers were inscribed on the radiographs for identification. The radiographs were grouped by three independent examiners as follows:

A = good adaptation between the tooth and the restoration;

B = a radiolucent area exists between the tooth and the restorative material.

An additional note was made when a bubble could be seen in the restorative material. In instances of disagreement among examiners, the radiographs were reexamined, and discussed until agreement was reached.

SEM evaluation

Twelve restorations (eight combined amalgam-composite and four composite alone) were used for SEM evaluation. Replicas of the approximal surfaces of the restorations were made with Epo-Kwick (Buehler, Lake Bluff, IL 60044), poured into elastomeric impressions of the teeth made with Provile (Bayer AG Leverkussen, West Germany), gold-coated and examined under a SEM (Model 505, Phillips, Eindhoven, Netherlands) at an accelerating voltage of 30 kV. The approximal surfaces were examined to evaluate the gingival margin of the restorations and the junction between the amalgam and the composite material. The criteria used for evaluation were as follows: a) excellent margins or excellent junctions, when no defect was detected, b) marginal fissure, or a gap between the restorative materials, c) underfilled margin, d) overfilled margin, and e) overhang.

Marginal leakage evaluation

All the teeth were subjected to thermocycling between 4±2 °C and 60±2 °C for 1000 cycles. The dwell times in each bath and the time intervals at room temperature between baths were one minute.

After thermocycling, the surfaces of the teeth, apart from the restoration and 1 mm of the surrounding enamel, were coated with a layer of nail varnish, a layer of utility wax, and another layer of nail varnish. The coated teeth were immersed in a 1% methyl blue and Borax solution for 24 hours, to allow dye penetration into possible existing gaps between the tooth substance and the restorative material and between the two restorative materials. The coatings were peeled off the teeth by grinding and the teeth were embedded in self-curing resin. The teeth were then sectioned from the buccal or lingual surface in a plane parallel to the tooth axis.

Each restoration was evaluated for dye penetration in three sequential section planes. The depth of dye penetration was evaluated separately for each of the following interfaces: the amalgam-enamel interface, the amalgam-composite interface and the composite-enamel interface, when the gingival margin of the box was placed in the enamel. When the gingival margin of the box was placed in the cementum, the amalgam-cementum interface, the amalgam-composite interface,and the composite-cementum interface were evaluated.

The depth of the dye penetration between the restorative material and the tooth was evaluated under a binocular microscope (Model XT, Olympus, Tokyo, Japan) and scored according

to the following criteria:

0 = no dye penetration;

1 = dye penetration between the restoration and the tooth up to the dentinoenamel junction (or up to 2/3 of the distance between the cementum and the axial wall of the box);

2 = dye penetration between the restoration and the tooth up to the pulpal wall;

3 = dye penetration between the restoration and the tooth along the pulpal wall;

4 = dye penetration between the restoration and the tooth along the pulpal wall and into the dentin; and

5 = dye penetration through the dentin into the pulp chamber.

Similar criteria were used evaluating dye penetration between the amalgam and the composite material.

The degree of dye penetration was compared between the different interfaces and the results were statistically analyzed using the Wilcoxon Matched Pairs Signed Ranks Test and the Mann-Whitney U Test (Siegel, 1956).

RESULTS

Clinical evaluation

All the restorations' surfaces and margins were scored A (no catch between the tooth and the restoration).

Radiographic evaluation

All the restorations were scored A (good adaptation between the tooth and the restoration without radiolucent defects between the restoration material and the tooth) (Fig 3). In 16 restorations bubbles could be seen in the restorative material.

SEM evaluation

The results of the evaluation of the teeth under the scanning electron microscope are presented in Table 1. Typical SEM micrographs are shown in Figure 4.

Dye penetration evaluation

The degree of dye penetration in the different interfaces is presented in Tables 2 and 3. As shown in these tables, there was no microleakage at the amalgam-composite interface in cavities with the gingival margin placed in the enamel; on the other hand, the same interface showed microleakage in 40% of cavities with the gingival margin located in cementum.

The degree of microleakage at the composite-enamel interface was significantly higher than at the amalgam-composite interface ($P < 0.01$) in cavities with the gingival margin placed in the enamel, and was also significantly higher than the amalgam-enamel interface ($P = 0.01$).

Microleakage at the composite-cementum

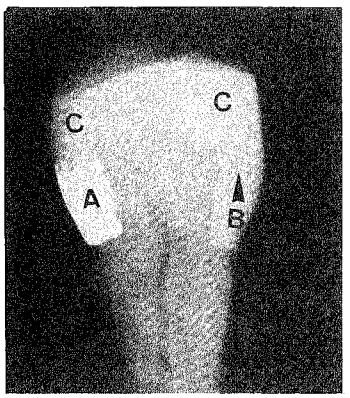

FIG 3. *Radiograph of a tooth with two restorations finishing in cementum; one is a combined amalgam-composite restoration, and the other a composite restoration. Note bubble (arrow) in body of the composite restoration. A = amalgam; B = bubble; C = composite.*

Table 1. SEM Evaluation of the Amalgam-Tooth, Composite-Tooth, and Amalgam-Composite Junctions

	Junctions		
Evaluation*	Amalgam-Tooth	Composite-Tooth	Amalgam-Composite
Excellent	5	5	6
Junctional Gap	1	1	0
Total	6	6	6

*None of the junctions presented overfilling, underfilling, or overhang.

