OPERATIVE DENTISTRY

march-april 1997 • volume 22 • number 2 • 49-96

(ISSN 0361-7734)

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MARCH-APRIL 1997 • VOLUME 22 • NUMBER 2 • 49-96

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

OPERATIVE DENTISTRY (ISSN 0361-7734) is published bimonthly for $55.00 per year in the US and Canada (other countries $70.00 per year) by University of Washington, Operative Dentistry, Health Sciences Bldg, Rm D-775, Seattle, WA 98195-7457. Periodicals postage paid at Seattle, WA, and additional mailing offices. **POSTMASTER:** Send address changes to: University of Washington, OPERATIVE DENTISTRY, Box 357457, Seattle, WA 98195-7457.

Subscriptions
Yearly subscription in USA and Canada, $55.00; other countries, $70.00 (sent air mail printed matter); dental students, $25.00 in USA and Canada; other countries, $34.00; single copy in USA and Canada, $14.00; other countries, $17.00. For back issue prices, write the journal office for quotations. Make remittances payable (in US dollars only) to OPERATIVE DENTISTRY and send to the above address.

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EDITORIAL

Operative Dentistry On-Line

Keeping up with advancing technology is no easy task. However, with the outstanding help of Mr Stephen Thielke, who is a computer guru employed by the Department of Restorative Dentistry here at the University of Washington, our journal now has its own home page:

http://weber.u.washington.edu/~opdent/

When Stephen established the home-page format for *Operative Dentistry*, I was doubtful that there would be much demand for it. However, within the first two weeks of its existence, it received over 2,000 "hits" from all over the world. This immediately verified to me that *Operative Dentistry* must keep up with advances in technology in order to maintain our ranking as one of the best dental journals in existence today. There are several aspects to our home page that I want to bring to your attention. In addition to these, we would welcome any comments or suggestions for improvements.

There are six sections to our folder: **Index**, **Search**, **Editorial**, **News**, **Upcoming**, and **Subscribe**. In **Index**, article titles and authors are indexed according to the year, beginning with Volume 17 (1992). We plan to add previous issues as time permits. Also listed are the articles to be included in the next issue as well as future articles that are ready for publication. **Search** allows you to search out articles in our index by author or by using major terms. **Editorial** will list the past six editorials (one year) and be available for those who want to review or copy them. **News** lists announcements of meeting dates for the Academy of Operative Dentistry and American Academy of Gold Foil Operators. In addition to this, we are including faculty positions being advertised in *Operative Dentistry* in this section, as well as unique items such as the availability of bound volumes and microfiche of current and past issues. **Upcoming** lists the articles to be included in the next issue as well as articles and their Clinical Relevance Statements accepted for future issues. **Subscribe** allows interested readers to request information about either of the Academies, as well as to notify us of a change of address. In addition to this, a form is available in this section for subscriptions to *Operative Dentistry*. Some of these categories will undoubtedly be changed to allow inclusion of more pertinent categories. For example, it might be appropriate to have a **Comment** section for readers to contact the editor. Additionally, we are beginning our section of **Clinical Tips** in the near future, and I feel that a listing of these in the home page, at least by topic, could provide a valuable service to our readers and subscribers.

To date there have been two requests for information about the Academies, one from California and one from Peru. Doesn't seem like much, but this occurred before we ever notified anyone that we had a home page. Our home page is a VERY valuable way to communicate with readers and/or subscribers from difficult access areas. We are also developing a folder for reviewers of *Operative Dentistry* to access the proper review form, which will make it easier for them to complete and forward the comments to us. Since we have referees from all over the world, this is expected to greatly facilitate their efforts.

So, put on your thinking caps and let us know how you would like to see us improve our page. You can contact me through the journal office or via e-mail: **rmccoy@u.washington.edu**.

Comments so far have dealt with our logos: too large and it takes too long to bring them up on the screen. We haven't had that problem here but are planning to make the logos smaller so they will boot-up faster. One fact is for sure: Stephen deserves a monumental round of applause for his Herculean effort on our behalf! Send your accolades for Stephen's support to the journal office, and we will forward them to him.

With subscriptions up 70 for 1996 over 1995 and an increase in top-quality manuscripts being forwarded to *Operative Dentistry* for publication consideration, 1997 looks like a banner year. We are also planning to publish two articles with color illustrations in the coming year and many other excellent clinically related articles. My humble thanks to each and every one of you for making all of this possible.

RICHARD B McCOY
Editor

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ORIGINAL ARTICLES

Shear Bond Strengths of 10 Adhesive Resin/Amalgam Combinations

K E DIEFENDERFER • J W REINHARDT

Clinical Relevance
The combination of a filled adhesive resin with a spherical amalgam alloy may produce improved bond strengths.

SUMMARY

This study compared the shear bond strengths of amalgam to dentin using two amalgam alloys and five adhesive resin systems. One hundred extracted human third molars were flattened occlusally to expose dentin. Dentin surfaces were treated with one of five adhesive resins: All-Bond 2, Amalgambond Plus, Amalgambond Plus with HPA Powder, OptiBond, and Resinomer. Tytin (spherical) or Dispersalloy (admixed) amalgam was condensed onto the treated dentin surface through a Teflon split mold. The samples were stored 7-10 days and thermocycled before shear testing using a Zwick Materials Testing Machine. Two-way ANOVA revealed significant differences among the 10 groups ($P < 0.05$). The combination of Tytin/OptiBond produced the highest bond strength to dentin (14.17 MPa), while Dispersalloy/Amalgambond Plus produced the lowest (3.89 MPa). In general, the filled resin systems (Amalgambond Plus with HPA Powder, OptiBond, Resinomer) produced higher bond strengths than the unfilled systems (All-Bond 2, Amalgambond Plus). Additionally, for four of the five resins, bond strengths were higher with Tytin than with Dispersalloy, although differences were statistically significant in only two groups.

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INTRODUCTION

In spite of efforts to find an acceptable replacement, dental amalgam remains the most widely used restorative material in operative dentistry, providing longevity, ease of use, and cost effectiveness not yet attainable with other materials. One of amalgam's primary shortcomings, however, is its inability to bond to tooth structure. Composite resins, on the other hand, are well established as capable of effectively bonding to both enamel and dentin. Many manufacturers now market adhesive resins for bonding amalgam to tooth structure. A strong, durable amalgam-to-resin bond would have many applications and potential advantages, including reduced marginal microleakage, improved retention, and reinforcement of tooth structure (Staninec & Holt, 1988; Gwinnett & others, 1994).

