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EDITORIAL

Faculty, Collegiality, and Institutional Support

Universities promote the concept of collegiality among their faculty. By definition, collegial is "with authority or power shared equally among colleagues," while collegiality is defined as "the sharing of authority among colleagues" (*Webster's New World Dictionary*, 1982). From the actions of many faculty members, one cannot help but wonder if they truly understand the meaning of these words.

Within the dental school there should be a recognized mission that all members of the school's administration, faculty, and staff should support. Collegiality in this instance means sharing the power and authority to carry out the mission for the common good of the institution and its goals. Sounds fairly simple and reasonable, does it not?

In such a collegial atmosphere we should expect to find a great deal of esprit de corps among members of the faculty, whose goals for the institution should be similar, if not the same. But how often do we find a group spirit and a sense of pride in our modern institutions?

Too often faculty members are so busy "doing their own thing" that they misuse the power vested in their positions. In many instances we see disharmony in schools brought about by individuals whose central goal is personal pursuits and not that of the institutions. In others, we may find departments where the faculty are at odds with the institution and/or the other departments. Such activities can only cause serious detrimental effects to the goals and image of the institution as well as to the students who are there for an education.

From my perspective, there are faculty who feel that academic freedom gives them the right to do whatever they feel inclined to do, and that their personal desires come first. For those who are on the tenure track, many are so overburdened with the many tasks of securing promotion and tenure that they lose sight of the mission. For some, after they have achieved tenure they believe incorrectly that they now have liberty to do whatever they desire. Many are constant complainers about the department, school, or institution, and their negative attitude adversely affects the efforts of others.

The faculty members I am describing certainly are not the majority, but they do make it difficult for the rest of the faculty to conduct the mission. If people misuse the power and authority of collegiality, then they are no longer collegial. Only through cooperative efforts can the faculty as a whole be successful and the school survive and flourish.

Schools and departments should spend more time and effort establishing a collegial atmosphere in which all can feel a true sense of esprit de corps not only for the institution but for the school, department, fellow faculty members, and their students.

Dental schools and their students have a right to insist on nothing but the best. In academics we can never be the best unless all of the faculty are fully supportive. Collegiality and esprit de corps should be considered very prominently when a faculty member comes up for promotion, tenure, or merit raise.

DAVID J BALES
Editor

Webster's New World Dictionary (1982) New York: Simon & Schuster Division of Gulf & Western Corporation

ORIGINAL ARTICLES

Marginal Leakage of Impregnated Class 2 Composites in Primary Molars: an in Vivo Study

G HOLAN • A CHOSACK
P S CASAMASSIMO • E EIDELMAN

Summary

In vivo impregnation of the cervical margin was used in an attempt to prevent leakage of class 2 composite restorations in primary molars. Examination after 18 months demonstrated clinical success of the restorations. However, the exfoliated teeth presented extensive dye penetration at the approximal margins of the restorations, suggesting that impregnation did not prevent marginal leakage.

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INTRODUCTION

Several laboratory and clinical studies have reported that the cervical margins of class 2 composite restorations had the highest risk for microleakage and secondary caries (Mjör, 1985; Lui & others, 1987; Eidelman, Fuks & Chosack, 1989). The microleakage results from polymerization shrinkage (Asmussen & Jørgensen, 1972).

Polymerization shrinkage can be decreased if the composite material is bonded to a wide area of acid-etched enamel (Øilo & Jørgensen, 1977). Recent studies have shown that filling the cavity by buccolingual increments reduced the polymerization shrinkage (Donly & Jensen, 1986).

Torstenson, Brännström and Mattsson (1985) have described a method for sealing composite resin contraction gaps by impregnating

them with a low viscous resin after the composite has cured. This in vivo study evaluated the clinical and radiographic appearance of posterior composite restorations, and by means of dye penetration, the effect of impregnation on the leakage at the cervical margins of class 2 composite restorations in primary molars.

EXPERIMENTAL DESIGN

To be eligible, the children had to have at least one primary molar with a small to moderate approximal carious lesion with an approximal contacting tooth. The children had to be available for recall appointments every six months until exfoliation of the teeth, and have parental consent to participate in this study.

Following a history and clinical examination, bitewing radiographs were exposed and a treatment plan developed. The teeth suitable for this study were divided by a toss of a coin into two groups, the impregnation and the nonimpregnation groups, numbering 34 and 26 teeth respectively. A total of 60 class 2 cavities in primary molars of 17 children eight to 10 years of age were filled with P-30 (3M Dental Products, St Paul, MN 55144) by the authors.

Clinical Procedure

Conventional class 2 cavities with the cervical margins placed in the enamel were prepared in primary molars, using a #330 carbide bur under coolant spray. All cavities were prepared and filled under a rubber dam. The restorative steps for the teeth of the impregnation group included the following:

(a) The axiopulpal dentin walls were protected with Dycal (L D Caulk Div, Dentsply International, Milford, DE 19963);

(b) A transparent celluloid matrix (Howe-Neos Dental, CH-6925 Gentilino, Switzerland) was placed and adapted with a Tofflemire matrix holder;

(c) The enamel surrounding that cavity was etched with acid for 60 seconds, then rinsed with water for 20 seconds and air-dried;

(d) Two layers of Scotchbond (3M Dental Products) were applied to all cavity surfaces and margins;

(e) A clear wedge with light-reflecting surfaces (Howe-Luciwedges, Howe-Neos Dental) was then inserted and the bonding agent was polymerized for 20 seconds: 10 seconds through the occlusal surface and 10 seconds through the light-reflecting wedge, to the approximal surface;

(f) One buccal and one lingual increment of P-30 were placed in the approximal box, leaving place for a third middle increment (Fig 1). Each increment was exposed to a light source directed from buccal and lingual for 20 seconds. The third increment, filling the cavity up to the level of the pulpal floor, was then placed and polymerized with light for 20 seconds;

(g) The wedge was slightly withdrawn and the matrix loosened and sightly separated from the composite but not removed;

(h) A drop of self-cure Concise enamel bond (3M Dental Products) was placed with a brush between the matrix and the approximal surface of the restoration;

(i) The matrix was tightened and wedge reinserted. This was done in an attempt to impregnate any gaps at the approximal margins of the restorations with the bonding material;

(j) The rest of the cavity was filled and polymerized with light; and

(k) The wedge and matrix were removed and the restorations finished with alpine stones and Sof-Lex discs (3M Dental Products).

For the nonimpregnation group the same steps were carried out, except for steps (g), (h), and (i).

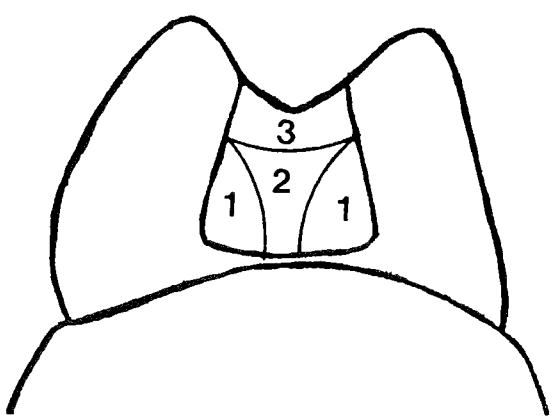

FIG 1. *Diagram showing the incremental method used for the composite restoration (approximal view). The numbers indicate the order of placement of the increments and light curing.*

In those cases in which adjacent approximal surfaces of two teeth were included in this study, the cavities were prepared, calcium-hydroxide base placed and matrix bands adapted simultaneously in both teeth. However, one of the cavities was randomly selected to be filled, hardened, and finished first and then the same steps were carried out for the other cavity.

EVALUATION

Clinical

The restorations were evaluated at base line and every six months for surface appearance, color match, marginal adaptation, marginal discoloration, anatomic form and secondary caries, using the criteria described by Cvar and Ryge (1971) in which four degrees of evaluation exist by described criteria: Alpha, Bravo, Charlie, and Delta, in decreasing order of excellence.

Contact Area

The quality of the contact area was assessed with waxed dental floss and classified as follows: (A) excellent contact: resistance was met while passing the dental floss; (B) the contact was present but the dental floss passed without resistance; and (C) no contact existed with the adjacent tooth. The evaluation of the contact area was not recorded in instances in which the approximating tooth exfoliated or was mobile, and amalgam restoration or a preformed crown, contacting the composite restoration, had been placed following the completion of the composite filling. The contact areas of restorations adjacent to an intact or previously restored tooth were recorded separately from contact areas produced by two adjacent composite restorations (i e, the evaluation of the contact area quality refers to both restorations).

Radiographic Evaluation

As part of the six-month recall, bitewing radiographs were exposed and examined for the presence of radiolucent defects at the cervical margins, and bubbles in the body of the restoration.

Postexfoliation Examination

The patients were encouraged to bring the teeth to the dental clinic after exfoliation. The approximal margins of the retrieved teeth were examined and evaluated for defects and discoloration using a dental explorer.

Dye Penetration

The retrieved teeth were kept in a humid environment until the time of sectioning. The surfaces of the teeth, apart from the restoration and 1 mm of the surrounding enamel, were coated with a layer of nail varnish and a layer of boxing wax. The coated teeth were then immersed for 24 hours, in a solution of 1.25% methylene blue in absolute ethanol to allow dye penetration into possible existing gaps between the tooth substance and the restorative material. The coatings were then peeled off by grinding and the teeth were embedded in Araldite (Epokwick, Lake Bluff, IL 60044). The teeth were then sectioned from the buccal surface in a vertical plane parallel to the mesiodistal axis of the tooth, using the Vari/Cut VC-50 (Leco Corp, St Joseph, MO 49085-2396). This allowed an evaluation of each restoration in four to five different sections 0.6 - 0.7 mm apart. The depth of the dye penetration at the cervical margin was evaluated under a binocular microscope and scored as follows: 0 = no dye penetration, 1 = dye penetration between the restoration and the tooth up to the dentinoenamel junction, 2 = dye penetration between the restoration and the tooth up to the axial wall, and 3 = dye penetration between the restoration and the tooth along the axial wall and/or into the dentin.

The restorations, contact areas, radiographs and dye penetration were evaluated by at least two evaluators. In case of disagreement, the teeth were reevaluated and the case discussed to reach consensus.

RESULTS

Of the 60 restorations performed in this study, 52 were available for clinical evaluation after 18 months. One patient with three restorations was unavailable. Five teeth were exfoliated before the 18-month recall.

Clinical Appearance

The results of the clinical evaluation of the impregnated and nonimpregnated teeth are summarized in Table 1. None of the restorations in either group was scored Charlie or Delta. Therefore, these ratings were excluded from the table.

Contact Area

Of the 52 restorations examined, 11 were excluded from evaluation because of mobility or loss of the adjacent tooth. The remaining 41 restorations were evaluated according to the type of the contact area as follows: Type 1 included 11 restorations, yielding 11 contact areas. Type 2 included 30 restorations with 15 contact areas. Excellent contact (score A) was found in 88% of the contact areas and was more frequent in Type 2 restorations, but the differences were not statistically significant (Table 2).

Radiographic Evaluation

In 42 teeth (81%) no radiographic defects were observed at the cervical margin, but bubbles were seen in the body of seven (13%) of the restorations (Fig 2). In 10 teeth (19%) defects were observed at the cervical margin, and in four teeth a radiolucent area between the composite material and the dentin at the axiogingival line angle, due to pooling of the bonding agent (Holan & others, 1989), was evident (Fig 3).

Table 1. Clinical Evaluation of 52 Restorations after 18 Months

	IMPREGNATED GROUP		NON-IMPREGNATED GROUP	
Evaluation Criteria	**Alpha**	**Bravo**	**Alpha**	**Bravo**
Surface appearance	28	0	24	0
Color match	28	0	24	0
Marginal adaptation	26	2	24	0
Marginal discoloration	27	1	24	0
Anatomic form	26	2	23	1
Secondary caries	28	0	24	0

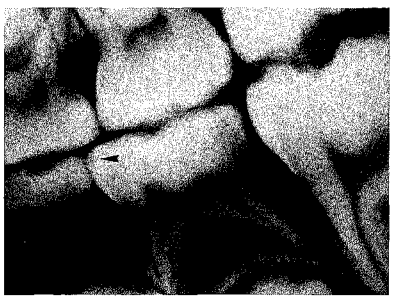

FIG 2. *Bitewing radiograph showing the distal cervical margin of restorations in teeth 64 and 74 with no gap or defect. In tooth 75 a bubble in the mesial marginal ridge of the restoration can be observed (arrow).*

Table 2. Evaluation of the Contact Areas of the Composite Restorations

	CLASSIFICATION OF THE CONTACT AREA					
Evaluation Score	**Type 1***	**%**	**Type 2****	**%**	**Total**	**%**
A	8	73	15	100	23	88
B	2	18	0	0	2	8
C	1	9	0	0	1	4
Total	11	100	15	100	26	100

$X^2 = 4.65$, $P > 0.05$

*Contact formed by composite restorations adjacent to an intact or previously restored tooth
**Contact formed by two adjacent composite restorations

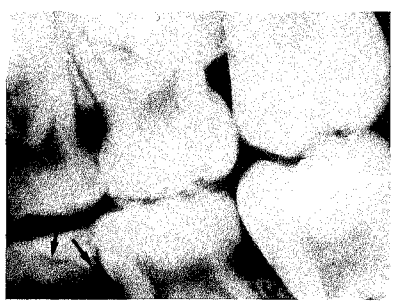

FIG 3. *Bitewing radiograph with arrows indicating pooling of the bonding agent and defective cervical margin in tooth 74*

Postexfoliation Evaluation

Twenty-two restored teeth were retrieved and available for evaluation of marginal defects, discoloration and dye penetration, 12 of the impregnated and 10 of the nonimpregnated group. Only one restored tooth was in the patient's mouth less than one year. The average intraoral period of the other 21 restorations was 23 months. None of the retrieved teeth was prematurely extracted or exfoliated.

Approximal Surface Appearance

Four of the impregnated and two of the nonimpregnated restorations presented marginal defects, mostly at the cervical margins (Figs 4a and 4b). Five of the impregnated and none of the nonimpregnated restorations presented marginal discolorations.

Dye Penetration

All teeth of both groups demonstrated dye penetration (Figs 5 and 6). Eleven of 12 teeth of the impregnated group and seven of 10 teeth of the nonimpregnated group presented the most severe degree of dye penetration (score 3). This difference was analyzed using the Fisher Exact Probability Test (Siegel & Castellan, 1988) and was not statistically

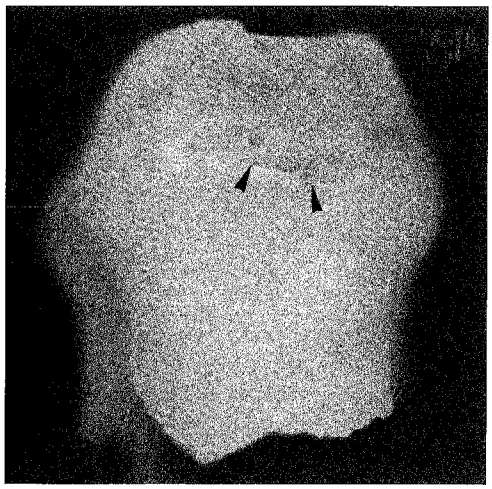

FIG 4a. *Photograph of the approximal surface of an impregnated restoration that had been in the mouth for 26 months. Notice defects and staining at the cervical margin (arrows).*

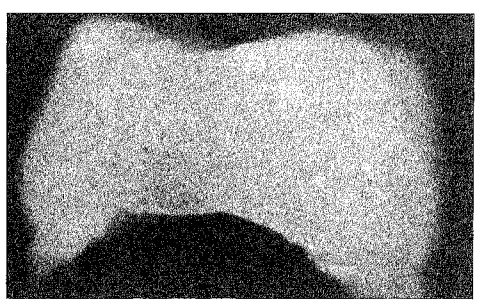

FIG 4b. *Photograph of the approximal surface of a nonimpregnated restoration that had been in the mouth for 24 months. Notice defects and no staining of the cervical margin can be detected.*

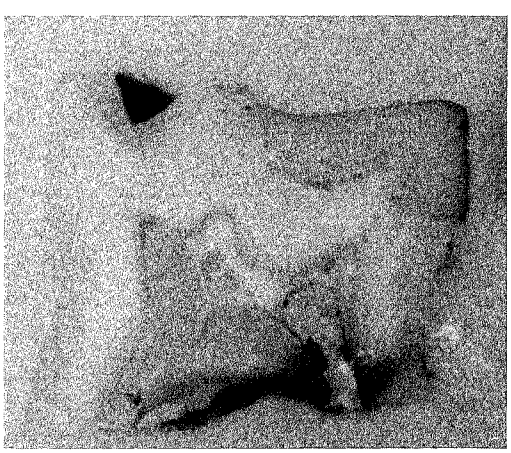

FIG 5. *Photograph of a mesiodistal section of a DO restoration. r = composite resin; p = pulp; d = dye penetration; (score 1).*

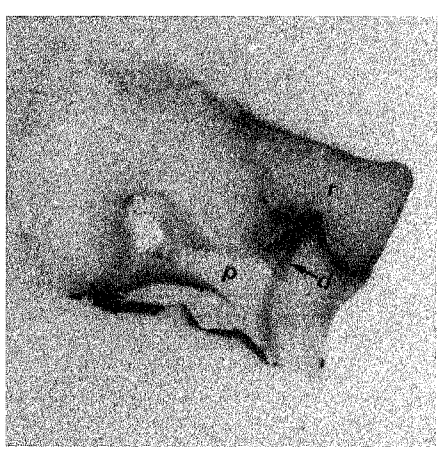

FIG 6. *Photograph of a mesiodistal section of a DO restoration. r = composite resin; p = pulp; d = dye penetration; (score 3).*

significant. The results of the dye penetration are summarized in Table 3.