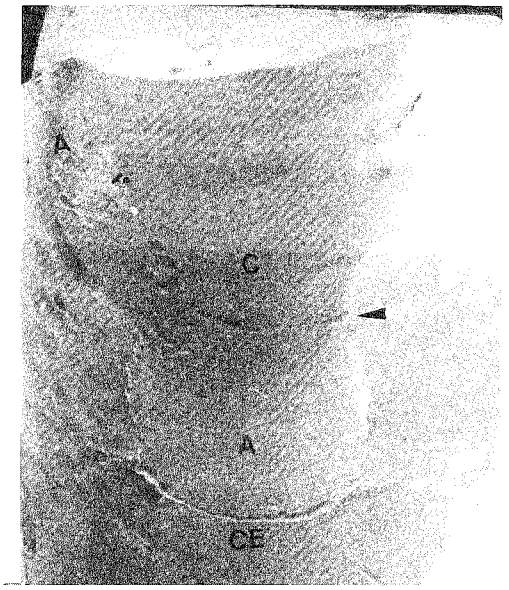

FIG 4A. *SEM micrograph of a combined amalgam-composite restoration with the gingival margin in cementum (X16). A = amalgam; C = composite; CE = cementum; Arrow = composite-amalgam interface.*

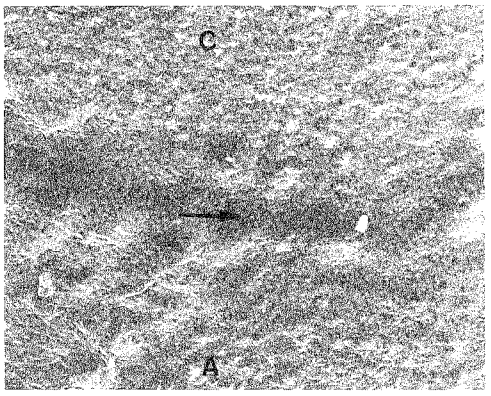

FIG 4C. *Higher magnification (X100) of the amalgam-composite interface in FIG 4. A = amalgam; C = composite; Arrow = amalgam-composite interface.*

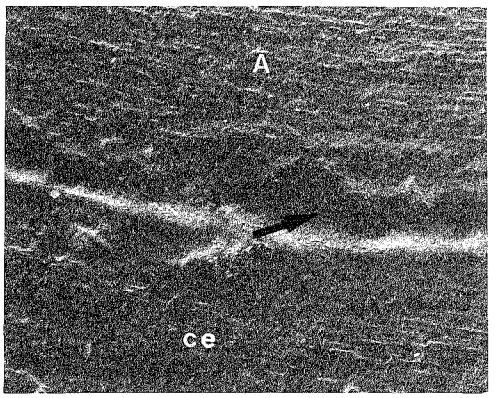

FIG 4B. *Higher magnification (X100) of the amalgam-cementum interface in FIG 4. A = amalgam; CE = cementum; Arrow = amalgam-cementum interface.*

Table 2. Degree of Dye Penetration in the Different Interfaces when the Gingival Margin of the Restorations is Located in the Enamel

	Interfaces		
Degree of Dye Penetration	**Amalgam-Enamel**	**Amalgam-Composite**	**Composite-Enamel**
0	8	10	1
1	1	0	3
2	0	0	2
3	1	0	0
4	0	0	0
5	0	0	4

Table 3. Degree of Dye Penetration in the Different Interfaces when the Gingival Margin of the Restorations is Located in the Cementum

Degree of Dye Penetration	**Amalgam-Cementum**	**Amalgam-Composite**	**Composite-Cementum**
0	7	6	0
1	0	2	1
2	0	1	0
3	1	0	1
4	0	0	1
5	2	1	7

interface was significantly higher than at the amalgam-cementum interface ($P = 0.01$) and at the amalgam-composite interface for cavities with the gingival wall placed in cementum ($P = 0.01$). The Wilcoxon Matched Pairs Signed Ranks Test was used for the statistical analysis.

The degree of microleakage at the composite-enamel interface was not statistically different from the composite-cementum interface ($P > 0.05$) using the Mann-Whitney U Test. Representative examples of the findings in these tables are shown in Figures 5 and 6. Figure 7 shows the percentage of the restorations with microleakage of the gingival margin in cementum or enamel, by type of restoration.

DISCUSSION

The results of this study showed that all restorations were clinically and radiographically successful. The margins of 89% of the restorations evaluated in SEM were excellent; but many bubbles were detected in the composite restorations;

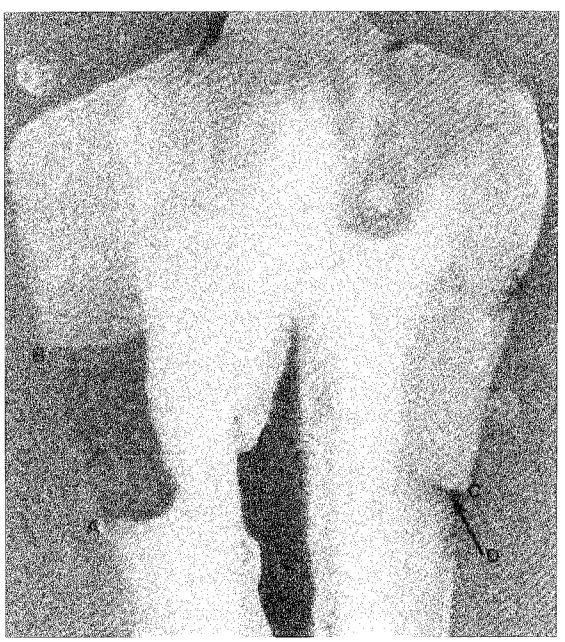

FIG 6. *Photograph of two restorations finishing in cementum; one being a combined amalgam-composite restoration and the other a composite restoration. A=amalgam-cementum interface; B=composite-amalgam interface; C=composite-cementum interface; D=dye penetration, score 2.*

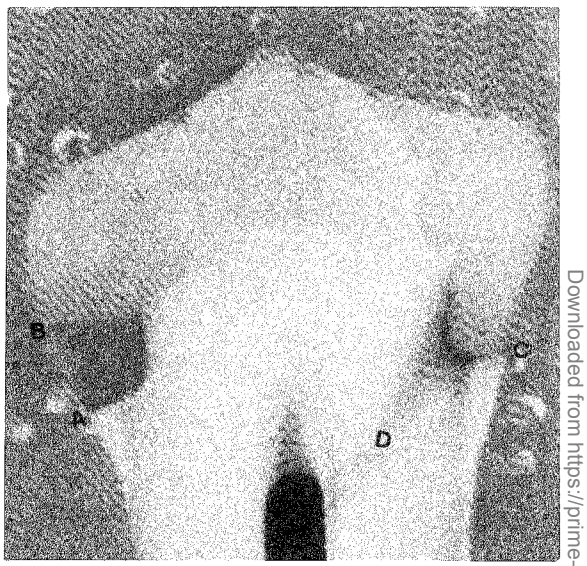

FIG 5. *Photograph of two restorations finishing in enamel; one being a combined amalgam-composite restoration and the other a composite restoration. A=amalgam; B=composite-amalgam interface; C=composite-enamel interface; D=dye penetration, score 5.*