Microleakage: Many studies have demonstrated that resin-lined amalgam restorations exhibit significantly less microleakage than unlined or varnish-lined

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restorations (Yu, Wei & Xu, 1987; Staninec & Holt, 1988; Edgren & Denehy, 1992; Turner, St Germain & Meiers, 1995). However, like copal varnish, adhesive resins may not be effective in completely eliminating microleakage in all restorations. Factors such as cavity design, as well as the aging and stressing of restorations, may affect material performance (Varga, Matsumura & Masuhara, 1986; Ben-Amar & others, 1987, 1990; Charlton, Moore & Swartz, 1992). With time, resin-lined restorations tend to exhibit a degree of marginal microleakage similar to, but certainly no worse than, that of varnish-lined restorations. However, unlike copal varnish, adhesive resins appear to maintain their dentinal seal. Resin-lined amalgams tend to leak at the resin-amalgam interface, rather than the resin-enamel or resin-dentin junction (Saiku, St Germain & Meiers, 1993; Ben-Amar & others, 1994).

Retention: Because dental amalgam does not bond adhesively to tooth structure, cavity preparations for amalgam must incorporate mechanical features to retain the restorative material. Parallel walls, box forms, undercuts, slots, and retentive grooves provide adequate retention, but often require the removal of healthy tooth structure, which may further weaken the tooth (Staninec, 1989; Lacy & Staninec, 1989). Many studies have demonstrated improved retention with the use of adhesive resin liners (Staninec, 1989; Staninec & others, 1993; Fischer, Stewart & Panelli, 1993; Eakle & others, 1994), suggesting that adhesive resin liners may be used as alternatives or adjuncts to mechanical retention, thus permitting more conservative cavity preparation.

Reinforcement of Tooth Structure: Even conservative cavity preparation can weaken the remaining tooth structure (Eakle, Staninec & Lacy, 1992). Restoration with either amalgam or composite resin regains a portion of the tooth's original strength (Gelb, Barouch & Simonsen, 1986; Joynt & others, 1987). Several studies have demonstrated significantly increased fracture resistance (Eakle, 1986; Liberman & others, 1990; Jagadish & Yogesh, 1990), as well as decreased cuspal deformation (Morin, DeLong & Douglas, 1984; Sheth, Fuller & Jensen, 1988) in teeth restored with bonded composite resins. Similar trends have been reported for teeth restored with amalgam bonded to tooth structure with adhesive resins (Eakle, Staninec & Lacy, 1992; Teigen & Boyer, 1994; Boyer & Roth, 1994).

Adhesion of amalgam to dentin offers interesting clinical applications. However, several important questions remain unanswered. Most studies to date have focused primarily on microleakage of spherical alloys; few have compared the microleakage of spherical and admixed alloys. Fracture resistance and bond strengths of adhesive amalgam restorations have been compared to those of composite resins; but, again, most studies have tested only spherical alloys, and few comparisons have been made with other alloys. Finally, with the continual introduction of new and improved adhesive resin systems, as well as increasingly bold claims by dental manufacturers, it has become difficult for clinicians to decide which materials are compatible and effective.

Therefore, the purpose of this study was to compare the shear bond strengths of various combinations of two amalgam alloys, one spherical and one admixed, and five adhesive resin bonding agents.

METHODS AND MATERIALS

This in vitro study tested the null hypotheses that with the adhesive amalgam technique: (1) various resin bonding agents produce equivalent shear bond strengths to dentin; and (2) spherical and admixed dental amalgam alloys also exhibit equivalent shear bond strengths to dentin.

A pilot study was conducted to determine the feasibility of the experimental design and identify potential problems. Test samples prepared with copal varnish (Copalite) as a liner consistently fractured during matrix removal, indicating no measurable adhesion between amalgam and dentin. Therefore, Copalite samples were not included in the study.

One hundred recently extracted unrestored human third molars, free of visible caries, were selected for the study. The teeth were cleaned of gross debris and stored in a solution of 0.2% thymol in distilled water at room temperature prior to and throughout the preparation phase of the study. Twenty-four hours prior to bonding, the teeth were transferred to pure distilled water.

Two regular-set high-copper dental amalgam alloys were chosen: Tytin (Sybron/Kerr, Romulus, MI 48174), which is composed of spherically shaped particles; and Dispersalloy (L D Caulk/Dentsply, Inc, Milford, DE 19963), which is admixed.

The resin bonding agents selected were (1) All-Bond 2 (Bisco, Inc, Itasca, IL 60143), (2) Amalgambond Plus (Parkell Products, Farmingdale, NY 11735), (3) Amalgambond Plus with HPA Powder (Parkell Products) (4) OptiBond (Sybron/Kerr), and (5) Resinomer (Bisco, Inc). According to a recent study by Clinical Research Associates (1994), these materials were among the best performing of 23 amalgam bonding products tested.

The teeth were mounted in phenolic rings (Buehler Ltd, Lake Bluff, IL 60044) with autocuring acrylic resin. The occlusal surface of each tooth was ground with a water-cooled model trimmer (Whip-Mix Corp, Louisville, KY 40217) to create a flat dentin surface with no remnants of enamel. The flattened dentin surface was then polished with wet 240-, 400-, and 600-grit silicon carbide abrasive paper (3M Dental

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Table 1. Two-Way Analysis of Variance

Source	df	Type III SS	F Value	Pr > F
Resin	4	519.865	9.86	0.0001
Alloy	1	192.562	14.61	0.0002
Resin*Alloy	4	200.418	3.8	0.0067
Error	89	1173.29		

Products, St Paul, MN 55144) on a water-cooled abrasive wheel (Ecomet V, Buehler Ltd).

Teeth were randomly assigned to one of 10 treatment groups (Tytin and Dispersalloy with each of the five bonding agents). Dentin surfaces were conditioned and all resin systems were used according to each manufacturer's instructions. An Optilux 150 light curing unit (Demetron Research Corp, Danbury, CT 06810) was used, as indicated by the instructions for each material, throughout all procedures. Prior to the study, the curing light was tested with a radiometer (Model 100, Demetron Research Corp), and light output was confirmed to exceed 300 mw/cm^2. Immediately after application of resin to the dentin surface, each specimen was secured in a Teflon split mold, the upper aspect of which contained an opening (internal diameter 3 mm; 2 mm high) to serve as a matrix for amalgam placement.