Table 3. Evaluation of Dye Penetration between the Tooth Structure and the Restorative Material in the Cervical Margins

Degree of Dye Penetration	Impregnated Group	Nonimpregnated Group
0	0	0
1	1	1
2	0	2
3	11	7
Total	12	10

DISCUSSION

Several reports have shown high success rates of class 2 composite restorations when evaluted clinically (Paquette & others, 1983; Oldenburg, Vann & Dilley, 1985; Eidelman & others, 1989).

The findings of this follow-up are similar to those previously reported. Over 96% of the teeth were graded Alpha for the criteria evaluated.

However, radiographic examination revealed that in 19% of the restorations, radiolucent defects could be seen at the cervical margins. This rate of defects compared favorably with a previous report (Eidelman & others, 1989) that demonstrated that 40% of the restorations had cervical defects.

The lower rate of cervical defects could possibly be a result of differences in the methodology used in this and a previous study (Eidelman & others, 1989): vertical instead of horizontal increments and clear matrix strip and light-reflecting wedges as compared to the conventional metal matrix and wedges. The bubbles observed in 13% of the restorations are probably air trapped in the composite material as a result of the incremental technique used. The radiolucent areas at the axiogingival line angle represent the pooling of dentin bonding agent, as was observed in a previous in vitro study (Holan & others, 1989).

The quality of the contact area in the present study was found to be excellent in 88% of the recorded contacts, and in 8% the contact was weak. No difference was found between the quality of the Type 1 and Type 2 contact areas. These results are comparable to those reported previously in the permanent dentition (Leidal, Solem & Rykke, 1985).

The severe marginal leakage at the cervical margins found in this study is in direct contrast to the excellent clinical and radiographic appearance of the restorations. This contradiction may be an expression of the high sensitivity of the acid-etch technique to the humid environment at the cervical margins of the restorations. Other possible reasons for this cervical marginal defect could be due to inadequate adaptation of the material to the gingival wall, pulling of the material during condensation caused by the stickiness to the condenser, polymerization shrinkage and contraction of the material toward the light source (Lui & others, 1987). A higher rate of microleakage at the cervical margins of class 2 composites was found in primary compared to permanent molars. This is based on two reports (Fuks & others, 1992; Hirschfeld & others, 1992) in which the same materials and techniques were used in primary and permanent molars. None of the restored teeth presented any symptoms of pulp pathology, or clinically detectable caries, and none of the retrieved teeth was prematurely extracted or exfoliated. However, the relative clinical success of the present study to keep the primary molars with a class 2 composite restoration for a mean intraoral period of 23 months without clinical symptoms does not ensure that areas of marginal leakage will not become carious, as was reported previously (Fuks & others, 1990), nor does it ensure that pulpal changes will not become evident with time (Browne & Tobias, 1986).

CONCLUSIONS

Impregnation of the cervical margins of class 2 composite restorations in primary teeth failed to prevent leakage at the approximal margins. Despite the clinical success observed in the present study, class 2 composite restorations

should be carefully evaluated for secondary caries at the cervical margins and for pulpal changes.

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Surface Roughness of Polished Amalgams

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D NOVICKAS • T R S TOEPKE

Summary

The purpose of this project was to determine the amalgam surface roughness following finishing and polishing procedures. Nine high-copper amalgams were tested. They were hand-condensed in a 3 x 3 x 30 mm mold. Each sample was divided into four sections, and each section was finished by one of four methods: carving only; carving and then burnishing 15 minutes after carving; carving and then polishing at the prescribed times; or carving, burnishing 15 minutes after carving, and then polishing at the prescribed times. Each bar of amalgam had these surface treatments done at either 1, 3, 6, or 24 hours. The results indicated surface roughness may be more dependent on particle size, shape, and distribution of the individual high-copper amalgams than the polishing time or the surface treatment performed.

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Introduction

To obtain the maximum benefit and service life of amalgam restorations, it is suggested they be polished and finished. The benefits of polishing include: removal of flash and refinement of the amalgam margins; improved restoration marginal adaptation; and smoothing of the amalgam surface, thereby reducing its susceptibility to plaque retention, corrosion, and tarnish (Gladwin & others, 1986).

The literature lists several studies on surface roughness measurements that are mainly concerned with different polishing techniques to obtain the smoothest surface and not the

effect on the surface roughness that depends on the time of polishing after condensation. Previously observed data for the surface roughness, R_a in μm, were from 2.95 to 6.10 μm for carved and burnished amalgams and 1.03 to 6.03 μm for polished amalgams (Charbeneau, 1965; Rupp, Paffenbarger & Waterstrat, 1979; Creaven, Dennison & Charbeneau, 1980; de Vries, de Wet & Eick, 1987; and Ulusoy, Aydin & Ulusoy, 1987).

Materials and Methods

The intent of this project was to investigate the surface roughness after polishing and finishing of nine high-copper dental amalgams (Table 1) at time periods of 1, 3, 6, and 24 hours. Thirty-six bars were hand-condensed in a 3 x 3 x 30 mm mold, divided into four sections, and each section finished by one of four methods: carving only; carving and then burnishing 15 minutes after carving; carving and then polishing at the prescribed times; or carving, burnishing 15 minutes after carving, and then polishing at the prescribed times.

The above polishing procedures were done at either 1, 3, 6, or 24 hours after condensation of the amalgam. The polishing procedures utilizing a low-speed rotary instrument consisted of a white stone, a brown Shofu rubber point (Shofu Dental Corp, Menlo Park, CA 94025), a green Shofu rubber point, flour of pumice on a brush, and Amalgloss (L D Caulk, Division of Dentsply International, Milford, DE 19963) on a brush. Surface roughness measurements (consisting of five separate measurements per variable) were run on each finished surface using a Surftest 201 surface analyzer (Mitutoyo Manufacturing Co, Ltd, Tokyo, Japan) after final surface treatment. Statistical analysis was conducted on the surface roughness (R_a in μm) using a Student-Newman-Keuls multiple means comparison test.

Table 1. Amalgams Investigated

Amalgam	Type	Batch	Manufacturer
Contour	spherical	052188	Sybron/Kerr, Romulus, MI 48174
Disperalloy	admixed	072288	Johnson and Johnson Dental Products Company, East Windsor, NJ 08520
Phasealloy	admixed	091252	Wykle Research Inc, Carson City, NV 89701
Sybraloy	spherical	031888	Sybron/Kerr
Tytin	spherical	042788	Sybron/Kerr
Valiant	spherical	050588	L D Caulk, Div of Dentsply International, Milford, DE 19963
Valiant PhD	admixed	070887	L D Caulk
Vivalloy	admixed	414601	Vivadent (USA), Tonawanda, NY 14150
Unison	spherical	050988	Johnson and Johnson Dental Products Company

Results and Discussion

The surface roughness for all four groups is presented in Figures 1-4 (Pages 132, 133). The statistical analysis at 24 hours of the amalgams is presented in Table 2. The observed trend was that Phasealloy, Dispersalloy, Vivalloy, and Unison were, in the carved state, rougher than the other five amalgams. There is no standard for surface roughness, although it is felt that the smoother the surface of amalgam, the less likelihood for plaque retention, corrosion, and tarnish. The statistical analysis indicates that the carved surface was significantly rougher than any of the other finished surfaces. The carved-burnished, carved-polished, and carved-burnished-polished surfaces were not significantly different from each other at any given time period.

Scanning electron micrographs of Valiant PhD surface treatments at 24 hours are presented in Figures 5-8 to provide a relative comparison between the four surface treatments. Figure 9 is a representative tracing of surface roughness for the four surface treatments using the Surftest 201 on Unison at six hours.

Table 2. Student-Newman-Keuls Test for Surface Roughness, R_a (μm), between the Amalgams at 24 Hours

CARVED SURFACE

SNK Grouping	Mean ± (SD)	N	Amalgam
A	13.93 ± 1.01	5	Phasealloy
A			
A	13.85 ± 0.84	5	Disperalloy
B	10.70 ± 0.18	5	Vivalloy
C	8.24 ± 0.67	5	Unison
C			
C	8.10 ± 1.10	5	Tytin
C			
C	7.73 ± 0.60	5	Sybraloy
C			
C	7.01 ± 0.99	5	Valiant PhD
D	5.15 ± 0.70	5	Valiant
D			
D	4.35 ± 0.87	5	Contour

BURNISHED SURFACE

SNK Grouping	Mean ± (SD)	N	Amalgam
A	9.67 ± 1.45	5	Unison
B	7.55 ± 1.13	5	Phasealloy
C	4.69 ± 1.06	5	Disperalloy
C			
C	4.18 ± 1.32	5	Vivalloy
D	2.91 ± 0.57	5	Tytin
D			
E D	2.72 ± 0.61	5	Valiant PhD
E D			
E D	1.72 ± 0.54	5	Valiant
E D			
E D	1.48 ± 0.33	5	Sybraloy
E			
E	1.24 ± 0.11	5	Contour

POLISHED-BURNISHED SURFACE

SNK Grouping	Mean ± (SD)	N	Amalgam
A	11.84 ± 0.85	5	Dispersalloy
B	4.58 ± 2.35	5	Unison
C	2.21 ± 0.76	5	Vivalloy
C			
C	1.91 ± 0.33	5	Phasealloy
C			
C	1.53 ± 0.33	5	Valiant PhD
C			
C	1.51 ± 0.25	5	Valiant
C			
C	1.41 ± 0.24	5	Tytin
C			
C	1.05 ± 0.16	5	Valiant
C			
C	0.96 ± 0.55	5	Contour

POLISHED SURFACE

SNK Grouping	Mean ± (SD)	N	Amalgam
A	5.92 ± 1.34	5	Unison
B	3.98 ± 0.76	5	Tytin
B			
C B	3.59 ± 0.97	5	Phasealloy
C B			
C B	3.40 ± 0.46	5	Dispersalloy
C B			
C B D	3.16 ± 1.19	5	Valiant PhD
C B D			
C B D	2.62 ± 0.54	5	Valiant
C D			
C D	2.32 ± 0.74	5	Vivalloy
C D			
C D	2.28 ± 0.41	5	Sybraloy
D			
D	1.77 ± 0.58	5	Contour

The means with the same letter are not significantly different from each other. N is the number of specimens tested.