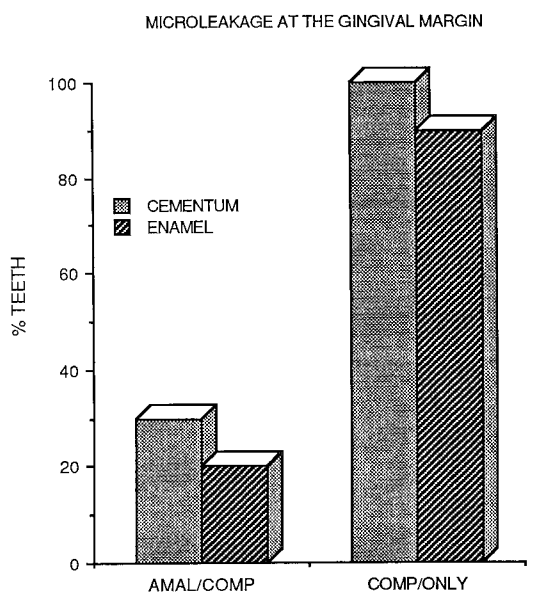

FIG 7. *Percentage of restorations with microleakage of the gingival margin in cementum or enamel by type of restoration*

this finding can be attributed to the incremental filling technique used. In this study, buccolingual increments were used; this method decreases the severity of the marginal leakage as compared to a bulk filling method (Hassan & others, 1987; Lui & others, 1987).

The excellent interface between amalgam and composite material could be explained by the fact that the bonding penetrates into the irregularities and porosities of the amalgam surface, thus creating a bond with the composite material (Mertz-Fairhurst & Newcomer, 1988). Since the approximal surfaces of the restorations were polished, possible irregularities at the interface were masked. We propose that future studies should eliminate this step, in order to detect possible defects such as overfilling, underfilling, and overhanging margins.

The degree of microleakage of the composite restoration at the gingival wall in margins placed in enamel or in cementum is comparable to those previously reported (Gross, Retief & Bradley, 1985). In this investigation, the composite-tooth interface demonstrated a significantly higher microleakage than the amalgam-composite interface. Microleakage at the amalgam-composite interface was present only in cavities with the gingival wall placed in cementum; these fillings have a greater volume of composite material and therefore a greater potential for microleakage due to contraction during polymerization (Crim & Shay, 1987). Another contributing factor could be technical difficulties during the filling procedure in a cavity with the gingival wall located in cementum. The results of this study suggest that a combined amalgam-composite class 2 restoration is clinically acceptable regarding microleakage, and that the use of a dentin bonding agent did not completely eliminate microleakage at the gingival margin when the cavity was filled with composite material alone.

CONCLUSIONS

Microleakage at the gingival margin of the experimental amalgam-composite restoration was significantly lower than in the conventional composite restorations.

The amalgam-composite interface had no microleakage in cavities with the gingival margin placed in the enamel.

The degree of microleakage at the composite-enamel interface was worse than at the amalgam-composite interface. A similar result was found in cavities with the gingival margin placed in cementum.

The combined amalgam-composite restoration was successful in controlling microleakage at the gingival margin of class 2 restorations.

Acknowledgments

This investigation was supported in part by the Den-Mat Corporation in Israel.

The authors wish to acknowledge the assistance of Professor R Grajower with the laboratory procedures.

(Received 23 October 1989)

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BUONOCORE MEMORIAL LECTURE

Michael Buonocore

The Evaluation of Materials: Relationships between Laboratory Investigations and Clinical Studies

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INTRODUCTION

Recent advances in dental materials science and clinical research are by any account impressive. Through the refinement of traditional forms of laboratory and clinical evaluations, the application of innovative technology, and the research and development of novel materials and techniques, new forms of laboratory investigations and clinical studies have evolved. These new forms of evaluation are now making ever increasing contributions to existing knowledge and understanding of dental materials, and, in addition, give new insight concerning the ways in which these materials behave and perform in clinical service. Such developments have been greatly facilitated by clinicians and materials scientists realizing and reaping the benefits of adopting multidisciplinary, collective approaches to their research. As a consequence, the days of dental materials science and clinical research being considered to be essentially separate disciplines are now long since departed.

Leaving aside the achievements of the combined approach to research by clinicians and materials scientists, such symbiosis has played a major part in helping to identify the ways in

which future materials research should be directed (Stanford, 1988). Possibly the most pressing and challenging priority identified by this approach is the intriguing field of relationships between laboratory investigations and clinical studies (Phillips, 1988).

To address this subject, which is fundamental to the related quest to identify tests in vitro that will allow accurate predictions of the behavior and performance of new and experimental materials in clinical service, it is appropriate to review the principal forms of laboratory investigations and clinical studies (table), and to discuss the value and importance of each of these forms of evaluation in the developing field of clinical dental materials science research.

LABORATORY INVESTIGATIONS

Laboratory investigations do not rely on patients and are therefore free of many of the variables and operational difficulties which exert such a potent influence on the outcome of studies undertaken in the clinical situation (Jacobsen, 1988). The artificiality of laboratory investigations, however, can result in findings which, despite their value, may fail to reveal how the materials tested may behave and perform in clinical service.

The three principal forms of laboratory investigation (table) will be considered.