Double-spill (600 mg) amalgam capsules were triturated in an amalgamator (Kerr Automix, Kerr Mfg Co) according to each manufacturer's instructions and condensed into the preparations using a flat, smooth-faced, circular condenser (2 mm in diameter) and hand pressure of 1 kg ± 250 gm. One operator completed all preparations and restorations. Tytin specimens were allowed to set for 15 minutes prior to removal of the Teflon mold. Because of Dispersalloy's slower setting time, Dispersalloy specimens were allowed to set for 30 minutes prior to mold removal.

The specimens were stored in distilled water at 37 °C for 7 to 10 days, then thermocycled in distilled water (5° ± 5 °C/50° ± 5 °C; 300 cycles; 30-second immersion time), and, finally, stored in 37 °C distilled water an additional 36 hours prior to shear testing.

Shear bond strengths were determined using a Zwick Materials Testing machine (#144560, Zwick of America Inc, East Windsor, CT 06088). Each sample was positioned in a mounting jig attached to a compression load cell (10 N), with the dentin-amalgam interface parallel to the direction of the applied force. A knife-edge shear probe was attached to the crosshead. Shear force was applied to the amalgam-dentin interface at a rate (crosshead speed) of 5 mm per minute. Shear forces were recorded in megapascals, obtained directly from the Zwick computer software. Debonded dentin surfaces were viewed under a stereomicroscope (Model Forty, American Optical Co, Buffalo, NY 14215) at X30 magnification to determine the mode of failure.

Data analysis was completed using the SAS System computer software,General Linear Models Procedure (SAS Institute Inc, Cary, NC 27513). The mean (and standard deviation) shear bond strength was calculated for each treatment group. The category means were compared using a two-factor Analysis of Variance. Calculations indicated statistically significant F-ratios ($P < 0.01$), so the data were further analyzed by Duncan's Multiple Range tests.

RESULTS

Two-factor Analysis of Variance (ANOVA) data are listed in Table 1. Shear bond strengths of amalgam to dentin were significantly affected by both the adhesive resin ($P < 0.0001$) and amalgam alloy ($P < 0.0002$). In addition, a statistically significant interaction effect was noted between the two variables ($P < 0.0067$).

Mean shear bond strengths for the 10 treatment groups are presented in Table 2. Each group consisted initially of 10 specimens. However, one specimen from the Dispersalloy/Amalgambond Plus group debonded during thermocycling. Because it was impossible to determine whether the separation occurred due to adhesive failure or physical trauma (i e, contact with another specimen or the thermocycling basket), that specimen was excluded

Table 2. Shear Bond Strengths of Amalgam to Dentin

Amalgam	Resin	Mean SB (MPa)*	SD
Tytin	OptiBond	14.17	4.48
Tytin	Amalgambond Plus/HPA	12.06	3.69
Tytin	Resinomer	10.82	3.56
Dispersalloy	Amalgambond Plus/HPA	9.91	3.11
Dispersalloy	Resinomer	9.19	3.98
Tytin	Amalgambond Plus	8.42	1.93
Dispersalloy	OptiBond	7.13	2.63
Dispersalloy	All-Bond 2	6.36	2.45
Tytin	All-Bond 2	4.98	4.25
Dispersalloy	Amalgambond Plus	3.89	2.50

n = 10 for all groups, except Dispersalloy/Amalgambond (n = 9); *Duncan's Multiple Range Test ($\alpha = 0.05$)--all groups; lines connect values that are not significantly different.

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Table 3. Comparison of Shear Bond Strengths of Dispersalloy and Tytin

Resin	Dispersalloy	Tytin	Significant Difference*
All-Bond 2	6.36	4.98	No
Amalgambond Plus	3.89	8.42	Yes
Amalgambond Plus/HPA	9.91	12.06	No
OptiBond	7.13	14.17	Yes
Resinomer	9.19	10.82	No

*$\alpha = 0.05$.

Table 4. Modes of Failure by Alloy and Resin

By Alloy:	Adhesive[1]	Mixed[2]	Cohesive[3]
Dispersalloy (n=50)	28	22	0
Tytin (n=50)	25	24	1
By Resin:	**Adhesive[1] (T/D)[4]**	**Mixed[2] (T/D)[4]**	**Cohesive[3] (T/D)[4]**
Filled (n=60)	22 (8/14)	37 (21/16)	1 (1/0)
Unfilled (n=40)	31 (17/14)	9 (3/6)	0

[1]Adhesive failure between amalgam and adhesive resin
[2]Remnants of amalgam remaining on resin/dentin surface
[3]Cohesive failure within amalgam
[4]Tytin/Dispersalloy ratio

from the study. Thus, all calculations and statistical analyses for the Dispersalloy/Amalgambond Plus group were completed using the nine remaining samples.

Table 3 compares the bond strengths of Dispersalloy and Tytin according to the various resins. The data are also presented graphically below. For four of the five resin systems, Tytin produced higher bond strengths than Dispersalloy. The lone exception was All-Bond 2: bond strength was higher with Dispersalloy, although the difference was not statistically significant ($P > 0.38$). Among the resins for which Tytin exceeded Dispersalloy in bond strength, the differences were statistically significant for OptiBond ($P < 0.01$) and Amalgambond Plus ($P < 0.05$), but were not for Resinomer ($P > 0.46$) or Amalgambond Plus with HPA Powder ($P > 0.18$).