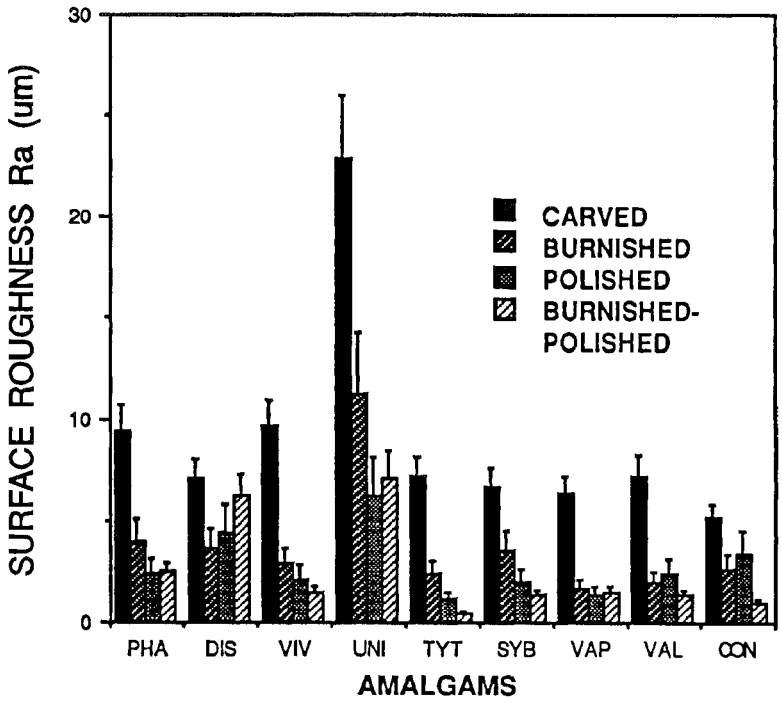

FIGURE 1: SURFACE ROUGHNESS AT 1 HOUR

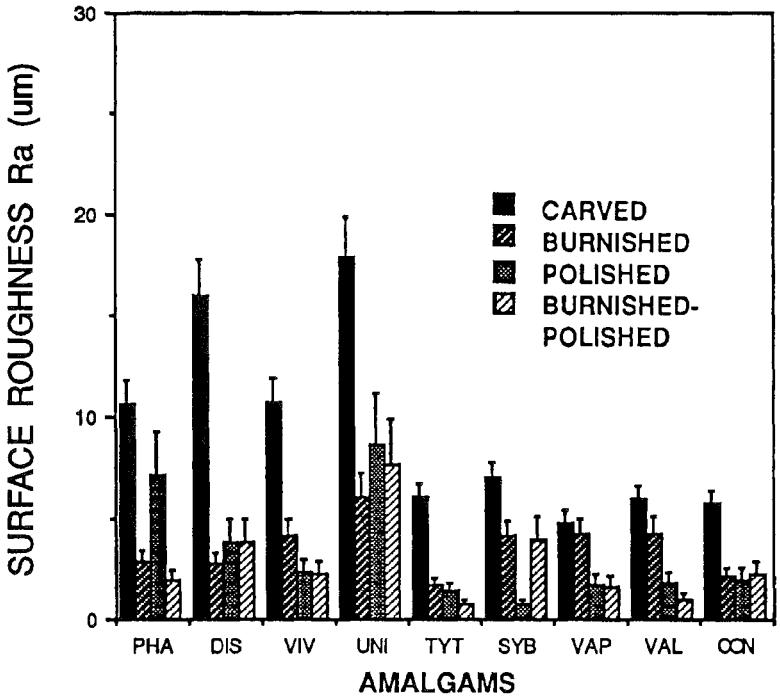

FIGURE 2: SURFACE ROUGHNESS AT 3 HOURS

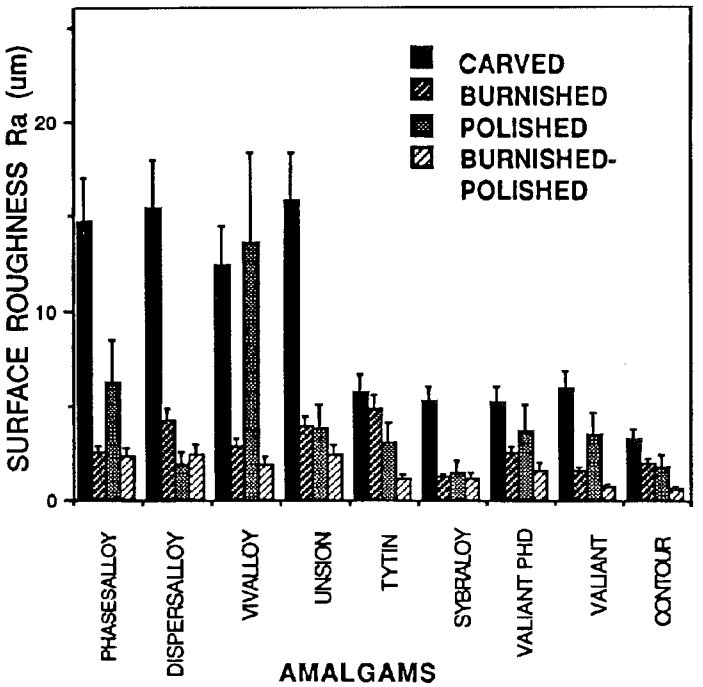

FIGURE 3: SURFACE ROUGHNESS AT 6 HOURS

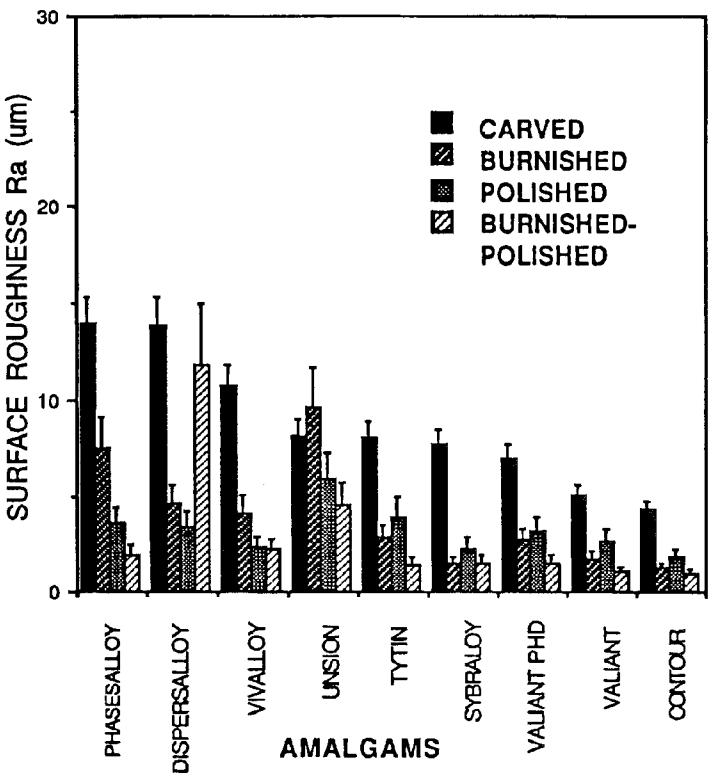

FIGURE 4: SURFACE ROUGHNESS AT 24 HOURS

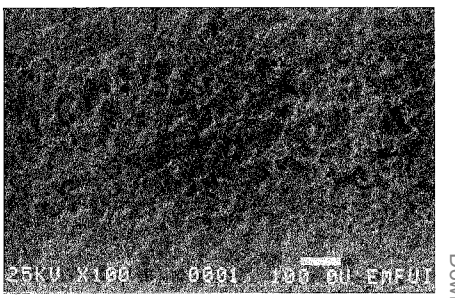

FIG 5. *Carved surface of Valiant PhD, 24-hour specimen*

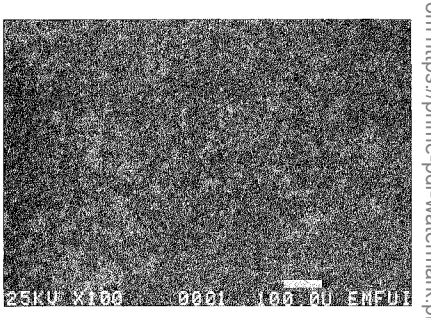

FIG 6. *Burnished surface of Valiant PhD, 24-hour specimen*

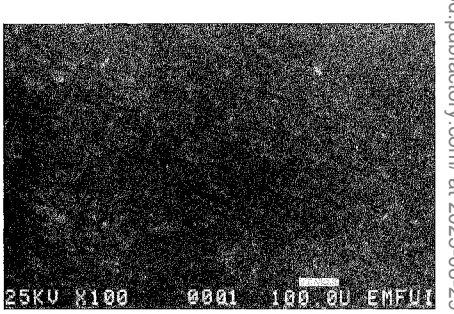

FIG 7. *Polished surface of Valiant PhD, 24-hour specimen*

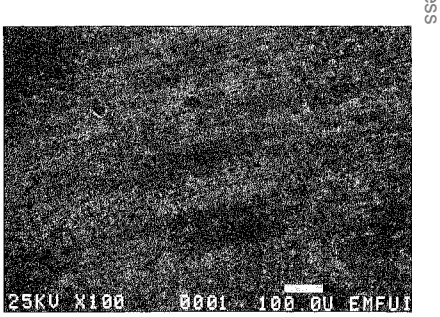

FIG 8. *Burnished-polished surface of Valiant PhD, 24-hour specimen*

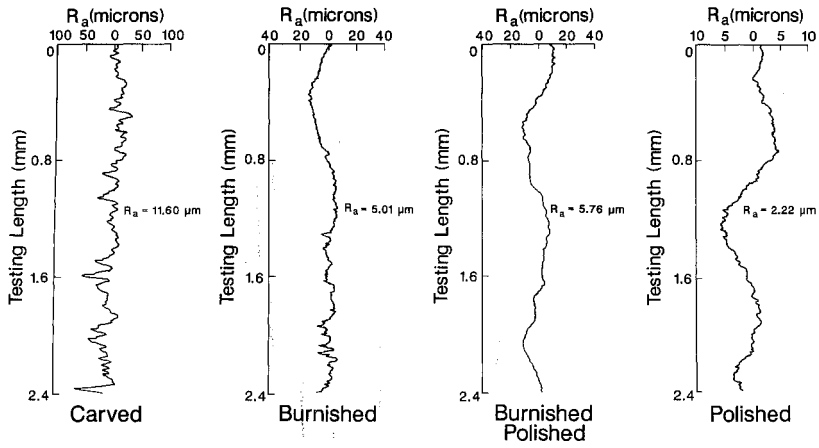

FIG 9. *Surface roughness, R_a (µm), of Unison at six hours of the carved, burnished, polished, and burnished-polished surfaces*

Conclusions

In light of these data, the surface roughness of high-copper amalgams may be more dependent on particle size, shape, and distribution and less dependent on the polishing technique. Polishing may not be necessary to achieve an acceptable level of surface smoothness for some high-copper amalgams. Further study is needed to determine if there is clinical significance between a burnished, burnished-polished, or polished high-copper amalgam surface.

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Influence of Curing Time and Distance on Microhardness of Eight Light-cured Liners

D F MURCHISON • B K MOORE

Summary

Eight visible-light-activated liners were evaluated to assess the degree of polymerization by microhardness comparison. Knoop hardness number values were measured on 1.0 mm-thick specimens with varied exposure times (20, 40, 60 seconds) and distances from the curing source (0, 3, 6 mm). Statistical analysis of the nine groups within each material revealed significant differences for time and distance ($P < 0.05$). Application of the light for at least 40 seconds resulted in significantly higher Knoop hardness number values than specimens cured for 20 seconds. The highest Knoop hardness values were obtained if the tip of the light source was 3 mm away from the light-activated liner.

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Introduction

Since 1930 the use of calcium hydroxide as a pulp-capping agent and cavity liner has been widespread. Calcium hydroxide has demonstrated the ability to stimulate reparative dentin formation, serve as a protective barrier to acids and leached products from dental materials, and induce "dentin bridging" in root amputations and apexifications (Pameijer, Stanley & Allen, 1983; Shovelton, 1972; Coolidge, 1960).

Recent advances with resin polymers have improved their acceptability as cavity liners, and favorable results have been demonstrated in biocompatability and cytotoxicity tests by Stanley and Pameijer (1985). The increasing use of light-polymerized materials in dentistry

sparked development of a calcium hydroxide formulation in this form.

Light-cured products now include fluoride-releasing resin liners and visible-light-cured glass-ionomer lining and base systems. Albers (1990) states that the lining systems should be collectively termed light-cured fluoride releasing liners. Though they are marketed for use under both composite and amalgam restorations, Albers states that the primary use for visible-light-cured liners is to protect dentin under posterior composite restorations. Thicker (greater than 2 mm) glass-ionomer bases may be applied over visible-light-cured or $Ca(OH)_2$ liners when indicated in stress-bearing restorations.

High strength and high modulus of elasticity (stiffness) are usually considered desirable properties for liners and bases to resist amalgam condensation forces and to contribute to the fracture resistance in a restoration (Farah, Hood & Craig, 1975; Tam & others, 1989). If difficulty is encountered in curing these materials due to depth of restorations or intraoral placement of the curing light, the physical properties could be altered and condensation of the chosen restorative could displace the lining material.

The purpose of this investigation was to evaluate the degree of polymerization of eight light-cured lining materials, measuring their microhardness by varying curing times and distances from the curing light.

Materials and Methods

The eight cavity lining materials selected for this study were: Prisma VLC Dycal and Timeline (L D Caulk Div, Dentsply International, Milford, DE 19963), Cavalite and XR-Ionomer (Sybron/Kerr, Romulus, MI 48174), Vitrabond (3M Dental Products, St Paul, MN 55144), G-C Fuji Lining LC (G-C Dental Industrial Corp, Tokyo, Japan), and Light Cured Zionomer (paste/paste and powder/liquid, Den-Mat Corp, Santa Maria, CA 93456). Knoop hardness testing was selected since this method has been shown to be an accepted predictor to estimate total monomer conversion (and thus completeness of cure) for light-cured composite materials (Rueggeberg & Craig, 1988).

A cured composite block to simulate dentin color was used as a standard curing background for the specimens. The circular Teflon mold with an internal diameter of 6 mm and thickness of 1 mm was placed over a plastic matrix strip on the background block and slightly overfilled with the liner. Another plastic matrix strip and a thin glass cover slip were positioned over the liner to produce a surface smooth enough to permit Knoop hardness measurements. A slight pressure was exerted on the cover glass to extrude any excess material. Copper rings were used to act as 3.0- and 6.0-mm spacers to vary the distances between the curing light and visible-light-cured liner.

Visible-light curing was accomplished with a Demetron VCL300 curing unit (Demetron Research Corp, Danbury, CT 06810). A curing tip with a diameter of 8.0 mm was used for all samples. The light source was tested for a constant output with a MACAM Radiometer (MACAM Photometrics, Livingston, Scotland) just prior to specimen preparation. After curing, hardness measurements were made immediately on the surface adjacent to the curing tip with a Knoop Hardness Tester (Leco Corp, St Joseph, MI 49085). Only one reading was obtained for each specimen due to the "dual cure" nature of the Vitrabond and XR-Ionomer materials. All specimens except XR-Ionomer were loaded with a 50-gram load for a dwell time of 20 seconds. The XR-Ionomer specimens required the use of a 10-gram load to obtain readings.

Nine experimental groups corresponding to the independent variables of time (20, 40, 60 seconds) and distance from the curing light (0, 3, or 6 mm) were established. Three specimens for each group for each material were prepared for a total of 216 specimens.

The data were analyzed by a two-way analysis of variance (ANOVA) and Tukey's multiple comparison procedure at the 0.05 level of significance.

Results

As shown in Figures 1-8, the lining materials tested varied greatly in Knoop hardness. Only Vitrabond exhibited a statistically significant interaction between time and distance of cure. However, examination of the plot for Vitrabond

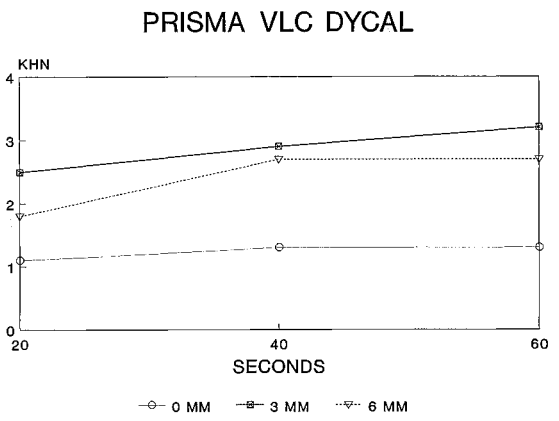

FIG 1. *Profile plot: Prisma VLC Dycal*

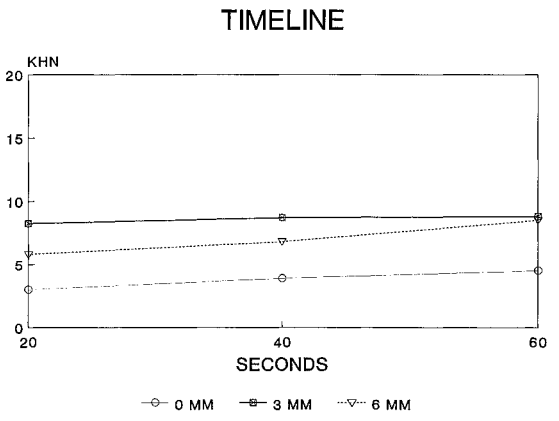

FIG 2. *Profile plot: Timeline*

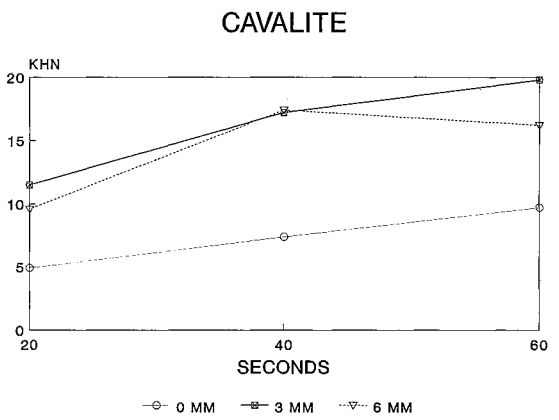

FIG 3. *Profile plot: Cavalite*

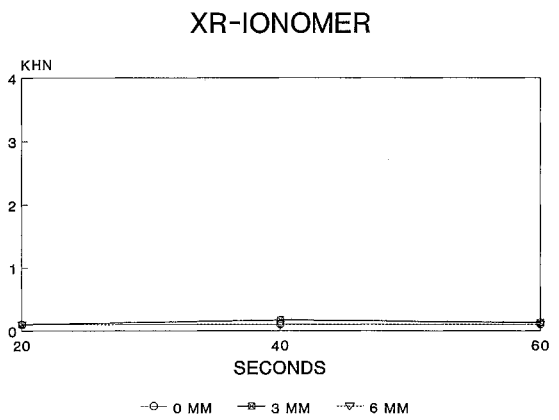

FIG 4. *Profile plot: XR-Ionomer*

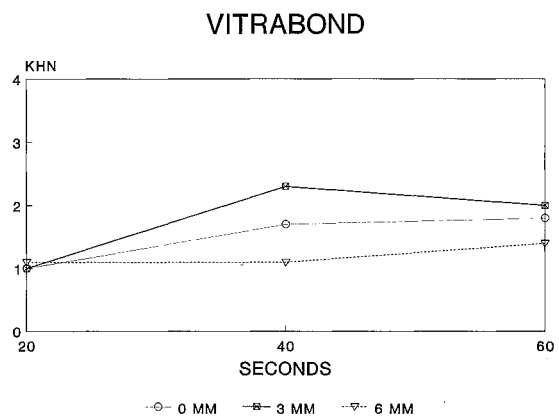

FIG 5. *Profile plot: Vitrabond*

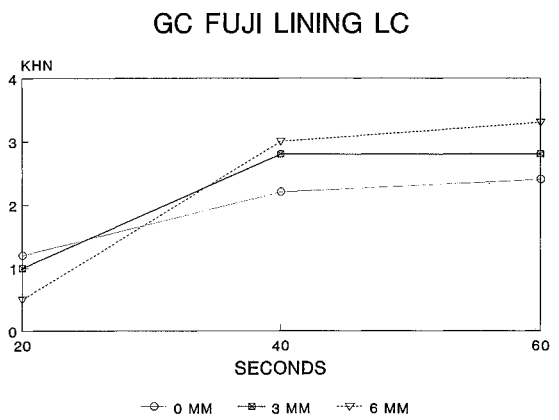

FIG 6. *Profile plot: G-C Fuji Lining LC*

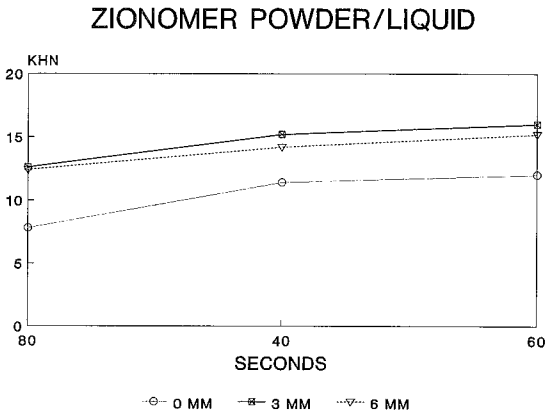

FIG 7. *Profile plot: Zionomer powder/liquid*

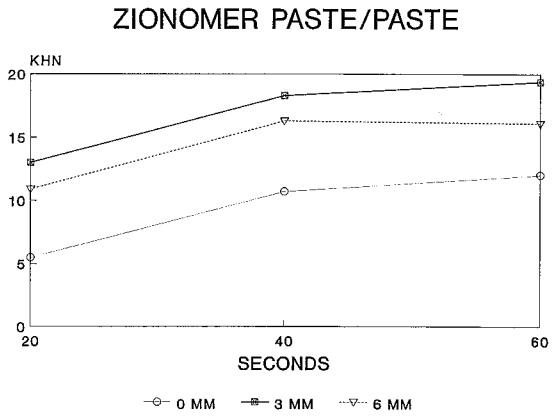

FIG 8. *Profile plot: Zionomer paste/paste*

Knoop Hardness Value Means

	Time (Seconds)			Distance (mm)		
Material	**20**	**40**	**60**	**0**	**3**	**6**
Prisma VLC	1.8 ± 0.7	2.3 ± 0.8	2.4 ± 0.7	1.3 ± 0.2	2.8 ± 0.4	2.4 ± 0.6
Timeline	5.7 ± 2.4	6.5 ± 2.1	7.3 ± 2.2	3.8 ± 0.7	8.6 ± 1.0	7.1 ± 1.3
Cavalite	8.7 ± 3.2	14.0 ± 5.2	15.2 ± 4.7	7.3 ± 2.2	16.1 ± 3.9	14.4 ± 4.0
XR-Ionomer	0.1 ± 0	0.1 ± 0	0.1 ± 0	0.1 ± 0	0.13 ± 0.05	0.1 ± 0
Vitrabond	1.0 ± 0.2	1.7 ± 0.6	1.7 ± 0.4	1.5 ± 0.4	1.7 ± 0.7	1.2 ± 0.2
G-C Lining	0.9 ± 0.4	2.6 ± 0.7	2.8 ± 0.7	1.9 ± 0.6	2.2 ± 1.0	2.3 ± 1.5
Zionomer P/L	11.0 ± 2.5	13.6 ± 1.8	14.4 ± 2.2	10.4 ± 2.0	14.6 ± 1.8	14.0 ± 1.6
Zionomer P/P	9.8 ± 3.5	15.1 ± 3.7	15.8 ± 3.5	9.4 ± 3.1	16.9 ± 3.4	14.4 ± 2.9

Underlined groups in the same row are not statistically different at $P < 0.05$; ± Standard Deviation, N = 3.

revealed an orderly interaction and no deviation from the overall trend in the curing behavior of the materials. The main effect variables of time and distance were analyzed separately (table). The values in the table represent Knoop hardness means for a time or distance averaged over the other independent variable.