Investigations of physical parameters

Evaluations of the physical parameters of materials form the backbone of contemporary dental materials science and encompass many fields of special expertise and state-of-the-art technology. Such evaluations may include investigations of a material's intrinsic, synergistic, bulk, and surface properties; equilibrium versus time-dependent properties; mechanical, chemical and thermal properties; and the material's interactions with radiation.

Evaluations of physical parameters, by virtue of their objectivity, sophistication, universal acceptance, and predominance in relevant literature, rightly form the basis for most standards in the field of dental materials; however, the relationship between the results of physical tests and the long-term clinical behavior and performance of materials remains largely obscure, according to the proceedings of the last International State-of-the-Art Conference on Restorative Dental Materials (International Association for Dental Research, 1988), which contains a plethora of references to this fact. Furthermore, it is suggested that no single physical test or series of such tests is, to date, able to reliably predict aspects of the typically complex, long-term clinical behavior and performance of a generic group of materials of similar composition and construction, let alone long-term in-service expectations for specific materials.

Despite the limitations of investigations of the physical parameters of materials in terms of reliably predicting to what extent a material will succeed in the clinical situation, such evaluations will continue to be the mainstay of laboratory investigation of dental materials; the results of such evaluations are invaluable with regards to standards, for comparative purposes, and by way of an important contribution to knowledge and understanding of materials. It is equally clear, however, that many more substantive findings are now required from well-conducted, long-term objective clinical studies to point the way towards both refinements to existing test methods and the development of new forms of physical testing capable of reliably predicting the performance and behavior of materials in clinical service (Stanford, 1988).

Investigations of biological properties

As stated by Browne (1988) in his keynote address to the International Conference on the In Vitro Assessment of the Biocompatibility of Dental Materials held in Birmingham, UK during 1987, "The need for the biological evaluation of dental materials is unquestioned."

Biological testing as we know it today principally comprises testing for cytotoxicity, mutagenicity, and carcinogenicity with the direct clinical toxicity of materials being tested in vitro and in vivo using various cell culture systems and human and non-human primates respectively, as specified in various standards (ANSI/ADA 41a, 1982; DIN 13390, 1983; FDI TR 7405, 1984). Both testing in vivo and traditional forms of testing in vitro, however, are now considered to suffer a number of limitations and to provide results which are often found to have a poor correlation with the results obtained in the clinical situation (Browne, 1988).

Traditional forms of testing in vitro, which

typically involve the use of a single cell type, are most heavily criticized for being too sensitive (Meryon, 1988) and on the grounds that the systems used preclude interactions involving metabolic, inflammatory, and immunological reactions which may occur in vivo. Testing in vivo, by contrast, is criticized as a consequence of certain difficulties with histological interpretation, the influence of uncontrolled and in some cases little understood variables such as smear layers, and the difficulty of interpreting findings in the presence of microbial microleakage (Browne, 1988), as well as the growing concerns of relying on non-human primates and human subjects in such evaluations.

The situation with biological testing could therefore be considered to be similar to that for investigations of physical parameters, namely that existing tests serve an important function, but that there is a pressing need to develop a readily reproducible method in vitro, or methods that are capable of reliably predicting what will occur in the clinical situation.

Investigations of simulation in vitro

Investigations of simulation in vitro may be undertaken in clinical simulation models, which can be as simple as extracted teeth maintained in controlled environments, or in artificial oral environments which are typically complex and costly.

CLINICAL SIMULATION MODELS

Clinical simulation models are used extensively in evaluations of most of the principal types of clinical dental materials, especially restoratives. Using simple clinical models, many aspects of the surface, adaptation, and interfacial characteristics of restorative materials have been investigated by widely used techniques including, for example, microscopic surveys of surfaces and techniques to investigate the marginal and interfacial sealing ability of restorative systems, and more objective, systematic techniques such as those involving quantitative margin analysis, a technique recently reviewed and described in detail by Roulet and others (1989). Such methods of evaluation are a most important form of evaluation in vitro, in particular if the methodology includes simulations of intra-oral insults to restorations by way of, for example, thermal and mechanical stressing.

In situations where it is possible to use a method of investigation to evaluate an aspect of a material both clinically and in a clinical simulation model, as can be achieved with certain techniques for quantitative margin analysis, a high degree of correlation can be found between findings in vitro and in vivo (Roulet & others, 1989); however, as with most other forms of investigation in vitro, limitations of the method of evaluation are apparent when correlations between in vitro and long-term clinical findings are investigated. For example, accepting that techniques such as quantitative margin analysis have demonstrated that most newly placed direct class 2 posterior composites have interfacial gaps along sections of their gingival margins (Roulet & others, 1989), and that numerous investigations of marginal and interfacial microleakage have confirmed that such deficient restorations allow the deep interfacial ingress of noxious substances and microorganisms capable of being instrumental in causing secondary caries and pulpal pathology, how do the results of such studies relate to findings from long-term (> 5 years) clinical trials which fail to report large numbers of direct class 2 posterior composites having failed as a result of secondary caries and pulpal pathology (Wilson, 1988)?

Despite limitations, investigations in clinical simulation models are, as indicated above, a most important form of evaluation in vitro in that they provide a typically rapid means of discriminating between materials in terms of a range of characteristics of clinical importance. Given the value of this form of laboratory evaluation and the need for more fundamental and applied research in the area, the development of clinical simulation models should continue to remain a priority for both clinicians and materials scientists, especially as there would appear to be a considerable promise of many more meaningful relationships between findings in vitro and in vivo in this field.

ARTIFICIAL ORAL ENVIRONMENTS

With the advent of many new materials in the early 1980s and an increasing awareness of the limitations of materials evaluations in clinical simulation models used at that time, there was a new interest in developing artificial oral environments to at least help reduce the number of candidate systems proposed for clinical testing.

As reported by De Long and Douglas (1983) in their account of the development of their artificial oral environment, three basic components are required in such a system: an artificial saliva which reacts with test materials in a manner similar to that which would occur in vivo; temperature fluctuations, aeration, and humidity variations comparable to that found in the mouth; and forces and movements found during mastication. When such a system (De Long & Douglas, 1983) is combined with a device which digitizes surfaces for graphic display by computer, and is capable of measuring small clinical changes from replicas, the result is a powerful research tool capable of generating comparable objective findings from clinical studies and sophisticated forms of simulation in vitro.