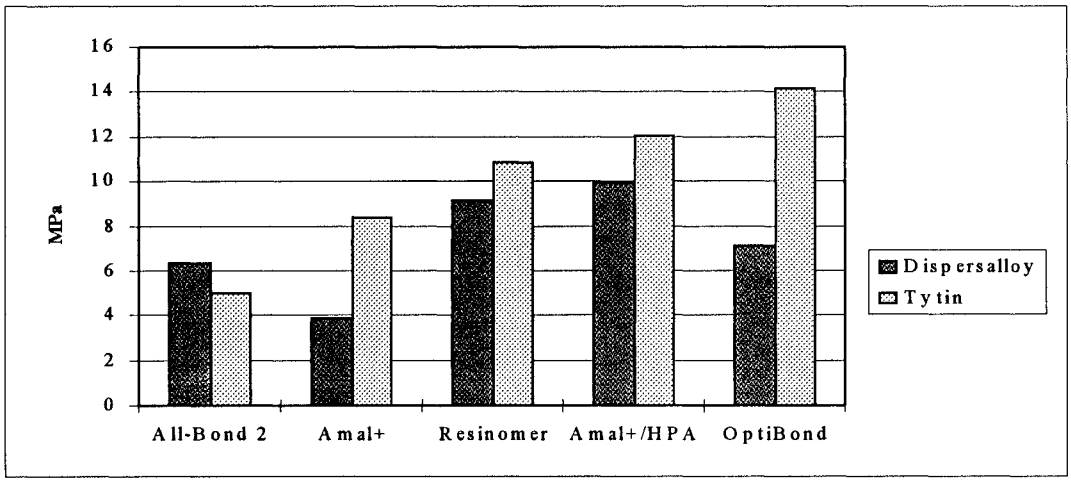
Modes of failure for each group are listed in Table 4. No samples were judged to have failed adhesively between the dentin bonding agent and dentin or cohesively within the dentin bonding agent. Therefore, failures were categorized as adhesive (failure between the dentin bonding agent and amalgam, with the resin attached to dentin and no visible amalgam particles on the resin/dentin surface), cohesive (within amalgam), or mixed (some amalgam remaining on resin/dentin surface).

Among samples restored with Dispersalloy, 28 of 50 exhibited adhesive failure, and 22 displayed mixed failures. Among samples restored with Tytin, 25 of 50 displayed adhesive failures, while 24 had mixed failures; one sample (Tytin/Resinomer) failed cohesively within the amalgam.

Mixed failures were more prevalent among the filled resins (38 of 60) than among the unfilled (9 of 40). Filled resins restored with Tytin produced more mixed failures (22 of 30 samples) than did filled resins restored with Dispersalloy (16 of 30). Unfilled resins exhibited predominantly adhesive failures for both alloys (14 of 20 for Dispersalloy; 17 of 20 for Tytin).

DISCUSSION

The more highly filled resins examined in this study (Amalgambond Plus with HPA powder, OptiBond, Resinomer) tended to produce higher bond strengths



Shear bond strengths of amalgam to dentin

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than the unfilled resins (Amalgambond Plus, All-Bond 2). The manufacturer of Amalgambond Plus recommends using the HPA ("High Performance Additive") powder only in "virtually impossible situations" where mechanical retention is lacking and additional adhesion is needed. The powder consists of polymethylmethacrylate fibers, that, when mixed with the Amalgambond Plus base and catalyst liquids, form a thick, viscous paste. Resinomer is a two-paste (base/catalyst) system that can be either light-cured for use as a liner or allowed to self-cure for use as an adhesive luting agent. Resinomer is used in place of Bisco's unfilled Dentin/Enamel Bonding Resin in the All-Bond 2 Kit, but does require the use of All-Bond 2 Primer A and B as a first step. With these four products (All-Bond 2, Amalgambond Plus, Amalgmabond Plus with HPA, Resinomer), the objective is to condense amalgam into the unset resin, thus facilitating formation of a mechanical union between amalgam and resin as the resin sets.

Unlike the other products in this study, OptiBond is not marketed as an amalgam adhesive. As a result, the manufacturer includes no amalgam bonding instructions. For this study, the "dual-cure technique" instructions for large restorations were followed: the dual-cure (3A/3B) components were mixed and light cured for 30 seconds immediately prior to amalgam condensation. Previous trials using OptiBond without light curing resulted in failure of the setting reaction, and, thus, no bonding between amalgam and dentin (Vargas, 1994, personal communication). These results were confirmed in the pilot for the present study. Light curing initiates the setting reaction and allows the bottom layer of resin to bond to dentin. The surface layer, however, remains unpolymerized in the presence of oxygen (Ruyter, 1985). As amalgam is condensed against this air-inhibited surface layer, oxygen is likely eliminated, allowing the resin to polymerize more completely and bond mechanically to the amalgam (Vargas, Denehy & Ratananakin, 1994).

A number of bond strength studies have included some of the same products examined in this study (Covey & Moon, 1991; Hasegawa & others, 1992; Bagley & others, 1994; Barkmeier & others, 1994; Kawakami & others, 1994; Souza & others, 1994). Vargas and others (1994) compared amalgam to dentin bond strengths of five dentin bonding agents. They reported mean shear bond strengths (MPa) for All-Bond 2 (6.23), Clearfil Liner Bond (6.82), Imperva Dual Bond (7.23), OptiBond (8.24), and Amalgambond Plus with HPA Powder (11.97). Amalgambond Plus with HPA Powder was significantly stronger than the four other resins tested.

In the present study, the Tytin/OptiBond combination produced a considerably higher bond strength (14.17 MPa) than that reported by Vargas and others (1994). Possible explanations may include the present study's longer storage time (7-10 days) prior to thermocycling and shear testing, which may have permitted the resin to more fully cure, or the different matrices used for amalgam placement. In the pilot for the present study, removal of plastic matrices similar to those used by Vargas and others (1994) resulted in a high number of bond failures, while the Teflon split mold did not. Perhaps matrix removal created stresses at the resin-amalgam interface, insufficient to cause debonding, but large enough to lower bond strength. With this lone exception, however, the present study appeared to agree reasonably well with published literature.

Tjan, Tan, and Berry (1994) also reported significantly higher shear bond strengths with OptiBond (10.53 MPa) than with Amalgambond (3.73 MPa) or All-Bond 2 (2.45 MPa). In the present study, the microscopic appearance of the debonded dentin/resin surfaces suggested that the amalgam was incorporated more intimately into the filled resins, creating a stronger mechanical interlocking. Ruzickova, Staninec, and Marshall (1994) also reported increased shear bond strengths to amalgam when more viscous or highly filled resins were used; x-ray microanalysis revealed that amalgam particles were entrapped within the resin.