Curing at a distance of 3 mm provided the highest Knoop hardness for all materials except one, G-C Fuji Lining LC. Only G-C Lining LC exhibited no difference in hardness with varying distances. The values obtained at the 3 mm distance were significantly higher than the 0 mm distance for the remaining seven materials.

Sixty-second cure times provided the highest mean Knoop hardness for all materials. However, when comparing 40- and 60-second cures there was no significant difference in hardness for any of the materials. In seven of the eight liners a 20-second cure resulted in a significantly lower Knoop hardness.

Discussion

Visible-light-cured lining materials must be adequately polymerized to exhibit clinically acceptable physical properties of strength and modulus of elasticity. These properties are important for proper support of amalgam restorations during condensation as well as during the amalgam setting reaction. If polymerization is compromised, a weak or flexible liner may predispose the amalgam restoration to tensile fracture. Lack of cross-linking and limited monomer conversion could conceivably lead to poor fit if light-cured liners are placed prior to fabrication of indirect composite or ceramic inlays and onlays. Stability throughout impression making, temporization, and cementation procedures requires adequate polymerization of these lining materials.

After statistical analysis, the data were normalized to compare curing trends. The highest mean Knoop hardness value obtained for each material was established as the norm and assigned a value of 1.0. All other values for the materials were expressed as a faction of this highest value. In this way poor polymerization could be readily identified.

It is evident from this data transformation that the hardness values from 3 and 6 mm exceed those obtained with the curing source as close as possible to the specimen (Fig 9). The reason for the increase in microhardness from the 0 mm to the 3 mm curing distance is unknown. Previous research by Kanca (1985) on posterior composite resins reported that surface hardness values varied little with changes in exposure time or distance (up to 4 mm). The findings of the present investigation

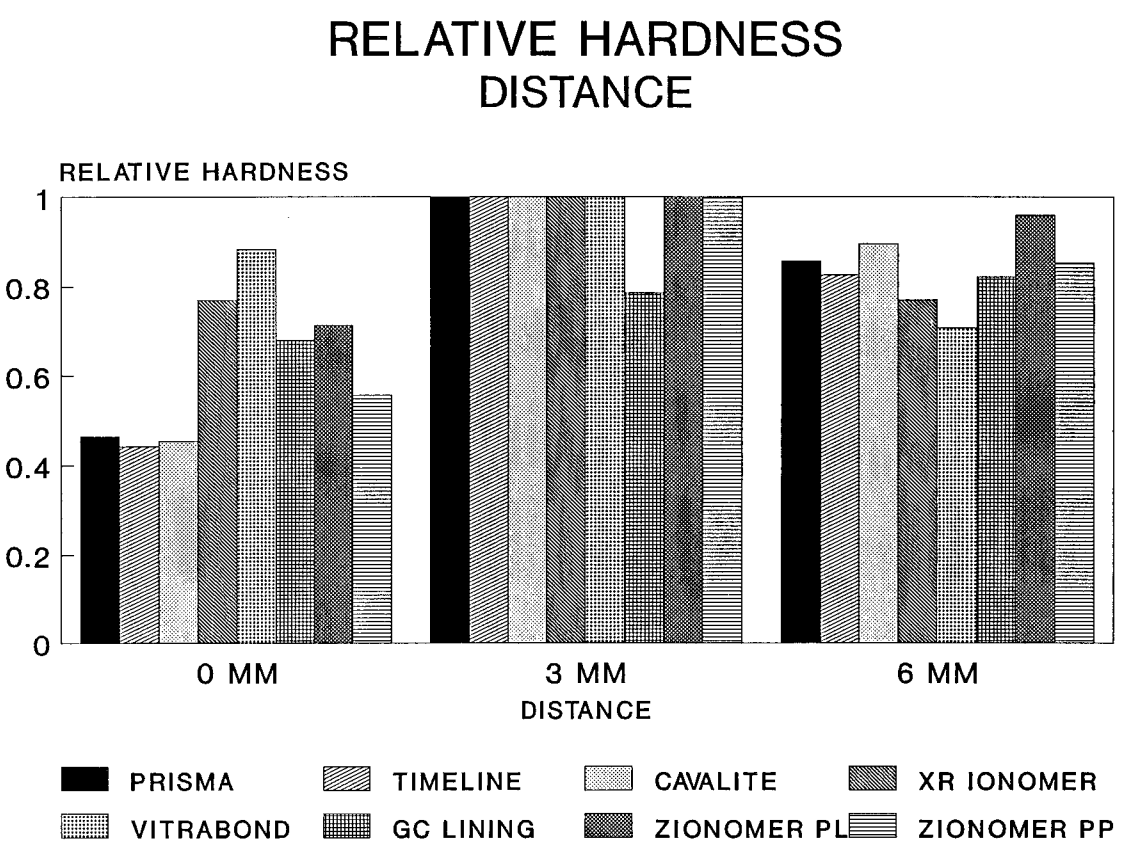

FIG 9. *Relative hardness versus distance from source*

are encouraging in that the cure of the visible-light-cured lining materials, used in recommended thicknesses, seems adequate at distances up to 3-4 mm away from the visible-light source. The diameter of the curing-light tip, recesses in preparations, and difficult intraoral maneuvering make this lack of distance sensitivity a desirable property for these materials.

Forty-second cure hardness values for all materials were not different than those obtained with a 60-second cure (Fig 10). The results of this study show that 20-second curing times for the liners yield significantly lower Knoop hardness values and less than optimum polymerization.

The Knoop hardness value varied greatly between materials, and operators should be aware that certain materials are quite soft immediately following exposure to the curing light. Specifically, XR-Ionomer exhibited very low hardness values after curing. A freshly placed amalgam over a thick base of this material may be at a higher risk of early tensile fracture. The manufacturers have responsibly recommended that XR-Ionomer be limited to a 0.5-1.0 mm thickness for cavity lining. If amalgam is the chosen restorative, and a thicker base is required, one of the harder setting materials (Cavalite, Timeline, or Zionomer) may be a more appropriate choice.

Since composite resin restorations do not usually fail by brittle fracture, the initial hardness of visible-light-cured liners may be less of a consideration when used with these restorative materials. For this application any of the tested materials, if manipulated properly, should be satisfactory. Clinicians should base

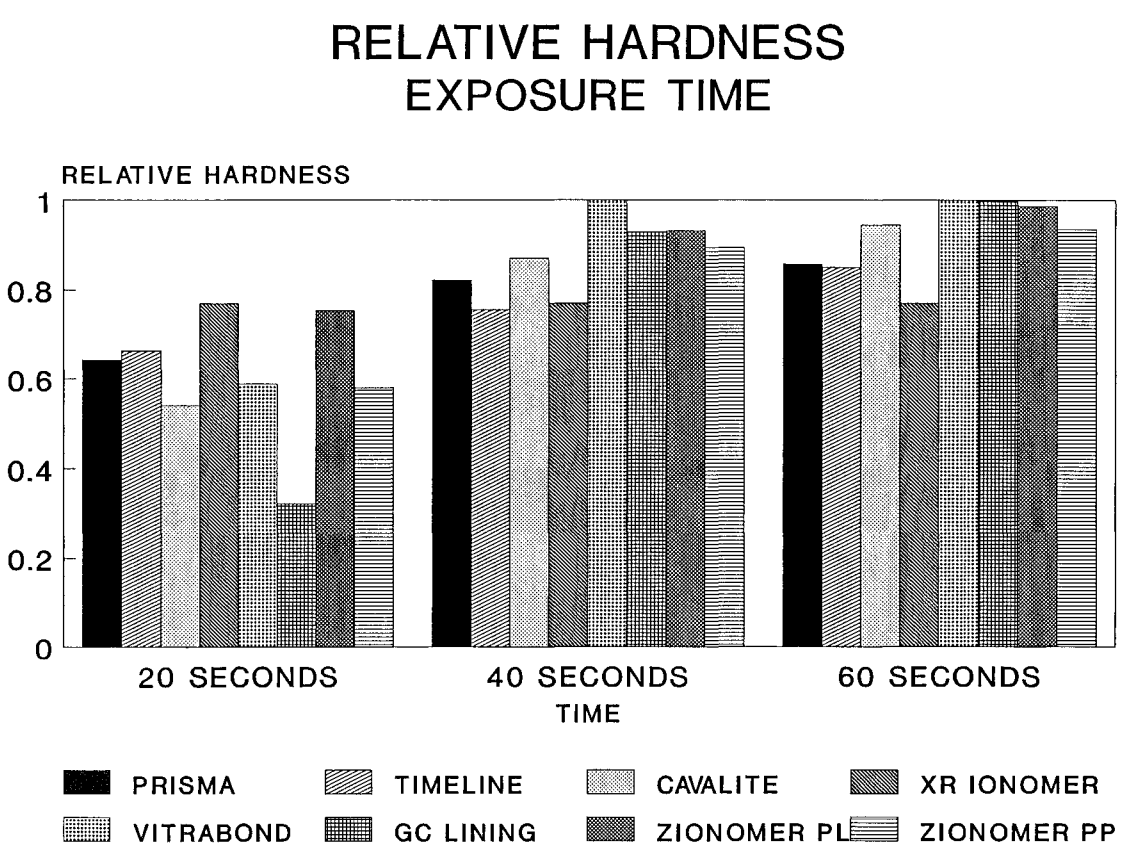

FIG 10. *Relative hardness versus exposure time*

their choice of a cavity liner on desired properties for individual clinical situations and maximize the advantages of each specific material. Hardness alone should not be the sole selection criterion.

Conclusions

1. When applied as recommended in thin layers for lining cavity preparations, visible-light-cured materials can be adequately cured to maximize polymerization and optimize physical properties.
2. A more complete cure was obtained if the tip of the light source was a minimum distance (up to 3 mm) away from the surface of the visible-light-cured liner.
3. Application of the curing light for at least 40 seconds resulted in a significantly higher Knoop hardness value, indicating a higher degree of polymerization than for specimens cured for 20 seconds.
4. Clinicians should be aware of the relative hardness values of these liners and apply them appropriately in clinical situations.
5. More study is indicated to explain the differences found in the Knoop hardness values between specimens cured at distances of 0 and 3 mm from the light source. The unique compositions combining glass-ionomer and resin chemistries provide properties that deserve further investigation.

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Effect of Air/Water Rinse versus Water Only and of Five Rinse Times on Resin-to-Etched-Enamel Shear Bond Strength

J B SUMMITT • D C N CHAN
J O BURGESS • F B DUTTON

Summary

This study compared the shear bond strength of composite resin bonded to etched, flattened enamel that had been rinsed for 0, 1, 2, 3, 5 or 20 seconds with either a water stream or an air/water spray. One hundred seventy-six molars were separated into mandibular and maxillary groups, then divided equally into 11 groups of 16 teeth each. The facial enamel surfaces were ground flat and etched for 20 seconds with 37% phosphoric acid gel. In one group, the etching gel was dried but not rinsed. In five groups the gel was rinsed with a direct stream of water at 22 psi. In the remaining five groups the gel was rinsed with an air/water spray (air at 53 psi, water at 22 psi). One tooth from each group was removed for scanning electron microscopy evaluation, leaving 15 specimens in each group for shear bond testing. Teflon tape with a 3 mm in diameter window was placed over each etched area, a light-curing liquid resin was applied and polymerized for 10 seconds, and a cylinder of light-curing composite resin was polymerized over the window. Specimens were thermocycled from 5 to 50 °C for 500 cycles (30-second dwell time). After 30 days' hydration at room temperature, the teeth were mounted and the composite resin cylinders were loaded in shear to failure with an Instron machine at a crosshead speed of 5 mm/min. Mean load to

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failure was calculated for each group. Specimens that were not rinsed had significantly ($P < 0.001$) less bond strength (mean 0.53 MPa) than any of the rinsed specimens (mean 18.7 MPa). Groups of specimens that were rinsed with either water or air/water spray for 1, 2, 3, 5 or 20 seconds were significantly stronger than specimens that were not rinsed, but rinsed groups were not significantly different from each other. A one-second rinse time with either water or air/water spray may be as effective as a 20-second rinse time if water is directed with adequate pressure at the etched surface. Scanning electron microscopy evaluation corroborated the findings of the shear bond tests.

LITERATURE REVIEW

Introduction

There has been a recent trend toward reduction of enamel etching time and rinsing time for bonding of composite resins. Literature concerning enamel etching is reviewed below to demonstrate the rationale for the methods used in this study.

The acid etching of enamel to allow bonding of resin polymers was introduced by Buonocore in 1955. Since then, the use of enamel bonding has been refined and today is accepted and relied on by the dental profession.

The original work of Buonocore (1955) involved the in vivo use of an 85% solution of phosphoric acid applied by rubbing the enamel surface for 30 seconds. He showed that when drops of acrylic restorative resin were bonded to etched enamel, they could only be removed mechanically. In 1968 Buonocore, Matsui and Gwinnett, using a 50% phosphoric acid preparation for one minute, bonded resin to etched enamel specimens, and reported an absence of microleakage using a mixture of basic fuchsin and radioactive sulfate. From this study, resin tag formation was reported as the mechanism for attachment of resin polymer to etched enamel.

Phosphoric Acid Concentration

Chow and Brown (1973) reported that a 50% phosphoric acid solution applied for one minute to an enamel surface, followed by a rinse with dry acetone, produced a precipitate of $Ca(H_2PO_4)_2 \cdot H_2O$ on the enamel surface. This precipitate, which in a clinical situation would be rinsed away with a water spray, was believed to protect teeth from greater dissolution by the acid during the etching process. These authors (Chow & Brown, 1973), along with Gwinnett and Buonocore (1965), expressed the view that low concentrations of phosphoric acid caused more etching because such a precipitate was not formed. Chow and Brown (1973) also reported that a concentration of less than approximately 27% phosphoric acid would result in the dissolution of hydroxyapatite to form calcium phosphate dihydrate, which would not be completely washed away in a clinical situation. However, the work of Barkmeier, Shaffer and Gwinnett (1986) supports that of Beech and Jalaly (1980) and suggests that bond strengths are not adversely affected when concentrations of phosphoric acid less than 30% are used to etch enamel.

Soetopo, Beech and Hardwick (1978) showed that with a one-minute etch time, enamel treated with concentrations of phosphoric acid in the range of 16% provided greater tensile bond strengths to resin than did enamel treated with a 40% solution of the acid.

Gottlieb, Retief and Jamison (1982), in Part 1 of a three-part report, used a one-minute etching time and found no significant differences in resin-to-enamel tensile bond strengths when concentrations of phosphoric acid etching solutions ranged from 10% to 60% in 10% increments. They did, however, find a significantly lower tensile bond strength when a 70% phosphoric acid solution was used. Specimens in the study received a 15-second tap water rinse. Part 2 of that study (Gross, Retief & Bradley, 1984) concentrated on microleakage of class 5 preparations in extracted premolars. Acid etching with 10% - 60% phosphoric acid reduced marginal leakage significantly; etching with a 70% solution of the acid did not significantly reduce microleakage. This supported the findings of Part 1 of the study. In Part 3 (Retief, Middleton & Jamison, 1985), the authors demonstrated that etching enamel increased the wetting of enamel with resin; greater wetting was demonstrated on surfaces etched with phosphoric acid concentrations of

10% - 60% compared to surfaces etched with 70% acid. Part 3 of the report thus supported Parts 1 and 2, and all three parts supported a 10% to 60% range of enamel etchant concentration.

Månson-Rahemtulla, Retief and Jamison (1984) used phosphoric acid concentrations similar to those used by Gottlieb and others (1982) and analyzed the depth of etch and the calcium dissolved by each phosphoric acid concentration. They demonstrated that the total amount of calcium dissolved and the depth of enamel etch increased with increases in phosphoric acid concentration and reached a maximum with the 40% solution. Further increases in acid concentration resulted in decreased calcium dissolution and decreased depth of etch.