Work using the artificial mouth described by De Long and Douglas (1983) and the artificial oral environment developed in the University of Zurich by Krejci (1990) has, for example, provided most encouraging correlations between findings in vivo and in vitro with regard to the wear of dental amalgam and posterior composite restoratives (De Long & others, 1985; Sakaguchi & others, 1986; Krejci, 1990).

Although artificial mouths are complex and costly, they have considerable potential in the field of establishing and better understanding relationships between findings in vitro and in vivo. Consequently, this form of laboratory investigation could be considered to have a most important role to play in future forms of materials evaluations.

CLINICAL STUDIES

Clinical studies will always be the ultimate test of materials used in the clinical practice of dentistry (De Long & Douglas, 1983); however, all three types of clinical studies (table) suffer major frustrations (Jacobsen, 1988), and as a consequence the value and importance of each is worthy of some discussion.

Explanatory clinical studies

Explanatory clinical studies are studies which are conducted under strictly controlled conditions that favor success and optimum effectiveness. Most of the clinical trials reported in the literature are forms of explanatory clinical studies, typically studies conducted in dental schools involving a small number of specially trained clinical investigators, working free of restraints experienced in the real world, with the aim of placing restorations of optimum quality in a group of highly selected patients. As a consequence, the results of such studies give an indication of the clinical potential of the material under investigation, rather than information which can be extrapolated to make claims concerning the possible long-term performance of that material in widespread clinical use (a common abuse of findings from explanatory clinical studies).

Although the findings of explanatory clinical studies, which are invariably limited to three or, on occasion, five years, fail to reveal how a material will behave and perform in the real world situation, and typically include precious little data on modes of failure, such studies, if well-designed and -conducted, are presently of importance. By providing much needed substantive data pertaining to the clinical behavior and performance of materials, such studies help to point the way towards improved materials and new forms of more meaningful laboratory investigations. In addition, certain forms of explanatory trials in which relatively sophisticated forms of data analysis are employed (for example, stepwise logistic regression, Wilson & others, 1989), provide new understanding of the influence of variables on the behavior and performance of materials in clinical service. Such information is considered to be of particular value to those involved in the further development of simulation tests in vitro, especially those in artificial oral environments.

The lack of a correlation between the findings

Principal forms of laboratory investigations and clinical studies

LABORATORY INVESTIGATIONS	CLINICAL STUDIES
Investigations of:	
Physical parameters	Explanatory
Biological properties	Pragmatic
Simulation in vitro	Observational

of strictly controlled, well-designed and -conducted explanatory trials and various forms of laboratory evaluation is considered to be a measure of the gap which exists between laboratory investigations and clinical studies. It is also a measure of the extent of the challenge which faces clinicians and materials scientists in this field.

Pragmatic clinical studies

Pragmatic clinical studies are studies in which the performance and effectiveness of materials are tested in the real-world situation. In this type of evaluation, of which there have been regrettably very few in the field of operative dentistry, a representative group of practitioners use the materials being studied in a relatively large sample of their patients, which should be representative of the population in which the materials may eventually be used. The application and method of use for the materials investigated in pragmatic studies are not subject to the panoply of strict controls which exist in well-designed explanatory trials.

By virtue of testing materials in the real-world situation, the findings of pragmatic studies typically exhibit a wide variation, and as such these studies are of value as they provide an important overview of the spectrum of performance to be expected of materials in widespread clinical use. Further benefits of pragmatic trials include a good indication of a material's technique sensitivity, susceptibility to inappropriate application, and patient acceptance. Such benefits, it is suggested, may only be gleaned clinically and, as a consequence, the possibility that laboratory evaluations could ever be a true substitute for all forms of clinical investigation, notably pragmatic studies, is considered to be inappropriate.

In the aggressive, fast-moving dental marketplace we know today, in which materials and techniques may come and go before any meaningful data can be obtained from long-term clinical studies, there are few opportunities to undertake this type of evaluation, important as it may be to better understanding of relationships between laboratory investigations and clinical experiences. Consequently, all opportunities to undertake such studies must be realized and used to optimum advantage.

Observational clinical studies

Observational clinical studies can be longitudinal (retrospective and prospective) in which data are collected from patient records, or cross-sectional, involving the examination of a sample of patients. Longitudinal observational studies are undertaken principally to measure durability, while cross-sectional studies provide an indication of the quality of, for example, restorations in a sample of the population at a given time.

These forms of clinical studies are of importance as they provide valuable information concerning critical aspects of the behavior, performance, and failure of materials forming restorations, prostheses, etc, in real-world situations. Such information, much of which, it is suggested, relates to the influence of clinical variables, would not normally be revealed by other forms of clinical investigation. In addition, observational clinical studies, with the exception of those of the prospective longitudinal type, can be completed relatively quickly as they do not rely on patients returning for reviews over periods of several years. The results of such studies, valuable as they are (Mjör, 1981), are difficult to relate to the findings of specific laboratory investigations, except possibly for those of materials salvaged from clinical service (for example, Mjör & Smith, 1985).

Consequently it is suggested that in the context of this paper, findings from observational clinical studies are a useful adjunct to understanding more of the relationships between laboratory investigations and explanatory and pragmatic clinical studies, rather than being central to research directed towards the further goal of bridging the gap between the laboratory and clinical situation for the evaluation of, in particular, new and experimental materials.

DISCUSSION

From a review of the importance and value of relationships between the principal forms of laboratory investigations and clinical studies as presented in this paper, it may be concluded that existing forms of laboratory investigations and clinical studies all serve a valuable purpose and provide information which contributes to contemporary understanding and knowledge of

materials. As far as relationships between the findings of laboratory investigations and clinical studies are concerned, the conclusion must be that, with a few notable exceptions, they are at best limited and, in most cases, specific to aspects of the behavior and performance of certain materials. Some newer forms of laboratory and clinical testing certainly show considerable promise, and some discussion of the way in which it is believed that substantial progress may be made in this field is considered appropriate.