The differences in the performance of the two amalgam alloys in this study were surprising and are difficult to explain. Cooley, Tseng, and Barkmeier (1991) found no difference between a spherical and an admixed alloy bonded with Amalgambond. However, Morrill and others (1994), also using Amalgambond, reported that a spherical alloy (Artalloy) had significantly higher shear bond strength to both composite and dentin than did an admixed alloy (Luxalloy). A spherical amalgam particle has more surface area available for contact with the adhesive resin. However, one might expect an admixed alloy, with its irregularly shaped particles, to be more easily entrapped by the resin, and, thus, produce higher bond strengths than a spherical alloy. Apparently, this does not occur. In the present study, Dispersalloy consistently exhibited both lower bond strengths and less residual amalgam on debonded dentin surfaces. Perhaps, because of Dispersalloy's slower setting time, removal of the Teflon mold disturbed the final set or created stresses that weakened the bond. The lower strengths may also be due to differences in chemical composition between the two alloys. Dispersalloy contains approximately 10% more silver and 10% less tin than Tytin. In addition, Dispersalloy contains 1% zinc, while Tytin contains none. A 600 mg capsule of Dispersalloy also contains 589 mg mercury, compared to 447 mg mercury for Tytin. It is possible that one or more of these components may inhibit the interaction between resin and amalgam.

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CONCLUSIONS

The adhesive or "bonded" amalgam restoration relies upon strong, durable bonding between tooth structure, adhesive resin, and amalgam. Its success requires that the resin liner possess not only adequate bond strength to amalgam and tooth structure, but also adequate marginal sealing abilities. Under the conditions of this study, for both amalgam alloys tested, filled adhesive resins produced higher amalgam-to-dentin shear bond strengths than unfilled resins. Similarly, for four of the five resins, a spherical alloy produced higher bond strengths than an admixed alloy. Results were statistically significant for one filled and one unfilled resin. It has been suggested that a shear bond strength of 21-24 MPa will eliminate microleakage at the dentin-dentin bonding agent interface (Retief, Mandras & Russell, 1994). It has also been suggested that the use of a partially filled resin liner can significantly reduce marginal microleakage (Fortin & others, 1994). If these are so, then the combination of a filled resin with a spherical amalgam alloy appears promising as an acceptable definitive restoration. Long-term clinical trials are needed to measure the performance of this type of restoration in vivo.

(Received 2 November 1995)

References

BAGLEY A, WAKEFIELD CW & ROBBINS JW (1994) In vitro comparison of filled and unfilled bonding agents of amalgam to dentin *Operative Dentistry* **19** 97-101.

BARKMEIER WW, GENDUSA NJ, THURMOND JW, & TRIOLO PT Jr (1994) Laboratory evaluation of Amalgambond and Amalgambond Plus *American Journal of Dentistry* 7 239-242.

BEN-AMAR A, LIBERMAN R, JUDES H & NORDENBERG D (1990) Long-term use of dentine adhesive as an interfacial sealer under Class II amalgam restorations *Journal of Oral Rehabilitation* **17** 37-42.

BEN-AMAR A, LIBERMAN R, ROTHKOFF Z & CARDASH HS (1994) Long term sealing properties of Amalgambond under amalgam restorations *American Journal of Dentistry* **7** 141-143.

BEN-AMAR A, NORDENBERG D, LIBERMAN R, FISCHER J & GORFIL C (1987) The control of marginal microleakage in amalgam restorations using a dentin adhesive: a pilot study *Dental Materials* **3** 94-96.

BOYER DB & ROTH L (1994) Fracture resistance of teeth with bonded amalgams *American Journal of Dentistry* 7 91-94.

CHARLTON DG, MOORE BK & SWARTZ ML (1992) In vitro evaluation of the use of resin liners to reduce microleakage and improve retention of amalgam restorations *Operative Dentistry* **17** 112-119.

CLINICAL RESEARCH ASSOCIATES (1994) Subject: Adhesives, silver amalgam *CRA Newsletter* **18** 2-3.

COOLEY RL, TSENG EY & BARKMEIER WW (1991) Dentinal bond strengths and microleakage of a 4-META adhesive to amalgam and composite resin *Quintessence International* **22** 979-983.

COVEY DA & MOON PC (1991) Shear bond strength of dental amalgam bonded to dentin *American Journal of Dentistry* **4** 19-22.

EAKLE WS (1986) Fracture resistance of teeth restored with Class II bonded composite resin *Journal of Dental Research* **65** 149-153.

EAKLE WS, STANINEC M & LACY AM (1992) Effect of bonded amalgam on the fracture resistance of teeth *Journal of Prosthetic Dentistry* **68** 257-260.

EAKLE WS, STANINEC M, YIP RL & CHAVEZ MA (1994) Mechanical retention versus bonding of amalgam and gallium alloy restorations *Journal of Prosthetic Dentistry* **72** 351-354.

EDGREN BN & DENEHY GE (1992) Microleakage of amalgam restorations using Amalgambond and Copalite *American Journal of Dentistry* **5** 296-298.

FISCHER GM, STEWART GP & PANELLI J (1993) Amalgam retention using pins, boxes, and Amalgambond *American Journal of Dentistry* **6** 173-175.

FORTIN D, SWIFT EJ Jr, DENEHY GE & REINHARDT JW (1994) Bond strength and microleakage of current adhesive systems *Dental Materials* **10** 253-258.

GELB MN, BAROUCH E & SIMONSEN RJ (1986) Resistance to cusp fracture in Class II prepared and restored premolars *Journal of Prosthetic Dentistry* **55** 184-185.

GWINNETT AJ, BARATIERI LN, MONTEIRO S & RITTER AV (1994) Adhesive restorations with amalgam: Guidelines for the clinician *Quintessence International* **25** 687-695.

HASEGAWA T, RETIEF DH, RUSSELL CM & DENYS FR (1992) A laboratory study of the Amalgambond Adhesive System *American Journal of Dentistry* **5** 181-186.

JAGADISH S & YOGESH BG (1990) Fracture resistance of teeth with Class 2 silver amalgam, posterior composite, and glass cermet restorations *Operative Dentistry* **15** 42-47.

JOYNT RB, WIECZKOWSKI G Jr, KLOCKOWSKI R & DAVIS EL (1987) Effects of composite restorations on resistance to cuspal fracture in posterior teeth *Journal of Prosthetic Dentistry* **57** 431-435.