Etching Time

In the past decade, adequate resin-to-enamel bond strength has been demonstrated with decreasing etch times. Mardaga and Shannon (1982) showed increased tensile bond strength with increased etching times using a 37% phosphoric acid solution for 15, 20, 30, and 60 seconds. In opposition to this finding, Beech and Jalaly (1980) reported no difference in shear bond strength with etch times of 5, 15, and 60 seconds, and Brännström, Malmgren and Nordenvall (1982) reported the results of an in vitro scanning electron microscopy study indicating that a 15-second enamel etch was adequate for good retentive conditions.

Two studies (Barkmeier, Gwinnet & Shaffer, 1985; Barkmeier, Shaffer & Gwinnett, 1986) reported that a 15-second etch provided as much shear bond strength as a 60-second etch. All groups in these studies received a 20-second rinse. Using a 15-second rinse after etching for 60 seconds or 15 seconds, Shaffer, Barkmeier and Kelsey (1987) found no difference in the degree of microleakage. Crim and Shay (1987) also demonstrated that a 15-second etch was as effective in eliminating microleakage as a 30- or a 60-second etch. Kinch and others (1981), in a clinical study of bonded orthodontic brackets, found no clinical disadvantage of a 15-second enamel etch compared to a 60-second etch. Tandon, Kumari and Udupa (1989) showed the 15-second etch time to be satisfactory for the enamel of primary teeth. These studies validated the effectiveness of a 15-second etch time to prepare enamel for bonding.

Rinsing Time

Soetopo and others (1978) reported increased tensile bond strengths with a rinse time of 60 seconds compared to shorter rinse times. Later Bates and others (1982) were able to demonstrate no difference in tensile bond strengths of specimens that were rinsed for 5, 10, or 30 seconds after a 60-second enamel etch.

Schulein, Chan and Reinhardt (1986) tested shear bond strengths when rinse times were varied. They used 60-second etch times followed by rinse times of 10, 20, 30, and 40 seconds. Shear bond strengths after rinse times of 20, 30, and 40 seconds were not significantly different from each other but were significantly stronger ($P < 0.05$) than shear bond strength after rinsing for 10 seconds.

Mixson and others (1989) compared the shear bond strength obtained by varying rinse volumes and air and water pressures. Specimens were gel-etched, then rinsed with one of 24 randomly assigned test conditions: 0, 2, 5, 10, 15, or 25 ml of water with air/water syringe pressures of 20/10, 20/40, 40/10, or 40/40. A statistically significant ($P < 0.05$) volume effect was found only between the no-rinse and each of the rinse groups. No statistically significant ($P < 0.05$) differences were seen between air and water pressure groups.

Phosphoric Acid Consistency and Method of Application

Brännström, Nordenvall and Malmgren (1978) compared a 37% phosphoric acid solution and 50% phosphoric acid gel and reported no difference in the enamel etch observed in scanning electron microscopy photomicrographs. Baharav and others (1988) found similar penetration of enamel when either a liquid or a gel etchant was used. Bates and others (1982) reported that acid application by dabbing, rubbing, or no agitation resulted in bond strengths that were not significantly different.

Other Factors

Depth of resin penetration into etched enamel does not correlate well with bond strength; other factors, such as wetting characteristics, viscosity of resin, and packing technique may play a more signficant role (Gwinnett, 1990). Soetopo and others (1978) showed that tag formation was not necessary for bonding composite resin to enamel etched with phosphoric acid.

Brännström and others (1978), using a scanning electron microscope analysis of the surface of bonded resin after decalcification of extracted teeth, showed that neither mechanical nor chemical cleaning of enamel prior to etching affected the appearance of the etched surface. In addition, they reported that a fluoride pretreatment that increased the surface enamel's fluoride concentration had no adverse effect on the etch as viewed with the scanning electron microscope. Schuermer, Burgess and Matis (1990) found that fluoride-pretreated enamel-composite resin bond was stronger than the cohesive strength of either the enamel or composite resin.

Olsen, Duke and Norling (1988) reported that mechanical reduction of enamel did not influence the shear bond strength of etched enamel. Ichiki and others (1990) found that varying time of air drying after rinsing etched enamel did not affect bond strength. Shay and others (1988) demonstrated no significant effect of age, race, or length of time from extraction on enamel solubility and etch.

Purpose

The purpose of this study was to determine the minimum effective rinse time, with water or air/water spray, for optimum shear bond strength of composite resin bonded to etched enamel.

MATERIALS AND METHODS

Specimen Selection

One hundred seventy-six extracted molar teeth were collected and separated into groups of maxillary and mandibular molars. They were further divided into 11 groups of 16 teeth, with an equal distribution of maxillary and mandibular molars in each group. One specimen was withdrawn from each group for scanning electron microscopy evaluation. The other 15 specimens in each group were used for shear bond testing as described below.

Preparation of Specimens for Shear Bond Testing

Roots were notched and the facial surfaces of the molars flattened and polished to 320-grit on a polisher/grinder (Polimet Polisher, Buehler, Ltd, Evanston, IL 60204). Enamel was etched for 20 seconds using a 37% phosphoric acid gel (Mirage FLC Enamel Etching Gel, Mirage Dental Systems, Kansas City, KS 66101). Rinsing was accomplished as shown in Table 1. The water and air for rinsing the

Table 1. Rinse Durations, Air and Water Pressures, and Water Volumes for Each Test Group

Group	Rinse Duration	Mean (SD) Air Pressure (psi)	Mean (SD) Water Pressure (psi)	Mean (SD) Water Volume (ml)
1	No rinse	54.1 (0.4)	NA	NA
2a	1 second, water	NA	21.9 (0.5)	1.5 (0)
2b	1 second, air/water	53.4 (0.9)	21.9 (0.4)	1.3 (0.3)
3a	2 seconds, water	NA	21.6 (0.7)	3.2 (0.3)
3b	2 seconds, air/water	52.7 (0.9)	21.5 (0.6)	3.1 (0.3)
4a	3 seconds, water	NA	22.2 (0.8)	5.1 (0.5)
4b	3 seconds, air/water	53.4 (1.1)	21.6 (0.7)	4.9 (0.4)
5a	5 seconds, water	NA	21.8 (0.4)	10.1 (0.4)
5b	5 seconds, air/water	54.0 (1.1)	22.1 (0.4)	9.5 (0.5)
6a	20 seconds, water	NA	22.2 (0.4)	36.3 (1.2)
6b	20 seconds, air/water	52.6 (1.1)	22.3 (0.5)	35.7 (1.2)

etched enamel surfaces were provided using a three-way syringe (Adec, Inc, Newberg, OR 97132). Water and air pressures were monitored using Adec pressure gauges. After thorough drying of each specimen with air, a piece of Teflon tape (Berghof/America, Concord, CA 94524) with a 3 mm in diameter window was applied to the center of the flattened, etched enamel of each molar. A liquid resin (Universal Bond 2 Adhesive, L D Caulk Division, Dentsply International, Milford, DE 19963) was painted on the exposed enamel circle with a small brush (L D Caulk) and polymerized for 10 seconds using a visible light source (Optilux 400, Demetron Research Corp, Danbury, CT 06810). A Teflon cylinder (6.5 mm outer diameter, 3 mm inner diameter, 6.5 mm long) (Berghof/America) was positioned over the window in the Teflon tape, and yellow sticky wax (Sybron/Kerr, Romulus, MI 48174) was used to lute the cylinder in place (Fig 1). Composite resin (Prisma APH, Universal Shade, L D Caulk) was inserted into the cylinder to a depth of 4 mm and polymerized for 60 seconds using an Optilux 400 light. Specimens were thermocycled from 5 to 50 °C for 500 cycles with a 30-second dwell time and stored in water for 30 days at room temperature. Using a fixture to provide precise horizontal positioning of the cylinders, teeth were embedded in Cerrobend Alloy (Cerro Metal Products, Bellefonte, PA 16823) confined in cylinders of polyvinyl chloride tubing (Fig 2).

Shear Bond Testing

Specimens were stored in tap water when not being prepared or tested. Shear bond testing, loading each composite resin cylinder until failure, was accomplished using a chisel-shaped blade (Fig 3) in an Instron Model 1125 (Instron Corp, Canton, MA 02021) at a crosshead speed of 5 mm/minute.

Scanning Electron Microscope Views

In one molar per group, instead of bonding resin to the etched enamel, the etched surface was viewed using a scanning electron microscope (JSM-840A, JEOL Ltd, Tokyo, Japan).

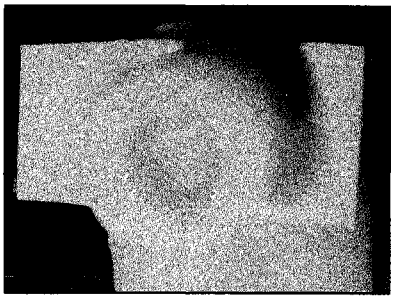

FIG 1. *Teflon tape on flattened facial enamel of molar, Teflon cylinder sticky waxed in place, with cylinder containing composite resin ready to be polymerized*

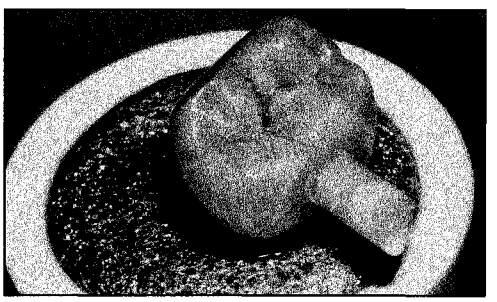

FIG 2. *Resin cylinder bonded to flattened enamel surface of molar that has been mounted for testing*

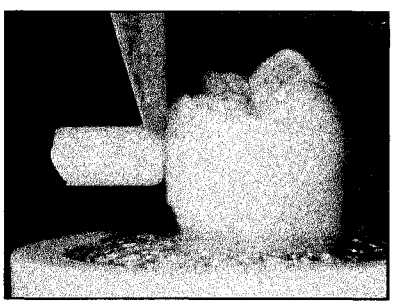

FIG 3. *Chisel-shaped blade of Instron Testing Machine in place to load composite resin cylinder to failure*

RESULTS

Shear Bond Tests

The failure load (MPa) was recorded for each specimen. Mean shear bond failure loads for each group are summarized in Table 2. The data were analyzed using a one-factor analysis of variance (ANOVA). A Tukey B post-hoc test was used to determine significance of intergroup differences. Groups with a 1-, 2-, 3-, 5-, or 20-second rinse with either water or air/water spray were not significantly different. The group that was not rinsed was significantly weaker ($P < 0.001$) than any group that was rinsed.

Scanning Electron Microscopy Views

A scanning electron micrograph (X1000) of the enamel surface that was etched but not rinsed showed a fairly complete coat of the dried etchant on the surface (Fig 4). Scanning electron micrographs (X1000) of the rinsed specimens demonstrated similar enamel etch patterns. The etched specimens that had been rinsed for one second with water only showed a very small amount of debris remaining on the etched enamel surface (Fig 5a). All specimens rinsed with air/water spray and all specimens rinsed for more than one second

Table 2. Shear Bond Failure Load (MPa) for Each Test Group

Group	Rinse Duration	Mean (SD) Load to Fracture (MPa)
1	No rinse	0.5 (0.9)*
2a	1 second, water	17.5 (3.7)
2b	1 second, air/water	18.4 (3.6)
3a	2 seconds, water	18.8 (3.6)
3b	2 seconds, air/water	16.8 (3.0)
4a	3 seconds, water	17.9 (3.6)
4b	3 seconds, air/water	19.3 (4.8)
5a	5 seconds, water	20.2 (4.3)
5b	5 seconds, air/water	18.3 (3.7)
6a	20 seconds, water	19.8 (4.3)
6b	20 seconds, air/water	19.8 (6.3)

*Group 1 was significantly weaker ($P < 0.001$) than the other groups. The other groups were not significantly different from each other.

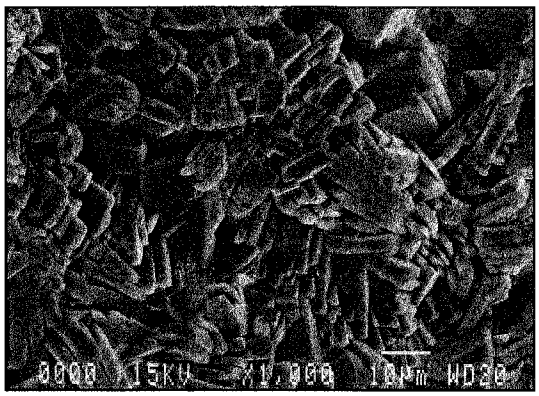

FIG 4. *Unrinsed etched enamel with etchant and etch products dried on the etched enamel surface, SEM photomicrograph (X500)*

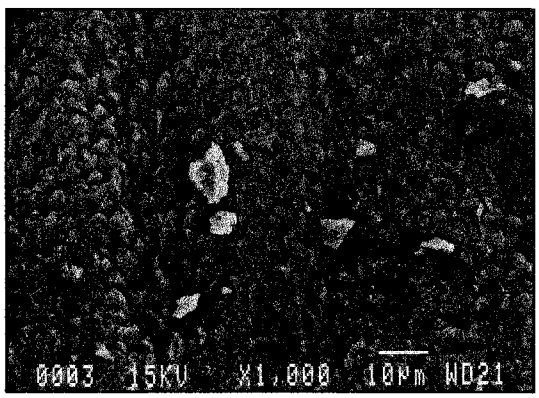

FIG 5a. *Etched enamel that had been rinsed for one second with stream of water, SEM photomicrograph (X500)*

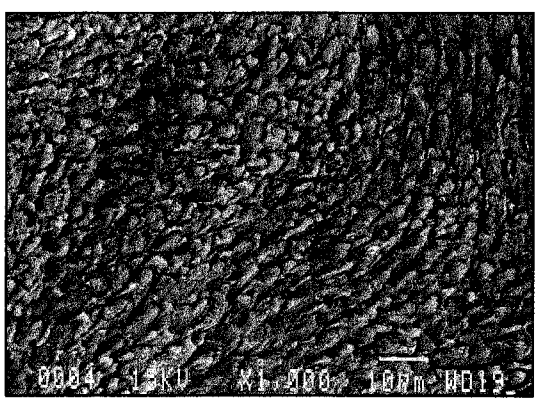

FIG 5b. *Etched enamel that had been rinsed for one second with air/water spray, SEM photomicrograph (X500)*

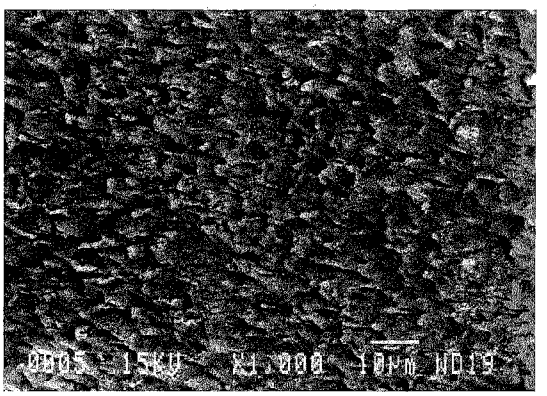

FIG 6a. *Etched enamel that had been rinsed for two seconds with stream of water, SEM photomicrograph (X500)*

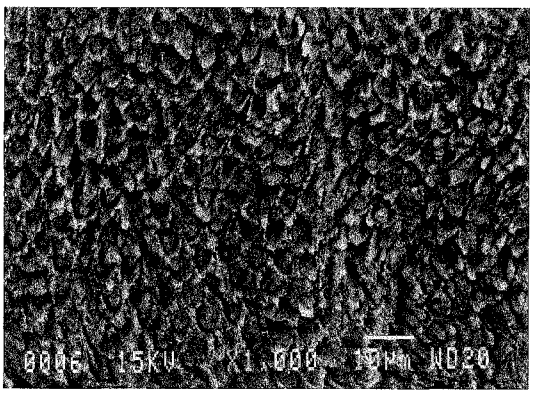

FIG 6b. *Etched enamel that had been rinsed for two seconds with air/water spray, SEM photomicrograph (X500)*

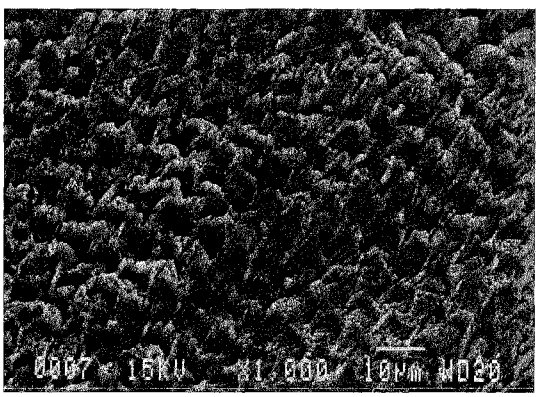

FIG 7a. *Etched enamel that had been rinsed for three seconds with stream of water, SEM photomicrograph (X500)*