By way of a key, it is suggested that clinicians with the assistance of materials scientists must work towards producing a substantial database comprising comparable results from well-conducted, long-term objective clinical studies with established relationships with clinical performance in the real-world situation. With such a bank of data, significant and rapid progress could be made towards both a better understanding of relationships between laboratory investigations and clinical studies, and the further goal of identifying and developing rapid and effective techniques for the evaluation of materials. Materials scientists would have a much-needed clinical lead to assist them in the identification and development of reliable forms of testing capable of providing reliable, predictive data (Wilson, 1988); those with interests in biological testing would be able to further develop promising approaches to testing in vitro such as those described by Hume (1985), Davies (1988), Jowett, Ferguson and Combe (1988), and Meryon (1988); and those with interests in the field of simulation in vitro, in particular artificial oral environments, should be provided with a substantially improved understanding of the influence of those factors which determine the behavior and performance of materials in clinical service. In addition, through an improved understanding of the limitations and failings of existing materials, many new materials and techniques may be forthcoming.

The new or at least modified forms of clinical testing which will be required to generate the type of data required will need to have very special characteristics and, as a consequence, will pose certain problems. It is suggested that the special characteristics should include: the ability to allow the early detection of the limitations and weaknesses of materials; the capacity to yield results which are not only objective and reproducible but able to be extrapolated to predict long-term (> 5 years) performance and behavior in the real-world situation; they should be relatively inexpensive and simple to mount and complete, and, of special importance, should not require large samples of patients to be drawn from the diminishing patient pool. With such characteristics in mind, the enormity of the challenge in this intriguing field can be fully appreciated by considering the associated problems. These problems include: the need for effective international cooperation and coordination in a manner not previously attempted in the field, the development and acceptance of innovative protocols including techniques for the collection of reproducible, objective data, the critical factor of appropriate funding, and the creation of incentives sufficient to ensure the involvement of those best-suited to the challenge.

Although somewhat daunting, the task ahead is, in the opinion of the author, a realistic and attainable mission. The first step towards achieving the various goals discussed in this paper is believed to be the wider realization of the pressing urgency of the situation whereby practitioners are expected to be able to separate fact from fiction in the reports of scientists and manufacturers, and to then modify clinical procedures accordingly (Phillips, 1988). This situation makes it difficult to consistently achieve the high ideals of the profession.

As concluded by Buonocore in the closing remarks of his last principal publication (albeit in relation to resin bonding): at present "laboratory evidence is only suggestive of in vivo success potential" and "much remains to be investigated in the clinical situation" (Buonocore, 1981).

Acknowledgment

The Buonocore Memorial Lecture is sponsored by the L D Caulk Company, Milford, Delaware.

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DEPARTMENTS

Press Digest

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

The preventive management of extensive caries induced by self-administered medications: A case report. *Walsh, L J (1989) *Clinical Preventive Dentistry* 11(6) 17-20.

(*University of Queensland Dental School, Turbot Street, Brisbane Q 4000, Australia)

The cariogenic properties of simple sugars are less well-appreciated than those of sucrose. The clinical features of an adult patient who presented with extensive caries of unknown etiology are described. The predominant etiologic factor was prolonged usage of self-administered mineral supplements containing lactose. The preventive management strategies are described, and an approach to dietary counseling for patients using unusual self-administered medications is outlined.

The microbiology and chemotherapy of odontogenic infections. *Moenning, J E, Nelson, C L & Kohler, R B (1989) *Journal of Oral and Maxillofacial Surgery* 47 976-985.

(*8140 Knue Road, Suite 200, Indianapolis, IN 46250)

The typical odontogenic infection is now considered to be a mixed aerobic/anaerobic infection with anaerobes outnumbering aerobes 2:1. The most common aerobes are alpha-hemolytic streptococci. The most common anaerobe is *Bacteroides melaninogenicus*. This realization is thought by some investigators to reflect selection of microorganisms due to widespread antibiotic use, but the authors feel the results of current reports are due to more sophisticated specimen and culture techniques that allow enumeration of anaerobic species. *B melaninogenicus* plays a key role in this infection. Other bacteria in the mixed infection may supply vitamin K, which is needed by *B melaninogenicus*, while *B melaninogenicus* can also produce penicillinase. However, many patients have already been treated successfully with penicillin therapy by the time culture and sensitivity studies demonstrate resistance to penicillin; this may be due to the biomechanics of the surgery. Penicillin is still the first-line drug in treatment of mild-to-moderate odontogenic infections. If the infection fails to respond to penicillin and surgical removal of the source of infection, a change of antibiotic to a penicillinase-resistant drug or a drug with better anaerobic coverage should be considered.

Microleakage and marginal placement of a glass ionomer liner. *Holtan, J R, Nystrom, G P, Douglas, W H & Phelps, II, R A (1990) *Quintessence International* 21 117-122.

(*University of Minnesota, School of Dentistry, 515 Delaware Street SE, Minneapolis, MN 55455)

Glass-ionomer liners, with their ability to bond to dentin, have been reported to produce less microleakage than several other restorative resin materials. This matched-pair study reported the effect on microleakage of the placement of light-curing glass-ionomer liner when extended out to the dentinal cervical cavosurface margin or held short of the margin. Pairs of circular class 5 cavities involving 50% enamel, with bevel, and 50% cementum were cut in 31 extracted third molars. After placement of the glass-ionomer liner (Vitrabond), etching of the bevel, and placement of a resin bonding system (Scotchbond 2), a microfilled resin (Silux Plus) was placed over

the bonding agent in one increment, light-cured, finished, and thermocycled. The extension of the glass-ionomer liner out to the dentinal cavosurface margin did not significantly improve microleakage performance compared to the performance of the liner when it was placed short of the margin and covered by a resin veneer. From other considerations, such as the potential for mechanical breakdown of the glass-ionomer liner when exposed to the oral environment, the clinician should consider holding the glass-ionomer liner short of the dentinal cavosurface margin and covering it with a composite resin veneer of a thickness consistent with structural integrity.