KAWAKAMI M, STANINEC M, IMAZATO S, TORII M & TSUCHITANI Y (1994) Shear bond strength of amalgam adhesives to dentin *American Journal of Dentistry* 7 53-56.

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LACY AM & STANINEC MA (1989) The bonded amalgam restoration *Quintessence International* **20** 521-524.

LIBERMAN R, BEN-AMAR A, GONTAR G & HIRSH A (1990) The effect of posterior composite restorations on the resistance of cavity walls to vertically applied occlusal loads *Journal of Oral Rehabilitation* **17** 99-105.

MORIN D, DeLONG R & DOUGLAS WH (1984) Cusp reinforcement by the acid-etch technique *Journal of Dental Research* **63** 1075-1078.

MORRILL F, GALBURT R, KUGEL G, ZIVE M & HABIB C (1994) Comparison of different shaped particles of amalgam alloy bonded to composite and dentin with 4-methacryloxyethyl trimellitate anhydride *Journal of Dental Research* **73** *Abstracts of Papers* p 221 Abstract 959.

RETIEF DH, MANDRAS RS & RUSSELL CM (1994) Shear bond strength required to prevent microleakage at the dentin/restoration interface *American Journal of Dentistry* **7** 43-46.

RUYTER IE (1985) Monomer systems and polymerization In *Posterior Composite Resin Dental Restorative Materials* eds Vanherle G & Smith DC pp 109-137 Utrecht, The Netherlands: P Szulc Publishing.

RUZICKOVA T, STANINEC M & MARSHALL GW (1994) SEM analysis of resin-amalgam adhesion after debonding *Journal of Dental Research* **73** *Abstracts of Papers* p 388 Abstract 2289.

SAIKU J, ST GERMAIN H Jr & MEIERS JC (1993) Microleakage of a dental amalgam alloy bonding agent *Operative Dentistry* **18** 172-178.

SHETH JJ, FULLER JL & JENSEN ME (1988) Cuspal deformation and fracture resistance of teeth with dentin adhesives and composites *Journal of Prosthetic Dentistry* **60** 560-569.

SOUZA MH, RETIEF DH, RUSSELL CM & DENYS FR (1994) Laboratory evaluation of phosphate ester bonding agents *American Journal of Dentistry* **7** 67-73.

STANINEC M (1989) Retention of amalgam restorations: undercuts versus bonding *Quintessence International* **20** 347-351.

STANINEC M & HOLT M (1988) Bonding of amalgam to tooth structure: tensile adhesion and microleakage tests *Journal of Prosthetic Dentistry* **59** 397-402.

STANINEC M, TRUONG PT, LOWE A & WATANABE LG (1993) Improved amalgam bonding resin tested in tension and retention *Journal of Dental Research* **72** *Abstracts of Papers* p 226 Abstract 982.

TEIGEN MD & BOYER DB (1994) Cusp stiffness of molars with bonded amalgam and composite restorations *Journal of Dental Research* **73** *Abstracts of Papers* p 221 Abstract 955.

TJAN AHL, TAN DE & BERRY FA (1994) Shear bond strength of amalgam to dentin pretreated with Optibond *Journal of Dental Research* **73** *Abstracts of Papers* p 221 Abstract 958.

TURNER EW, ST GERMAIN HA & MEIERS JC (1995) Microleakage of dentin-amalgam bonding agents *American Journal of Dentistry* **8** 191-196.

VARGA J, MATSUMURA H & MASUHARA E (1986) Bonding of amalgam filling to tooth cavity with adhesive resin *Dental Materials Journal* **5** 158-164.

VARGAS MA, DENEHY GE & RATANANAKIN T (1994) Amalgam shear bond strength to dentin using different bonding agents *Operative Dentistry* **19** 224-227.

YU XY, WEI G & XU JW (1987) Experimental use of a bonding agent to reduce marginal microleakage in amalgam restorations *Quintessence International* **18** 783-787.

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The Effect of a Training Program on the Reliability of Examiners Evaluating Amalgam Restorations

F J ROBERTELLO • F E PINK

Clinical Relevance
The training program improved the reliability of the examiners evaluating the clinical serviceability of the amalgam restorations.

SUMMARY

There have been long-term problems in establishing agreement among clinical and preclinical examiners in dentistry. The purpose of this study was to develop a training program and study its effect on examiner agreement when judging the clinical serviceability of amalgam restorations. Ten examiners with varying backgrounds, levels of experience, and no previous training with methods to standardize clinical evaluation evaluated 44 amalgam restorations in 17 patients before and after a brief training session. The restorations were judged as either acceptable (leave alone), or unacceptable (replacement or alteration required). The training program was brief and consisted of the introduction of a rating scale with descriptive criteria, followed by a clinical session where the examiners practiced using the rating scale and criteria to arrive at operational decisions. Interexaminer and intraexaminer agreement were calculated for both evaluation sessions. The training program improved the reliability of the examiners evaluating the clinical serviceability of the amalgam restorations. Although the gain was not to the level commonly accepted in the literature, it clearly demonstrates a step in the right direction.

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INTRODUCTION

While the reported survival time of amalgam restorations varies widely, the replacement and re-replacement rate for amalgam restorations is high and accounts for a significant portion of the workload in general dental practice. Some investigators have looked at the reasons for the replacement of restorations (Mjör, 1981; Boyd & Richardson, 1985; Klausner & Charbeneau, 1985; Klausner, Green & Charbeneau, 1987; Allander, Birkhed & Bratthall, 1990; Qvist, Qvist & Mjör, 1990; MacInnis, Ismail & Brogan, 1991; Nuckles & others, 1991; York & Arthur, 1993; Friedl, Hiller & Schmalz, 1994; Pink, Minden & Simmonds, 1994), while others have attempted to establish reliable predictors of amalgam restoration longevity (Smales & others, 1991). These studies indicate that, although dentists have placed amalgam restorations for over 150 years, there is widespread variability in the methods and criteria used for assessing restoration quality and the need for

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replacement. Further, decisions to replace "faulty" amalgam restorations may have significant cost implications as well as "appropriateness of care" concerns.