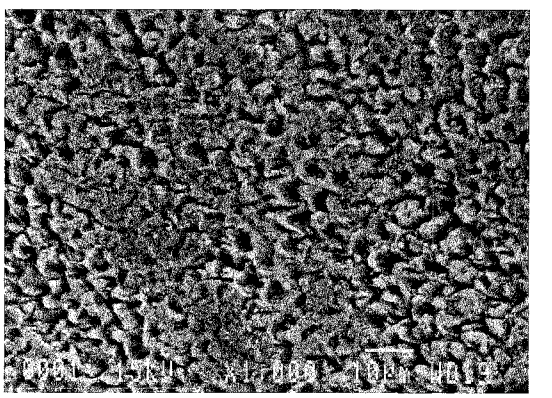

FIG 7b. *Etched enamel that had been rinsed for three seconds with air/water spray, SEM photomicrograph (X500)*

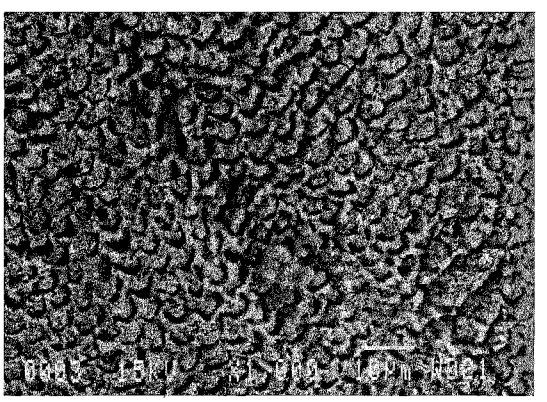

FIG 8a. *Etched enamel that had been rinsed for five seconds with stream of water, SEM photomicrograph (X500)*

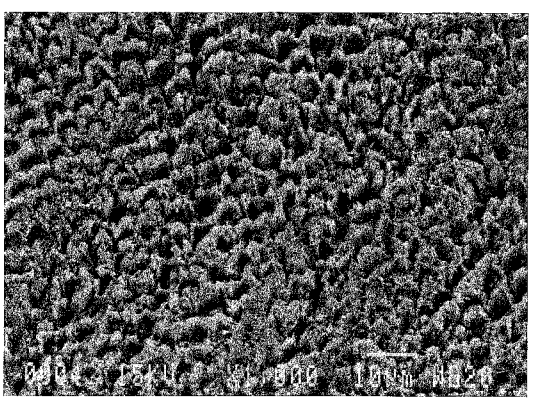

FIG 8b. *Etched enamel that had been rinsed for five seconds with air/water spray, SEM photomicrograph (X500)*

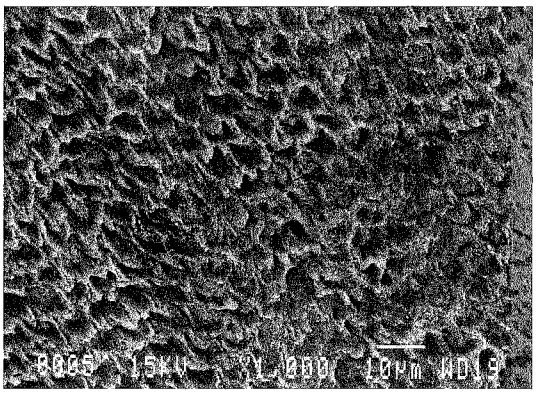

FIG 9a. *Etched enamel that had been rinsed for 20 seconds with stream of water, SEM photomicrograph (X500)*

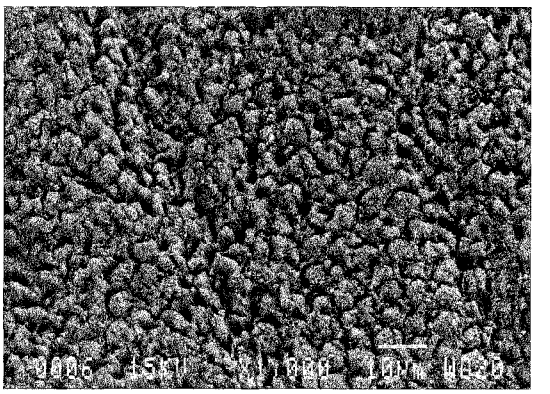

FIG 9b. *Etched enamel that had been rinsed for 20 seconds with air/water spray, SEM photomicrograph (X500)*

showed clear etched surfaces with no apparent debris (Figs 5b, 6 - 9).

DISCUSSION

Since acid etching of enamel was first used to retain resin restorations (Buonocore, 1955), investigators have evaluated acid concentrations, etching times, and rinsing times. The work of a few investigators led to the common clinical practice of using a 35% to 50% concentration of phosphoric acid in a one-minute etch followed by a one-minute rinse (Buonocore, 1955; Soetopo & others, 1978). However, in the 1980s, the work of several investigators (Brännström & others, 1982; Bates & others, 1982; Barkmeier & others, 1985 & 1986; Schulein & others, 1986; Shaffer & others, 1987; Crim & Shay, 1987; Kinch & others, 1981; Tandon & others, 1989; Mixson & others, 1989) showed that a reduced etch time and a reduced rinse time would provide adequate retention of resin to enamel.

Mixson and others (1989) used an air/water spray, with varied air and water pressures, to rinse etched enamel. They showed that, at water pressures of 10 or 40 psi, combined with air pressures of 20 or 40 psi, a water volume of 2 ml produced shear bond strengths equal to those obtained when greater volumes of water, up to 25 ml, were used. They also showed that rinsing efficiency was not affected by varying the pressures of the air and water used.

The air pressure of approximately 53 psi used in this study was somewhat higher than the air pressures used in the Mixson and others (1989) study. Our water pressure of approximately 22 psi fell between the 10 psi and 40 psi water pressures used by the Mixson group.

This study added the element of etching time and of the use of water alone compared with the air/water sprays that Mixson and others (1989) used. Our study showed no effect on shear bond strength or the appearance of the etched surface (on scanning electron micrographs) from air/water spray being used, compared to water alone. Additionally, time of rinse did not affect bond strength, with a one-second rinse as effective as rinse times of two or more seconds. This finding differs from Schulein and others (1986), who reported that a rinse time of 20 seconds or more yielded bond strengths significantly greater than a 10-second rinse. The difference may lie in the different etch times used. The 60-second etch time used in the Schulein and others (1986) study may allow more precipitate to form, thus requiring a longer rinse time. Our finding that a small volume of water (at 22 psi water pressure and 53 psi air pressure for one second) in an air/water spray provides an adequate rinse supports the findings of Mixson and others.

The absence of any appreciable bond to enamel with the no-rinse group was expected. When the etching gel was not rinsed from the etched enamel, it was apparent that the residue of dried gel and dried etch product that remained on the surface inhibited bonding, perhaps by preventing penetration of the resin

into the etched enamel. Eleven of the 15 specimens in the no-rinse group dropped off either during thermocycling or during the hydration period. Scanning electron microscopy examination of the etched and dried surface confirmed that the dried etchant residue remained on the etched surface and prevented mechanical bonding of the resin with the etched surface. On the other hand, all rinsed surfaces appeared to be essentially clean, a finding that correlates with the bond strengths established on those surfaces.

Recently a trend has developed toward decreased etch times and decreased rinse times. Taking into consideration the findings of this study and the findings of Mixson and others (1989), it is apparent that rinsing just long enough to remove any grossly evident etching gel from the surface of the etched enamel is also long enough to provide a clean etched surface and unimpeded bonding. This study and the Mixson study were performed with smooth surfaces that were readily rinsed. Etched walls of cavity preparations might require longer rinsing times and variation in the direction of the rinse, but rinse times longer than three to five seconds for any cavity preparation would seem to be unnecessary. The effect of the short rinse time on microleakage has yet to be investigated.

CONCLUSIONS

1. Rinsing the gel etchant from a smooth enamel surface for one second with a stream of water at 22 psi produced shear bond strengths not significantly different from those produced by longer rinse times or by rinsing with an air/water spray (air 53 psi, water 22 psi).
2. Scanning electron micrographs confirm that essentially all of the etching agent was rinsed from the etched surface in one or more seconds by either water alone or an air/water spray.
3. One- to five-second rinse times per tooth surface with either a stream of water or an air/water spray should adequately remove the etching gel from the etched enamel surface to provide adequate bonding of composite resin.

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The Retention of Amalgam and Composite Resin by a Smooth, Reverse-tapered Pin

W W BRACKETT • J H BAILEY

Summary

In this study, the retention of composite resin and amalgam by a smooth, reverse-tapered pin was compared to that of threaded pins. The smooth pin was significantly lower in retention than the threaded pins for each material, and caused a greater frequency of failure of the restorative material than the threaded pins. The newer smooth pin is probably not an improvement over the conventional threaded design.

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Introduction

Stainless steel pins have long been used to enhance the retention and resistance of extensive restorations. Although various diameters of pin have long been available, Durkowski and others (1982) have shown that pins 0.6 mm in diameter provide the best balance of minimal risk to the pulp and axial stiffness. More corrosion-resistant titanium alloy pins have become available in recent years and retain amalgam almost as effectively as stainless steel pins (Brackett & Johnston, 1989).

The retention of 0.6 mm pins in dentin ranges from 12 to 25 kg (Moffa, Razzano & Doyle, 1969; Butchart, 1987; Van Nieuwenhuysen & Vreven, 1985; Eames & Solly, 1980; Dilts, Welk & Stovall, 1968). This range is also the optimum retention of restorative material by pins, since retention much beyond this range would be superfluous.

The area of the pin intended to retain the restorative material has been threaded or serrated in all previous threaded-pin systems. Recently, a new titanium alloy pin with a smooth, reverse-tapered retentive area (Max^{R} pin, Whaledent International, New

York, NY 10001) has been introduced. The retentive area of this new pin is 1.5 mm in length, which is shorter than the optimum length for amalgam (Brackett & Johnston, 1989; Podshadley,1990) and composite resin (Podshadley, 1989) found in previous studies.

In this study, retention of composite resin and amalgam by Max^R pins was compared to that of pins of more traditional design and composition. To evaluate the effect of their relatively short length on retention, 0.6 mm Max^R pins were compared to 0.6 mm threaded pins of 2.75 mm standard length and of a similar titanium alloy. As an evaluation of the effectiveness of smooth, reverse-tapered geometry of the Max^R pin, retention was compared to that of 0.6 mm threaded pins trimmed to a 1.5 mm length, but of the stronger stainless steel type (Table 1).

Materials and Methods

A representative posterior composite resin (VisioMolar, ESPE/Premier Sales Corp, Norristown, PA 19401) and high-copper amalgam (Valiant PhD, L D Caulk, Div of Dentsply International, Milford DE 19963) were used for this study. Retention of the materials by the various pins was measured by embedding the pins in the smaller end of tapered cylinders of restorative material, centered and parallel to the long axis of the cylinder. These cylinders were 6 mm in length and 4-5 mm in diameter. The sample size was 10.

Pins were positioned in the specimen molds with a slightly oversized pin channel prepared in a Plexiglas block. The block was indexed such that pins could be uniformly positioned. Both restorative materials were hand-condensed in six increments into the mold. Each increment of composite resin was cured for one minute.

All specimens were stored at ambient room temperature for one week. To evaluate retention, the tapered cylindrical specimens were placed in a similarly tapered sleeve and the pins secured in a custom holding device (Fig 1). Tensile load was applied to the pins with a universal testing machine (MTS Systems Corp, Minneapolis, MN 55344) at a crosshead speed of 0.25 mm/min.

The resulting load at failure of the specimens was statistically analyzed using an analysis of variance and Tukey's Studentized Range test, at a confidence level of 0.05. Type of failure, categorized as failure of the pin or failure of the restorative material (Fig 2), was also recorded.

Table 1. Pin Types and Dimensions

Pin Type	Brand Name (diameter)	Length
stainless steel, threaded	Minim, Link Plus (0.6 mm)	1.5 mm*
titanium alloy, threaded	Minim, Link Plus (0.6 mm)	2.75 mm **
titanium alloy	Max (0.6 mm)	1.5 mm **

All pins manufactured by Whaledent International, New York, NY 10001.
*Trimmed to length
**Manufacturer's standard length

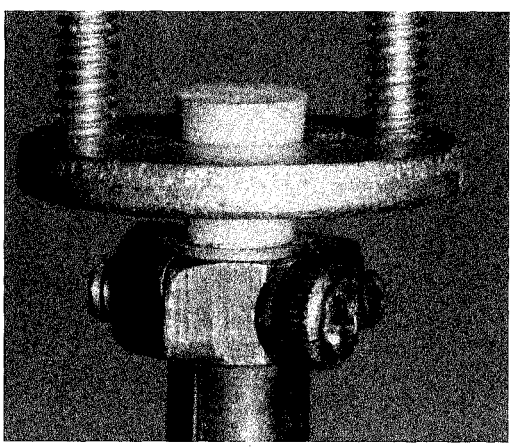

FIG 1. *Tapered cylindrical specimen in tapered sleeve with pin secured in custom holding device (original magnification X0.5625)*

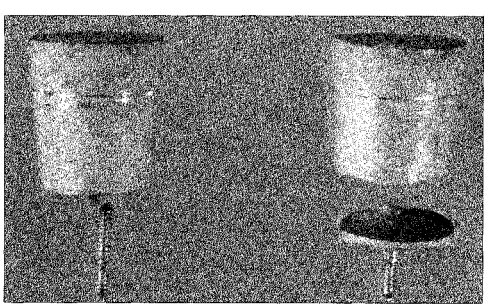

FIG 2. *Modes of failure: failure of pin (left) and failure of restorative material (right) (original magnification X0.5)*

Results

The average load at failure for all groups is presented in Table 2 for the amalgam specimens and Table 3 for the composite resin specimens, as is the frequency of both types of failure. For both amalgam and composite resin, the Max^R pins failed at significantly lower loads than either the stainless steel or titanium alloy threaded pin (Figs 3, 4). The Max^R pins placed in amalgam exclusively

Table 2. Retention of Amalgam (n = 10)

Pin Type (length)	Mode of Failure: Pin	Mode of Failure: Material	Load kg (sd)
titanium alloy, Link Plus (2.75 mm)	10	0	27.8 (3.4)
stainless steel, Link Plus (1.5 mm)	6	4	22.4 (1.3)
titanium alloy, Max (1.5 mm)	0	9*	14.3 (1.2)

All differences in load significant (ANOVA, Tukey's Studentized Range Test, $P < 0.05$)
*specimen damaged during testing

Table 3. Retention of Composite Resin (n = 10)

Pin Type (length)	Mode of Failure: Pin	Mode of Failure: Material	Load kg (sd)
titanium alloy, Link Plus (2.75 mm)	9	1	29.2 (0.3)
stainless steel, Link Plus (1.5 mm)	7	3	23.8 (1.3)
titanium alloy, Max (1.5 mm)	3	7	19.5 (2.2)

All differences in load significant (ANOVA, Tukey's Studentized Range Test, $P < 0.05$)

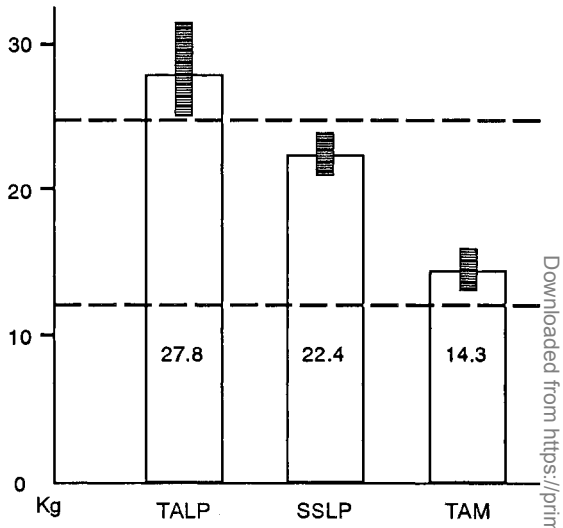

FIG 3. *Average failure forces for retention of amalgam. All means significantly different (ANOVA, Tukey's Studentized range test, P ≤ 0.05). The 12-25 kg range is represented by broken horizontal lines. TALP = titanium alloy, Link Plus; SSLP = stainless steel, Link Plus; TAM = titanium alloy, Max.*

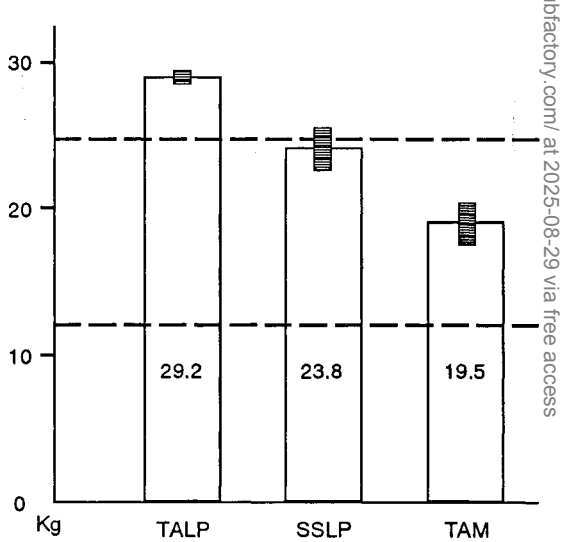

FIG 4. *Average failure forces for retention of composite resin. All means significantly different (ANOVA, Tukey's Studentized range test, P ≤ 0.05). The 12-25 kg range is represented by broken horizontal lines. TALP = titanium alloy, Link Plus; SSLP = stainless steel, Link Plus; TAM = titanium alloy, Max.*

produced failure of the restorative material, while failure of the material occurred seven times in the resin group. Failure occurred almost exclusively in the 2.75 mm titanium alloy pins for both restorative materials, while the 1.5 mm stainless steel pin produced a mix of failure types, with failure of the pin predominating for both materials.