Adaptability of two amalgams to finished cavity walls in Class II cavity preparations. *Khera, S C, Askarieh, Z & Jakobsen, J (1990) ***Dental Materials*** **6 5-9.**

(*University of Iowa, College of Dentistry, Department of Operative Dentistry, Iowa City, IA 52242)

Adaptability of two amalgams, the dispersed-phase Dispersalloy and the spherical-particle-type Sybralloy, to cavity walls in a class 2 cavity preparation was investigated. Four techniques for finishing cavity walls were compared, as was the adaptability of alloys at different occluso-gingival levels. The issues were examined by direct measurement of microleakage between cavity wall and amalgam without the use of cavity varnish. There was no statistically significant difference in the adaptability of the two amalgams directly to the cavity walls, except those finished by a sharp hand instrument (hatchet) and restored with Dispersalloy. This combination demonstrated the best overall adaptability of amalgam to cavity walls. Sybralloy demonstrated best adaptability to walls finished with sandpaper disks. However, overall Disperalloy demonstrated significantly better adaptability than Sybralloy.

Clinical performance of resin-bonded bridges: a 5 year prospective study. Part III: failure characteristics and survival after rebonding. *Creugers, N H J, Snoek, P A, van't Hof, M A & Käyser, A F (1990) ***Journal of Oral Rehabilitation*** **17(2) 179-186.**

(*University of Nijmegen, School of Dentistry, Department of Occlusal Reconstruction, Phillips van Leydenlaan 25, 6526 EX Nijmegen, The Netherlands)

A total of 203 resin-bonded bridges were inserted under controlled clinical conditions and evaluated over a period of five years. During the evaluation period there were 47 dislodgements and 30 pontic fractures. The majority of the failures were retreated successfully. Dislodgement was in most cases due to fracture at the resin/retainer interface. Dislodged and rebonded resin-bonded bridges had a lower retention than original bonded bridges. The bridges which were removed for repair of the pontics and rebonded showed an acceptable retention. There was no relationship found between the failure characteristic and the retainer type or the cementation material used.

A long term study of the relationship of third molars to changes in the mandibular dental arch. Ades, A G, *Joondeph, D R, Little, R M & Chapko, M K (1990) ***Journal of Orthodontics and Dentofacial Orthopedics*** **97 323-335.**

(*University of Washington, School of Dentistry, Department of Orthodontics, SM-46, Seattle, WA 98195)

The purpose of this study was to determine the relationship of third molars to changes in the mandibular arch. Ninety-seven patients had mandibular third molars that were either extracted, impacted, congenitally absent, or erupted into function. Four different orthodontic treatments were performed on these patients and full orthodontic records were taken. The mean post retention time was 10 years. No significant differences in mandibular growth were found between the groups; this suggests that persons with third molars erupted into satisfactory function do not have a significantly different mandibular growth pattern than those whose third molars are impacted or congenitally missing. In the majority of cases some degree of mandibular incisor crowding took place after retention,

but this change was not significantly different between the groups. This finding suggests that the recommendation for mandibular third molar removal with the objective of alleviating or preventing mandibular incisor irregularity may not be justified.

Survival analysis of amalgam restorations in long term recall patients. *Bjertness, E & Sonju, T (1990) ***Acta Odontologica Scandinavica*** **48(2) 93-97.**

(*University of Oslo, Faculty of Dentistry, Box 1109 Blindern, 0317 Oslo 3, Norway)

The longevity of amalgam restorations in premolars and first and second molars in long-term recall patients was calculated by means of survival analysis. This retrospective longitudinal study included information from 32 patients and their records over a time period of 17 years. The data were recorded by six dentists. The estimated time of 90% survival was seven years. After 17 years the survival estimate decreased to 78%, indicating a favorable longevity of amalgam restorations in patients taken care of in an established recall system.

Shear bond strength and scanning electron microscopic observation of four dentinal adhesives. *Chappel, R P, Eick, J D, Mixson, J M & Theisen, R C (1990) ***Quintessence International*** **21 303-310.**

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

The purpose of this study was to evaluate the shear bond strengths of four dentinal adhesives (Gluma, Dentin Adhesit, Scotchbond 2, and Tenure). Sixty-four unerupted human third molars were sectioned perpendicular to their long axis, leaving a complete layer of dentin surrounded by enamel. The dentinal surface was abraded to form a uniform smear layer and then treated with the dentinal adhesive according to the manufacturer's instructions. The appropriate composite resin was applied using a mold 2 mm in length and 3.3 mm in diameter. The shear bond strength of each specimen was determined by testing in an Instron Testing Machine and was as follows: Gluma = 5.7 MPa; Dentin Adhesit = 5.6 MPa; Tenure = 14.4 MPa; and Scotchbond 2 = 22.9 MPa. Scotchbond 2 had significantly greater bond strength than the other three dentinal adhesives. SEM observation of Scotchbond 2 showed that the strength of the adhesive could exceed the cohesive bond strength of either the composite resin or dentin.

Microleakage of glass ionomer/composite laminate Class V restorations. *McInnes, P, Perkins, E & Weinberg, R (1990) ***American Journal of Dentistry*** **3 21-24.**

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

This investigation evaluated the effects on microleakage of pretreating dentin with polyacrylic acid prior to placing a glass-ionomer base/composite laminate restoration. Class 5 erosive-type lesions with incisal margins on enamel and cervical margins below the cementoenamel junction were prepared in 50 sound, extracted teeth. Teeth were divided into five dentin treatment groups: (1) 10% polyacrylic acid; (2) 20% polyacrylic acid; (3) and (4) 40% polyacrylic acid; and (5) no dentin preconditioning. In groups 1-3 and 5, a glass-ionomer base was placed within 1 mm of the margins. In group 4 the glass-ionomer base extended to the cervical margin. The glass-ionomer base and the incisal enamel were acid-etched prior to placing a bonding agent and restoring with a resin. The restorations were finished and polished and stored in distilled water for seven days, thermocycled, and embedded in epoxy resin. The teeth were

then sectioned through the restorations. Dye penetration along the tooth/restoration interface was evaluated both cervically and incisally using an ordinal scale of 0 to 3. Statistically there were no significant differences among the groups either cervically or incisally. The dentin bonding agent used was not able to prevent cervical leakage. Preconditioning dentin with the polyacrylic acid prior to placing the glass-ionomer base decreased but did not eliminate microleakage. Extension of the glass-ionomer base to the cervical cavosurface margin did not increase microleakage.