When making the decision to either replace or leave an existing amalgam restoration, dentists may be influenced more by their dental education, clinical experiences, and individual beliefs rather than by specific, well-defined scientific criteria (Boyd, 1989). These treatment decisions may be further influenced by whether the dentist is seeing the patient for the first time (Davies, 1984), by patient-dentist interpersonal interactions (Bader & Shugars, 1992), or even by the use of magnification during the examination (Whitehead & Wilson, 1992).

Attempts to standardize the clinical decision-making process is complicated by the well-documented difficulty in establishing agreement among examiners in dentistry (Elderton & Nuttall, 1983; Merrett & Elderton, 1984; Elderton, 1989; Bader & Shugars, 1992; Tveit & Espelid, 1992; Bader & Shugars, 1993). These studies indicate that dentists are not consistent in making clinical judgments. Whenever two or more examiners evaluate dental procedures, it is possible that a wide range of variability will exist. Some dentists even consider these decisions a function of their unassailable "clinical judgment" (Bader & Shugars, 1992). Therefore, treatment decisions to replace "defective" restorations may frequently be subjective, inconsistent, and the result of idiosyncratic decision making.

When clinically assessing the quality of amalgam restorations, it is imperative that those aspects of the restoration directly related to longevity be assessed according to standardized guidelines that link the clinical decision-making process to existing scientific data. While epidemiologists have developed a widely accepted set of criteria to detect the presence of caries (Radike, 1968), no single set of criteria to evaluate the condition of previously placed amalgam restorations is in widespread use. Several investigators (Cvar & Ryge, 1971; Ryge & Snyder, 1973) developed rating scales supported by descriptive criteria for use in making quality assessments of restorations in dental materials research. This rating system is based upon an operational approach to clinical evaluation, and results in a diagnostic decision of whether a restoration is clinically satisfactory or in need of replacement. This system has seen continual refinement (Charbeneau, 1975; Ryge, 1980) and has been used in peer review programs (Ryge, 1989). Other investigators have used indirect methods for clinical and preclinical evaluation such as photographs and study casts of restorations in attempts to improve examiner agreement (O'Connor & Lorey, 1978; Borgmeyer, Advokaat & Akerboom, 1983; Bryant, Mahler & Engle, 1985; Jokstad & Mjör, 1991; Kreulen & others, 1993).

In general, however, attempts to calibrate or train examiners to improve agreement have met with mixed results. Some investigators have reported success with examiner training programs (Natkin & Guild, 1967; Abou-Rass, 1973; Mjör & Haugen, 1976; Goepferd & Kerber, 1980), while others have shown that training to improve examiner reliability is frequently equivocal or unsuccessful (Fuller, 1972; Hinkelman & Long, 1973; Houpt & Kress, 1973; Poulsen, Bille & Rugg-Gunn, 1980; Scruggs & others, 1989). What investigators considered examiner training varied widely in length and content. Weaver and Saeger (1984) reviewed 15 rater training programs and found some to include only discussions of the rating scale to be used, while others used more formal training with practice sessions, error models, or color slides. However, there is inadequate information available to guide the researcher in the design of training for examiners evaluating clinical products.

Table 1. Rating System for Quality Evaluation of Amalgam Restorations

	Rating	Operational Explanation
Satisfactory	R = meets all rating standards.	The restoration is of acceptable quality. It restores the tooth to health, form, and function, and is expected to protect the surrounding tissue.
	S = satisfactory with reservations.	The restoration is of satisfactory quality, but exhibits one or more features that deviate from ideal conditions.
Not Acceptable	T = correct or replace for prevention.	The restoration is not of acceptable quality. Future damage to the tooth and/or surrounding tissues is likely to occur.
	V = replace statim.	The restoration is not of acceptable quality. Damage to the tooth, restoration, and/or surrounding tissues has now occurred, or early failure of the restoration is inevitable.

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This investigation studied the effect of a limited training program that used a rating scale with operationally defined criteria supported with line drawings, on the reliability of clinical examiners evaluating amalgam restorations. The purpose of this study was to determine whether or not limited training resulted in improved agreement among examiners when judging the clinical serviceability of amalgam restorations.

METHODS AND MATERIALS

Development of the Training Program

A program was developed to train examiners in the use of operational explanations and the criteria and definitions of conditions deemed important for clinically assessing the serviceability of amalgam restorations. The training program was designed to be brief in order to evaluate the effect of a limited training experience that would require few resources and little examiner time. A rating scale with descriptive criteria (Charbeneau, 1975), was used as the basis for the training program. The rating scale (Table 1) employed two quality designations: satisfactory and not acceptable, and four operational categories: (1) meets all standards, (2) satisfactory with reservations, (3) correct or replace for prevention, and (4) replace statim (immediately). Descriptive criteria (Table 2) were organized under the following headings: Surface, Margin Integrity, Occlusal Anatomy/ Function, and Axial Contour/Approximal Contact.

Line drawings were made to represent each clinical condition described by the criteria. Since it was difficult to represent surface criteria with line drawings, the Surface category was not represented by drawings. The rating scale with operational definitions, the criteria that described the rating scale, and the drawings were assembled into a booklet. Each examiner was provided with a booklet at the beginning of the training session.

A series of 35 mm color slides of the rating scale, operational explanations, and the criteria for evaluation were prepared for use in the training session and were organized for presentation in the same sequential order as the information in

Table 2. Quality Evaluation Criteria for Amalgam Restorations

Rating		Surface	Margin Integrity	Occlusal Anatomy/ Function	Axial Contour/Approximal Contact
Satisfactory	R	uniformly smooth	Tooth-restoration junction: not detectable or scarcely detectable with explorer	cusp planes, grooves, and marginal ridge; continuous with existing tooth form; functional contact and anatomy restored	Axial contour continuous with existing tooth form. Approximal embrasures and approximal contact restored.
	S	slightly rough, pitted or lacking finish	slightly detectable with explorer; amalgam slightly underextended or overextended	Slightly undercontoured: marginal ridge low, occlusal embrasure wide, amalgam low, not continuous with enamel or reduced locally. Slightly overcontoured: marginal ridge high or lacks embrasure, amalgam high, not continuous with enamel. Anatomy lacks definition. Occlusal contact slightly heavy.	Slightly undercontoured: axial surface, approximal line angles flattened, amalgam low, not continuous with enamel. Slightly overcontoured: axial surface full, approximal line angles overaccentuated, amalgam high, not continuous with enamel. Approximal contact visually closed, light.
Not Acceptable	T	decidedly rough, pitted or lacking finish	decidely detectable with explorer; amalgam decidedly underextended or overextended	Decidedly undercontoured: excessive depth of anatomy. Decidedly overcontoured: anatomy lacking.	Decidedly undercontoured: axial surface, approximal angles (tissue trauma likely). Decidedly overcontoured: soft tissue impinged. Minor damage to gingival or tooth tissue during finishing.
	V	deeply pitted, grooved, or unfinished	margin open, explorer can penetrate into tooth-restoration interspace; gross overfinish; gross overhang	Restoration fractured, missing. Traumatic occlusion. Occlusal contact negative.	Approximal contact open. Mutilation of gingival or tooth tissue during finishing. Grossly over- or undercontoured.