Discussion

Retention of restorative materials by pins should compare favorably with the previously cited range of 12 - 25 kg. Retention of both amalgam and composite resin by the standard length titanium alloy threaded pins exceeded 27 kg. Retention of both materials by the 1.5 mm stainless steel threaded pin exceeded 22 kg, while the Max^R pin retained amalgam and composite resin at 14 and 19 kg respectively.

The relatively low retentive values found for the Max^R pin, especially for amalgam, raise concerns about the length of this pin and its ability to retain restorations receiving heavy forces. The predominance of failures in the restorative material for the Max^R pin, as compared to a slight predominance of pin failures for the stronger and equal-length stainless steel pins, suggests that the geometry of the Max^R pin is not the optimum interface between pin and restorative material. As is the case with any in vitro study, concerns about the Max^R pin raised in this study should be further appraised via clinical trials.

Conclusions

The retention of both amalgam and composite resin by Max^R pins is significantly lower than that of threaded stainless steel pins of comparable length and that of threaded titanium alloy pins of standard length.

The smooth, reverse-tapered geometry of the Max^R pin is probably not as compatible with restorative materials, particularly amalgam, as a threaded design.

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The Effect of Retention Grooves on Posterior Composite Resin Restorations: an in Vitro Microleakage Study

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Summary

An in vitro study was undertaken to evaluate the effect of retention grooves on the gingival marginal seal of class 2 posterior composite resin restorations when filled by the bulk and incremental techniques. Class 2 cavities were prepared in 40 extracted molar teeth. Retention grooves were prepared at the axioproximal line angles in 20 teeth. The teeth were then filled with Herculite posterior composite resin using the bulk and incremental techniques. Microleakage was assessed by radioisotope (I^{125}) diffusion at the gingival margin, quantitatively by radiation counting on an I^{125} Gamma Counter and qualitatively by autoradiographs. Those class 2 cavities that were prepared with retention grooves and filled in layers showed the least radioisotope diffusion (a mean radiation count of 1588.5), while bulk insertion of the composite resin in cavities without retention grooves showed the most microleakage (mean count of 6092.4).

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INTRODUCTION

The remarkable progress achieved in the field of dental material technology has enabled the profession to cater to patients' ever-increasing esthetic requirements. Today the esthetic impact of restored teeth is a matter of great concern to the prospective patient. With the successful placement of virtually undetectable composite resin restorations in anterior teeth, there is now a marked increase in the

use of resin-based materials in the restoration of posterior teeth.

As with any restoration, an optimal marginal adaptation of the composite restoration to the tooth structure is of great importance to its success. Most of the currently available restorative materials do not truly adhere to the tooth structure. Composite resins being no exception, microleakage at the tooth/resin interface is only to be expected. The marginal seal is further threatened by the stress of polymerization shrinkage at the gingival margin of the approximal box in class 2 restorations, the Achilles' heel of posterior composite restorations. This study was designed to evaluate the effect of retention grooves on an incremental buildup and on polymerization in a single mass, in terms of marginal microleakage at the gingival wall of class 2 light-cured posterior composite resin restorations.

MATERIALS AND METHODS

Forty-four caries-free freshly extracted molar teeth were selected at random. Each tooth was cleaned and carefully examined to eliminate those teeth with cracks, or defects in the enamel. The selected teeth were then stored in 10% formalin.

Class 2 (mesio-occlusal) standardized cavity preparations were prepared in 42 teeth according to the following specifications (Fig 1):

1) Occlusal portion: width of occlusal portion at the transverse/oblique ridge = 2 mm, depth of pulpal floor at the central fossa region = 2 mm;

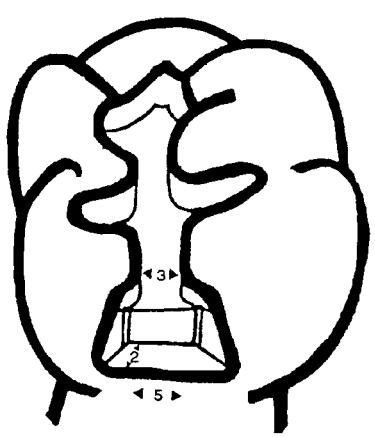

FIG 1. *Schematic representation of cavity outline*

2) Approximal box: buccolingual width of gingival seat = 5 mm, occlusal width = 2.5 - 3 mm, axial depth = 2 mm; and

3) Gingival seat: located 1 mm occlusal to the cementoenamel junction, so that all borders of the preparation are surrounded by enamel.

Forty prepared teeth were divided into four equal groups with 10 teeth in each group:

Group 1: Cavities prepared with retention grooves and restored with Herculite composite resin (Sybron/Kerr, Romulus, MI 48174) and polymerized in one single mass;

Group 2: Cavities prepared without retention grooves and filled with composite resin and polymerized in one single mass;

Group 3: Cavities prepared with retention grooves and filled with composites in layers. Each layer was light-activated before the next layer was applied;

Group 4: Cavities prepared without retention grooves and filled and activated in layers.

The remaining four teeth served as controls: two prepared teeth (one with grooves and one without grooves) filled with temporary stopping (a material known for its poor marginal seal) served as positive controls, while two unprepared teeth served as negative controls.

Retention grooves (as used in Groups 1 and 3) were prepared as suggested by Ben-Amar, Metzger and Gontar (1987). One retention groove was placed buccolingually in the dentin of the gingival seat in each preparation. This groove was placed with a small round bur with a diameter of 0.5 mm. Two additional grooves were placed at the axiofacial and axiolingual line angles with a taper-fissure diamond point and accentuated with the small round bur used for the gingival grooves.

Because of the inaccessibility of measuring the retention grooves directly, an indirect approach using a rubber-base impression of the preparation was used. The dimensions of the grooves in the impression were measured with a vernier caliper (Svenska Dental Instrument AB, Stockholm, Sweden).

The enamel margins at the occlusal cavosurfaces and approximal embrasures of all the preparations were then etched with a colored gel-etchant (37% phosphoric acid) (Kerr/Sybron) for 60 seconds, after which they were washed off with distilled water and air-dried. Colored etchant allows limiting the etchant only to the enamel margins and

prevents inadvertent etching and irritation of the dentin.

The etched enamel margins and internal walls of the preparations were coated with two layers of Bond Lite dentin enamel bonding agent (Kerr/Sybron) and polymerized with a visible-light curing unit (Prisma Lite, L D Caulk, Division of Dentsply International, Milford, DE 19963) for 40 seconds.

The preparations were then restored with Herculite light-cured posterior composite resin (Kerr/Sybron), and a Tofflemire matrix band and holder (Teledyne Getz, Elk Grove Village, IL 60007) was used to contain the composite resin while condensing. The restorations were done in the following manner.

Bulk-packing technique: In Groups 1 and 2, the material was introduced into the cavity in five layers. Initial placement was at the gingival floor, and subsequent increments were placed occlusally. Each layer was hand-condensed before the next layer was applied. Then the whole mass was polymerized in one single mass: 40 seconds on the occlusal surface, and after removing the matrix, 40 seconds on the approximal side.

Incremental-packing technique: When polymerized in layers, each of the five layers, each time, was light-cured from the occlusal direction for 40 seconds before the next layer was introduced and condensed (Fig 2). After completion of the incremental filling, the matrix band was removed and the approximal surface of the restoration was again light-cured for 40 seconds from an approximal direction. Finishing of the completed restoration was accomplished with finishing tungsten carbide burs for shaping and contouring (12-fluted burs) and fine-finishing (30-fluted burs). Surface luster was obtained with composite polishing pastes.

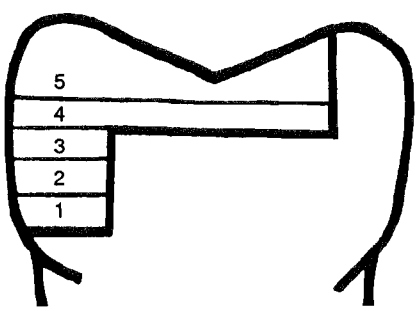

FIG 2. *Schematic representation of incremental layers of composite resin*

The restored teeth were incubated in saline at 30 °C for seven days to allow complete setting reactions of the restoration in a simulated oral environment. Thermocycling was conducted by transferring the specimens between two water baths (4 °C and 60 °C): two minutes in each bath with a 15-second transfer time. The specimens were subjected to 40 such cycles. The teeth were then dried and coated with a thin layer of acrylic lacquer (nail varnish) and sticky wax, exposing only 1 mm around the gingival margin of the restoration to allow radioisotope diffusion at this margin only.

The specimens were immersed in the radioisotope (I^{125} in sodium iodide solution) for 48 hours. A strength of 2.5 microcurie/milliliter was used, as this gave readings that were sufficient for significant statistical analysis, after which meticulous decontamination steps were taken to remove radionucleoids on the surface of the specimen, and the coatings on the teeth were removed.

Gingival marginal leakage was assessed quantitatively by the number of disintegrations/seconds (gamma pulses) emitted by the radioisotope that had penetrated the gingival tooth/resin interface. A radiation (gamma) count on an I^{125} Gamma Counter (Model IC 4702, Serial #071, Electronic Co of India, Bombay, India) for a period of 30 seconds was taken and an average of three readings was taken for each specimen. The observations were complemented qualitatively by examining the intensity and surface area of blackening produced on the autoradiographs.

Preparation of Autoradiographs

After completion of gamma counting, five teeth in each group were sectioned longitudinally in a mesiodistal direction through the center of the restoration, and sections were made longitudinally in a buccolingual direction at the approximal box of the restoration in the remaining five teeth in each group. The sectioned tooth surfaces were then placed against the dental x-ray film for 48 hours. For orientation of the tooth during interpretation of the autoradiograph, it was briefly exposed to x-rays for 0.1 seconds, while placed on the film. To avoid the remainder of the film being blackened by exposure to x-rays, it was protected by a lead foil. All films were then developed

in a conventional manner under identical time/temperature conditions. Since I^{125} emits gamma-photons there was no need to remove the protective shielding, and autoradiographs could be prepared in daylight.

Statistical Analysis

For comparing the marginal leakage in the different groups of samples, the mean (x) and standard deviation (SD) of the gamma counts were calculated and the *t*-test was used to determine the significance of differences between the mean values of variables being compared.

RESULTS AND DISCUSSION

The results of the present study are tabulated in Table 1 (mean and standard deviation of readings obtained on the gamma counter) and in Table 2 (the significance of difference in microleakage between the four groups).

From Tables 1 and 2 it was observed that retention grooves reduced gingival marginal leakage when the composite resin was polymerized either in one single mass (Group 1, with a mean pulse count of 2728.7, differed

Table 1. Mean and Standard Deviation of Readings Observed on the Gamma Counter

	Group	Number of Samples	Mean	Standard Deviation
1	with grooves, bulk fill	10	2728.7	± 857
2	without grooves, bulk fill	10	6092.4	± 2270
3	with grooves, incremental buildup	10	1588.5	± 520
4	without grooves, incremental buildup	10	4690.8	± 1720
Positive Control	Teeth filled with temporary stopping	2	43486	—
Negative Control	Unprepared teeth	2	912	—

Table 2. Significance of Difference in Microleakage between the Four Groups

Comparison between Groups			Calculated *t*-values	Level of Significance
Group 1 (with grooves, bulk fill)	&	Group 2 (without grooves, bulk fill)	4.136 ++	Significant difference
Group 1 (with grooves, bulk fill)	&	Group 3 (without grooves incremental buildup)	1.800 -	Difference not significant at 5% level
Group 1 (with grooves, bulk fill)	&	Group 4 (without grooves incremental buildup)	4.008 ++	Significant difference
Group 2 (without grooves, bulk fill)	&	Group 3 (with grooves incremental buildup)	5.801 +++	Highly significant difference
Group 2 (without grooves, bulk fill)	&	Group 4 (without grooves incremental buildup)	1.476 -	Difference not significant
Group 3 (with grooves, incremental buildup)	&	Group 4 (without grooves incremental buildup)	5.181 ++	Significant difference

Table (critical) value of *t* for 18 degrees of freedom at 5% level = 2.101.
Table (critical) value of *T* for 18 degrees of freedom at 1% = 1.734.

significantly from Group 2, with a mean count of 6092.4) or when polymerized in layers (Group 3, with a mean count of 1588.5, differed significantly from Group 4, with a mean count of 4690.8).

Highly significant differences were observed between the two extreme cases. Restorations with retention grooves and polymerized in layers (Group 3, mean count of 1588.5) presented a marginal seal that was significantly better than that of restorations without grooves that were polymerized in one single mass (Group 2, 6092.4).

In teeth without retention grooves, although polymerization in layers (Group 4, mean count of 4690.8) had less leakage compared to bulk packing (Group 2, mean count of 6092.4) (Table 1), the difference was not statistically significant (Table 2) at both the 5% and 1% levels.

In teeth with retention grooves, composite resin polymerized in layers (Group 3, mean count 1588.5) had less leakage than polymerization in a single mass (Group 1, mean count 2728.7). However, the difference was not statistically significant at the 5% level, but was significant at the 1% level.

The results of this study indicate that when retention grooves were placed at the axioproximal and gingival seat of a class 2 preparation to be restored with composite resin, it contributed to an improvement in the marginal seal of the critical gingivoproximal margin, when filled by bulk-packing technique or incremental-packing technique (Table 1). Autoradiographs confirmed this finding, i e, autoradiographs of teeth in Group 1 (with grooves and bulk) (Figs 3a & b) and Group 3 (with grooves and incremental) (Figs 4a & b)

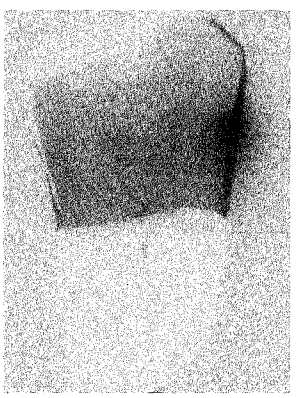

FIG 3a. *Autoradiograph of a tooth in Group 1 (mesiodistal section)*

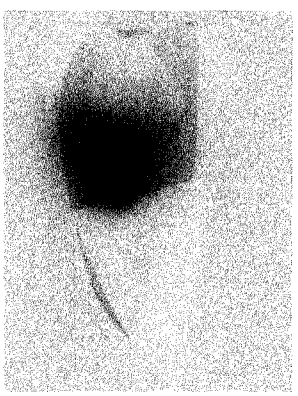

FIG 3b. *Autoradiograph of a tooth in Group 1 (buccolingual section)*

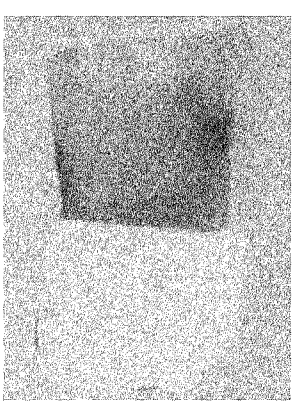

FIG 4a. *Autoradiograph of a tooth in Group 3 showing least diffusion of radioisotope at the gingival margin (mesiodistal section)*

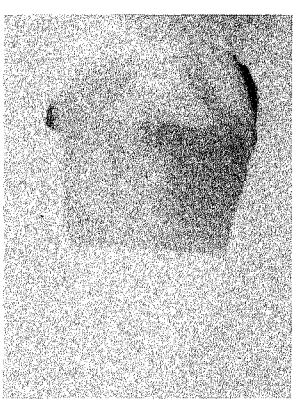

FIG 4b. *Autoradiograph of a tooth in Group 3 showing least diffusion of a radioisotope at the gingival margin (buccolingual section)*

showed less blackening of the film adjacent to the gingival margin of the approximal box than Group 2 (without gooves and bulk) (Figs 5a & b) and Group 4 (without grooves and incremental) (Figs 6a & b). Autoradiographs of control teeth are seen in Figures 7a & b.

Ben-Amar and others (1988) suggested preparation of retention grooves at the axioproximal line angles and gingival seat of class 2 preparations to reduce "lifting away" of the restoration from the gingival margin. The axioproximal grooves, by virtue of the design, that is, wider at the gingival end and tapering occlusally, acted as a mechanical brace to shrinkage of the resin away from the gingival margin. The groove in the gingival seat served to prevent shrinkage of the composite toward the light-source (approximal) when curing the approximal box after removal of the matrix. A very good adaptation of the composite resin to rounded and acute-angled retention grooves at the axiopulpal line angles has been reported by Allanigue and others (1986). Wieczkowski and others (1988) observed that retention grooves as used in their study may have contributed to increasing the surface area of dentin (over enamel at the periphery only) available for retention of the class 2 composite resin restoration via dentin-bonding agents.