The effects of periodontal ligament injection on pulpal and periodontal tissues. *Roahen, J O & Marshall, F J (1990) *Journal of Endodontics* 16 28-33.

(*Oregon Health Sciences University, School of Dentistry, Portland, OR 97201)

The purpose of this study in vivo on dogs was to investigate, histologically, the effect of the periodontal ligament injection on the dental pulp with or without subsequent placement of amalgam restorations, and the effects of the injection on the periodontium. Eighty-eight injections were made on 55 teeth using the Ligmaject syringe and 0.2 ml of 2% lidocaine with 1:100 000 epinephrine. Eighteen teeth were not injected and were used as controls. Specimens were obtained for histological examination at 10 minutes and two, 15, and 30 days after injection. All pulps showed either no inflammation or mild inflammation. The placement of a class 5 amalgam restoration immediately following injection had no apparent effect. Histological examination of the periodontal ligaments of 36 teeth showed 16 teeth with definite evidence of tissue disruption including areas of active external root resorption in 30-day specimens. Another 14 showed possible evidence of disruption. It was concluded that the periodontal ligament injection technique has no long-term deleterious effects on the pulp, but can induce localized external root resorption.

Book Reviews

CROSS INFECTION CONTROL IN GENERAL DENTAL PRACTICE

David Croser and John Chipping

Published by Quintessence Publishing Co, Inc, Chicago, 1990. 128 pages, 25 illustrations. $32.00.

This book is subtitled *A Practical Guide for the Whole Dental Team*. The description is apt. The authors emphasize the need for involving everyone in an office while making the changes associated with improved procedures. The many lists, outlines of specific procedures, diagrams, and statements of underlying principles will be useful in staff meetings and will serve as a timely review for anyone needing additional information.

The authors work in the United Kingdom, so the references to UK law, sources of information, and statements of relevant professional groups might seem distracting. On the other hand, it may be reassuring to learn that practitioners in another country have examined the many problems associated with the "AIDS epidemic" and have come to similar conclusions.

The authors make every effort to assure that product information is sufficiently general to be useful to readers in other parts of the world.

They state the reasons for their personal preferences and never fail to offer some reasonable solution for every problem they identify.

In summary, this book will be useful as a starting point for staff meetings, as a reference text for staff, and as an adjunct to any of the many manuals or guides designed to help offices cope with the many regulatory agencies interested in dental offices.

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DENTAL OCCLUSION AND THE TEMPOROMANDIBULAR JOINT

Albert Gerber, Gerhard Steinhardt, Robert P Carmichael

Published by Quintessence Publishing Co, Inc, Chicago, 1990. 145 pages, 198 illustrations. $68.00.

The English translation of this German work, first published in 1989, is intended to "augment the dentist's knowledge and understanding of TMJ disturbances and to enhance his/her ability to help TMJ patients." It focuses on the "diagnosis and causal therapy of facial pain resulting from occlusal disturbances in the purview of dentistry." As such, the book ignores other etiologic entities involved with TMD and is intent on fostering an occlusion paradigm of TMD. The book contains numerous unsupported anecdotal statements such as "Hyperbalances can trigger an elevation in muscle activity, such as clenching and bruxing..." or "Condylar displacement can trigger pain locally and in structures innervated by the trigeminal nerve." Neither of these statements is validated.

The book is written as if the cause/effect relationship between occlusion and joint disorders was well-established. Since it is controversial, such a thesis deserves substantiation.

While well-referenced, most of the references are from the 50s, 60s, and 70s. This book presents a nice historical perspective of the development of modern TMD therapy. It is flawed by arresting its development of the topic in the mid-70s.

Though the book includes 16 chapters and is well-illustrated, it fails to meet the authors' stated purpose and therefore cannot be recommended for addition to one's library.

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A COLOUR ATLAS OF RESIN BOND RETAINED PROSTHESES

R T Walker, PhD, MSc, BDS, FDSRCPS, A Dimmer, BDS, FFDRCS, FDSRCS, P R H Newsome, BChD, FDSRCS, DRDRCS, S K Ngai, FBIST

Published by Excerpta Medica Asia, Ltd, Hong Kong, 1989. 81 pages, indexed, 196 color and 37 black-and-white illustrations.

Available from: Dept of Conservative Dentistry, Prince Philip Dental Hospital, 34 Hospital Road, Hong Kong, for US$40. (Add US$5 for a single copy; postage is free on orders of two or more.)

The stated purpose of this work is to offer a book which will be useful to the general practitioner, technician and student alike. It is apparent that the authors have accomplished their objective in an excellent manner.

The book has 12 chapters, with three appendices. It is exceptionally well-organized with outstanding color reproduction of the photographs. The text is minimal, but the content is well-communicated by the excellent selection of the photographs and their captions.

A brief historical background is given in Chapter 1 (four pages). The following chapters commence with patient assessment, diagnosis, and treatment planning and procedure and continue through indications and contraindications, patient treatment, and all the steps involved in the design and fabrication of such a restoration.

There is an excellent reference list provided for those who desire to read further on the subject.

This is an excellent book and should be of great value to both students and practicing general dentists who want to acquire the knowledge essential for treating patients with this type of prosthesis.

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OPERATIVE DENTISTRY

JULY-AUGUST 1990 • VOLUME 15 • NUMBER 4 • 121-160

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