The bonding to the enamel margins at the occlusal portion of the class 2 preparation was much stronger than bonding to dentin or prismless enamel at the gingival margin. When the bulk-packing technique was used, the bulk of the resin tended to shrink toward the occlusal margins, which had better anchorage (Hansen, 1982). Also the volumetric contraction of composite resin being much greater, it overcame the tooth/resin bond at the gingival portion of the restoration, resulting in a higher degree of marginal leakage (as observed in Group 2, without grooves and bulk) with the bulk-packing technique. Retention grooves reduced the gap created by polymerization of the composite resin in one single mass (as observed in Group 1).

With the incremental-packing technique, when the first increment was placed over the gingival portion of the cavity and polymerized, it bonded to the enamel and dentin, and this helped it to withstand the forces of polymerization shrinkage of the next increment of composite resin. Also the volume of each increment being less, it would be accompanied by less polymerization shrinkage, and the unpolymerized resin in the subsequent layer would fill up part of the space created by shrinkage of the first layer, (Koenigsberg, Fuks & Grajower, 1989). Feilzer, De Gee and Davidson (1988) found the volumetric polymerization contraction of hybrid composite (Herculite) to be approximately 3.2% by volume.

When cavities prepared with retention grooves were filled by an incremental-packing technique, there was a synergistic reduction in microleakage at the gingival margin. This was evident by both the least-observed readings on the gamma counter as well as by the least area of blackening of the autoradiograph produced by teeth in Group 3 (with grooves and incremental buildup).

From Table 1 it may be inferred that although an incremental buildup of the composite resin did reduce microleakage to some extent as compared to bulk-packing, the difference was not statistically significant (Table 2) enough to recommend an incremental-packing technique as an alternative method to reduce microleakage. With the bulk-packing technique the composite resin was cured for a total of 40 seconds from the occlusal and 40 seconds from the approximal after removal of the matrix band. The in vitro depth of cure was in the range of 2 - 6 mm (Kilian & Mullen, 1980). In the present study, the gingival margin of the restoration was approximately 8 to 10 mm away from the light source at the occlusal, so it is probable that the resin at the gingival margin was not completely polymerized. However, when the light was directed from the approximal after the removal of the band, the shrinkage vectors were directed toward the approximal and this, coupled with flow of the incompletely polyermized resin, would allow better adaptation at the gingival margin (Davidson, de Gee & Feilzer, 1984). Another possible explanation for the insignificant difference observed between teeth filled by the bulk-packing and incremental-packing technique could be that the higher degree of polymerization obtained by longer exposure to the photocuring light when the incremental-packing technique was used (i e, 40 seconds for each of the five increments and 40 seconds from the approximal after removing the matrix), would

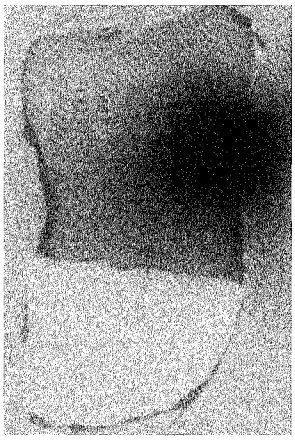

FIG 5a. *Autoradiograph of a tooth in Group 2 showing severe microleakage (mesiodistal section)*

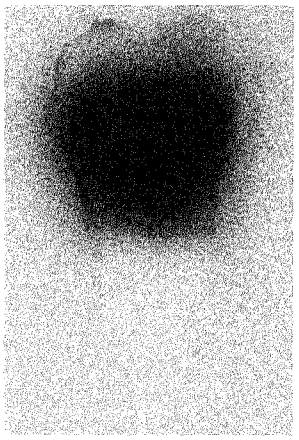

FIG 5b. *Autoradiograph of a tooth in Group 2 showing severe microleakage (buccolingual)*

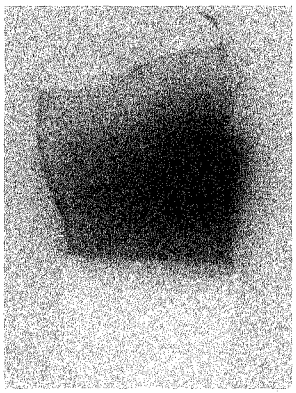

FIG 6a. *Autoradiograph of a tooth in Group 4 (mesiodistal section)*

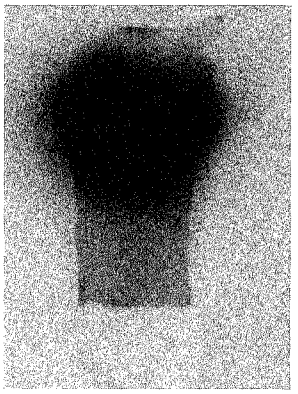

FIG 6b. *Autoradiograph of a tooth in Group 4 (buccolingual section)*

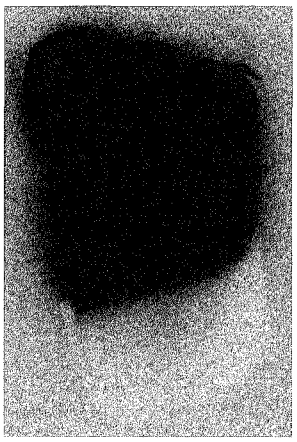

FIG 7a. *Autoradiograph of positive control tooth (filled with temporary stopping)*

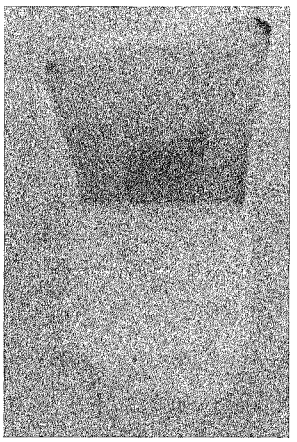

FIG 7b. *Autoradiograph of negative control tooth (unprepared tooth)*

be associated with a higher total summation of contraction gaps (Swartz, Phillips & Rhodes, 1983). It is probable that with the incremental-packing technique the advantage gained by curing a smaller volume of composite in each increment would be countered by the total polymerization shrinkage that occurs after total irradiation (i e, 40 seconds times five and 40 seconds from the approximal).

In the present in vitro study, the approximal part of the restoration was cured directly from the approximal after removal of the matrix band. However, in a clinical situation, this is not feasible. When clinically restoring a class 2 cavity with composite resin, it would be advantageous to first direct the polymerizing light from the facial or lingual surface with a light-reflecting transparent wedge placed interproximally (Lutz & others, 1986), which internally reflects the light towards the cervical margin,causing shrinkage vectors to be directed in a gingivoproximal direction.

The clinical implications of the current in vitro study are to be interpreted with caution. The greatest challenge to the success of the posterior composite resin restoration is adequate isolation during its placement into the prepared cavity. In the present in vitro study, moisture had been excluded from the experimental environment, and therefore the composite restoration was placed under ideal circumstances. In clinical situations, adequate isolation is necessary to ensure complete control of moisture. Inability to achieve the same would be detrimental to the marginal adaptation of the restoration. Pulpal protection, especially from the toxic effects of diluent monomer, is of prime importance. The choice of the best pulpal protective agent as related to a good marginal seal would be the basis of another study.

CONCLUSIONS

The following conclusions can be drawn from the findings of this in vitro study:

1) Retention grooves at the axioproximal line angles and gingival seat of the approximal box significantly reduced the gingival marginal microleakage associated with class 2 composite resin restorations when the fillings were placed by either the bulk-packing or incremental-packing technique;

2) The reduction in microleakage offered by the incremental-packing technique was not significantly greater than that which occurred with the bulk-packing technique, not great enough to recommend an incremental-packing technique as the sole alternative to overcome polymerization contraction gaps at the gingival margin of posterior composite restorations;

3) The use of retention grooves in class 2 cavity preparations or composite, coupled with an incremental buildup of the restoration in this study, was found to offer a promising means of overcoming one of the major limitations facing posterior composite resin restorations, gingival marginal leakage; and

4) In light of the results of the present study, it would appear worthwhile to carry out clinical studies to evaluate the true effectiveness of retention grooves as a means of reducing gingival marginal microleakage in vivo of posterior light-cured composite resin restorations.

Acknowledgments

The authors would like to thank Dr S R Amladi, professor and head of the Department of Pharmacology, and Dr S A Desai, in charge of the Radioisotope Unit and associate professor of the Department of Pharmacology, Topiwalla National Medical College, for their assistance in the radioisotope study that was carried out at the Radioisotope Unit at the Topiwalla National Medical College, Bombay.

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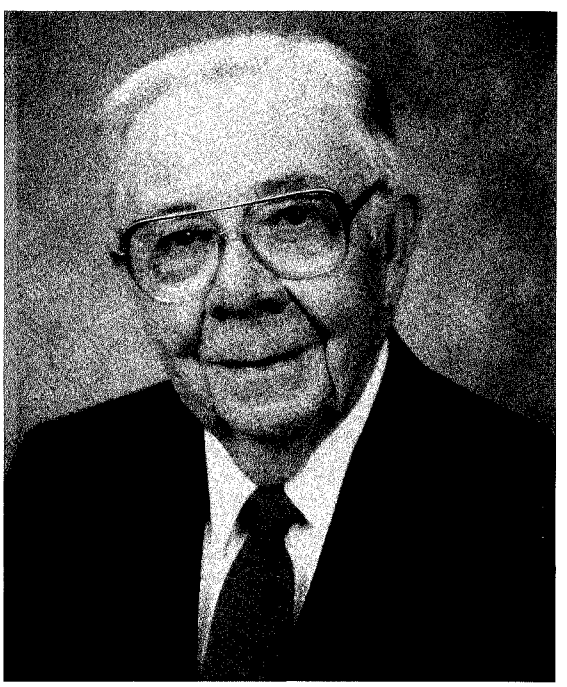
Distinguished Member Award

The recipient of the 1991 Distinguished Member Award needs no introduction to the American Academy of Gold Foil Operators or to the Academy of Operative Dentistry. Floyd Hamstrom has served both academies with his essays, clinical demonstrations, and tireless enthusiasm on project committees.

Floyd graduated from the North Pacific College of Dentistry (now the University of Oregon) in 1935, and he then established a dental practice in Seattle. With the advent of World War II he enlisted in the Navy. He served aboard the USS *Enterprise*, a ship receiving a presidential citation for service in the South Pacific. Additional service as a dental officer at dispensaries in Bremerton, Seattle, and Lakehurst, New Jersey, completed his naval career. Following his discharge in 1945, he established a practice in Burlington, Washington, retiring in 1986.

Dr Hamstrom is a charter member of the Washington Foundation for Dental Education, the Academy of Gold Foil Operators, and the Academy of Operative Dentistry. A founding member of the American Board of Operative Dentistry, he served as its secretary-treasurer the first five years of its existence. He was an associate professor of operative dentistry at the University of Washington, and he served a three-year term on the Washington Board of Dental Examiners. Dr Hamstrom has served as president and secretary of the Associated Gold Foil Study Clubs of Washington and British Columbia, as president of the Mount Baker District Dental Society, and as chairman of the operative section for the ADA meeting in Las Vegas. A lifetime member of the Washington Gold Foil Study Club and the



Floyd E Hamstrom

Fleetwood Crown and Bridge Study Club, he has also been the mentor of the Dr Don A Spratley Study Club since 1957, and he continues to serve in that capacity. He is a member of the American College of Dentists and has served as secretary and president of the Washington and British Columbia sections.

Dr Hamstrom has presented chairside clinical demonstrations both at home and abroad. He frequently presents table clinics and lectures on the use of the rubber dam and retainers, and he wrote a chapter on the subject for an operative dentistry textbook. Dr Hamstrom was instrumental in collecting dental textbooks for shipment to foreign dental schools and has been active in training handicapped people to be dental technicians.

Dr Hamstrom and his wife, Anita, reside in Burlington. He has two daughters and three grandchildren. He enjoys golf, gardening, fly fishing, and taking time to smell the roses. Floyd frequently invites young dentists to his home for a little socializing, where often they are entertained by Anita, an accomplished pianist. After one of her small recitals, he appeared, violin in hand, announcing that he, too, was musical and would not be upstaged by his wife. Tucking the violin under his chin, he raised the bow and had just begun to play when a string broke. The performance was over, he said, because his G-string had snapped.

Distinguished Member Award for 1991

It is with great pleasure that the Academy presents its Distinguished Member Award to Floyd E Hamstrom, one of the Academy's most accomplished members.

RALPH J WERNER

DEPARTMENTS

Book Reviews

TEETH THAT TOLD: A SELECTION OF CASES IN WHICH TEETH PLAYED A PART

Søren Keiser-Nielsen

Published by Odense University Press, 1991. 95 pages, 10 illustrations.

US$13.00, plus $8.40 postage. Available through Odense University Press, Campusvej 55, DK 5230 Odense M, Denmark; prefer payment in Danish currency, drawn on a Danish bank, or Eurocheque in Danish currency.

Human teeth and their distinct characteristics are likely to remain long after other components of the human body have succumbed to destruction or decay. Thus the science of forensic dentistry provides a means for identification of victims of violent crimes, battles, or mass disasters. Bite marks, which also exhibit unique properties, have been used to secure criminal convictions. The teeth and their x-rays, casts, and models sometimes permit reexamination of evidence decades and even centuries after the event.

In this book Søren Keiser-Neilsen, an internationally recognized expert with more than 45 years of experience in the field of forensic dentistry, presents a collection of 30 cases from the literature that demonstrate the contributions of dental experts in removing doubt about the correct identity of human remains. The earliest case reported is the identification of a Roman political figure whose assassination was ordered in 49 A D by Nero's mother. More recent cases include the confirmation of the deaths of Adolf Hitler and his new bride, Eva Braun. A particularly interesting case involves a nineteenth-century serial killer in Poland who ate his victims, made suspenders from their skins, but saved the perfect teeth.

The author's style is very readable for both the general dentist and the interested lay person. Dentists will gain insight into the wide range of problems that they may encounter in the course of professional practice. For individuals who wish to pursue the selected cases in greater detail, a list of references for each case is provided. The author has supplemented the specific references with a list of general references on forensic dentistry.

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TISSUE INTEGRATION IN ORAL, ORTHOPEDIC & MAXILLOFACIAL RECONSTRUCTION

W R Laney and D E Tolman

Published by Quintessence Publishing Co, Chicago, 1992. 400 pages, 130 illustrations. $68.00.

This book is a collection of papers presented at the Second International Congress on Tissue Integration in Oral, Orthopedic and Maxillofacial Reconstruction, which was held in Minnesota, September 1990. Where the articles have been published elsewhere, the abstracts have been included.

At the end of each section, comments from the open discussion are presented in actual dialog form, eliminating the possible interjection of biased opinions or interpretations from the editors.

The text also includes abstracts of the poster presentations and reports from the four consensus panels. The papers, which seem to be more heavily weighted in the area of intraoral than extraoral implants, deal with such key issues as splinting of implants to teeth, immediate implants, tissue reactions to implants and various materials, and the use of guided tissue regeneration and various types of grafts and ridge augmentation techniques with implants.

Tissue Integration in Oral, Orthopedic & Maxillofacial Reconstruction is highly recommended for all clinicians and scientists involved with implants who would like to be aware of the latest in scientific and clinical developments.

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ADVANCES IN PERIODONTICS

Thomas G Wilson, Jr, Kenneth S Kornman, Michael G Newman

Published by Quintessence Publishing Co, Inc, Chicago, 1992. 400 pages, 623 illustrations. $120.00.

This edition is consistent with the Quintessence tradition for timely publications with lavish color illustrations. The editors are well-known authorities in periodontal research and in the clinical application of periodontal therapy. They approach this update on periodontics in four general topics: 1) Examination, Disease Activity, Diagnosis, and Treatment Planning; 2) Therapy for Chronic Gingivitis and Chronic Adult Periodontics; 3) Adjunctive Therapy, Esthetics, and Considerations for Medically Compromised Patients; and 4) Implant Dentistry. Within these major headings, 21 chapters authored by a Pleiades of periodontal pundits address a wide variety of topics. Most chapters are divided into a concise synopsis of current concepts on the topic, followed by an illustrated overview of relevant clinical applications. The major concepts in the chapter are then neatly summarized in a brief review section just before a thorough list of references. The topics addressed in the chapters include The Role of Microbiology in Periodontal Therapy, Mucogingival Surgery: Esthetic Treatment of Gingival Recession, and Choice of Implant Systems and Clinical Management. The format of *Advances in Periodontics* provides a concise, readable update on developing areas of periodontal diagnosis and therapy, along with clinical illustrations and applications of these evolving concepts. The chapter make-up, with reviews and references, makes *Advances in Periodontics* of interest to a wide range of readers. While this volume is neither a complete scientific treatise on periodontal disease mechanisms nor a periodontal technique 'cook-book,' as a number of topics are necessarily treated in abbreviated form, the book is still a ready reference of many levels that provides a tidy overview of many current trends in periodontal research and the evolution of clinical practice to match these advances.

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