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the training booklet. The booklets were used by the examiners as a reference and for making notes during the training session and during the posttraining evaluations. The training session lasted 90 minutes.

Experimental Phase

SELECTION OF EXAMINERS AND STUDY LOCATION

Ten general dentists assigned to a large Naval Dental Center were selected as clinical examiners. They were all volunteers, and their selection was based on two factors: (1) the examiners had to be a heterogeneous group with varying backgrounds, dental education, and levels of experiences, (2) they were to have had no formal training with methods of calibration or standardizing clinical evaluations. The examiners' levels of experience ranged from 6 months to 17 years following graduation from dental school, and the examiners attended 10 different dental schools.

SELECTION OF RESTORATIONS FOR EVALUATION

Forty-four amalgam restorations in 17 volunteers were selected for evaluation. The patients were six females and 11 males ranging in age from 18 to 39. The distribution of restorations in each patient was as follows: Three patients had four restorations each, seven patients had three restorations each, four patients had two restorations, and three patients had one restoration each for evaluation. The distribution of the 44 amalgam restorations by surface was as follows: 15 had one surface, 23 had two surfaces, and six restorations had more than two surfaces. The same restorations were evaluated in both the pretraining and posttraining evaluations and thus served as their own controls.

PRETRAINING EVALUATIONS

Each patient was randomly assigned to one of 17 dental operatories. An examination form indicating the restorations the examiners were to evaluate on each patient was available in each operatory and was used to record the data. The 10 examiners circulated through each of the operatories until all of the designated amalgam restorations had been evaluated by each examiner. A standard dental mouth mirror (EXD5 explorer, Hu-Friedy Mfg Co Inc, Chicago, IL 60618), compressed air, and direct clinical lighting were provided in each operatory. Using whatever criteria they considered to be important, each examiner determined the disposition of each restoration by assigning it to one of three possible categories: the restoration was to be left alone, replaced, or significantly altered to make it acceptable. A decision to leave the restoration alone was considered a Romeo or Sierra (R, S) rating. If the decision was to replace the restoration, it was judged a Victor (V) rating. If a significant alteration was required to make the restoration acceptable, it was placed in the Tango (T) rating. The R and S ratings were considered acceptable, while the T and V ratings were considered unacceptable (Table 1).

When all the restorations had been evaluated, the intraexaminer agreement was determined by having 16 randomly selected restorations reevaluated by four of the 10 evaluators. The four examiners represented all levels of experience, and were not aware of how they rated the 16 restorations during the initial examination. The pretraining interexaminer and intraexaminer agreement was then calculated from the acceptable (R, S) and unacceptable (T, V) ratings using Kappa analysis (Landis & Koch, 1977). Kappa analysis allows for expected agreement when judging intraexaminer and interexaminer reliability.

TRAINING

After the completion of the pretraining evaluations, the examiners gathered in a lecture room, and each examiner was given one of the training booklets. The need for a standardized method of clinically evaluating amalgam restorations was introduced by presenting the observation that there was considerable disagreement among the examiners during the pretraining evaluations. No specific disagreements or "correct" judgments were discussed, however. A rating scale with well-specified criteria (Tables 1 & 2) was introduced and presented to the examiners as a means of arriving at operational decisions regarding the clinical serviceability of amalgam restorations.

The training program consisting of the rating scale, the criteria, and color slides of the line drawings representing the criteria was presented next in a lecture/discussion format. Discussion of the criteria was encouraged, and the examiners agreed to accept them as presented. Each criterion was explained thoroughly using the line drawings in the booklets and corresponding color slides. Note taking was encouraged, and the booklets were available for immediate reference during the posttraining evaluations.

The training session was intentionally brief and lasted only 90 minutes, following which the examiners were paired and a clinical practice session using the rating scale and criteria was conducted by having the examiners evaluate amalgam restorations in each other's mouths. Moderators were available for consultation and assistance in using the scale and criteria to make clinical judgments.

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Table 3. Modal Agreements Before and After Training

Mean modal agreement before training	74
Mean modal agreement after training	80
Improved modal agreements after training	25
Decreased modal agreements after training	8
Agreements that remained the same	11

POSTTRAINING EVALUATION

The day following the training session, the patients were again randomly seated in the designated operatories. The evaluation form used for the posttraining evaluations contained the criteria, tooth number, and restoration surface(s), examiner code, and subject code number. An evaluation form was filled out by each examiner for each restoration. The statement(s) in each vertical column of criteria that best described that aspect of the restoration were circled. The lowest-rated vertical column was used to determine the overall rating for that restoration based on the assumption that a restoration can only be as good as its poorest feature. The examiners were instructed to use only the criteria presented during the training session to arrive at clinical decisions. As in the pretraining evaluations, the Romeo (R) and Sierra (S) ratings were considered acceptable, while Tango (T) and Victor (V) ratings were unacceptable.

The evaluations proceeded as in the pretraining session, and when all the restorations had been evaluated by each examiner, the four examiners previously selected during the pretraining evaluation reevaluated the same 16 restorations. The collected data established the posttraining interexaminer and intraexaminer agreement based on acceptable or unacceptable ratings. The posttraining data were compared with the pretraining data to establish the effectiveness of the training program in improving agreement among the examiners.

The success of the training program was assessed in two ways: (1) by determining if the proportion of examiners who agree on judgments of acceptable or unacceptable for the 44 restorations was greater after training than before training; (2) the effectiveness of the training program would be supported if the percent agreement among pairs of examiners judging restoration quality was greater after training than before training.

Table 4. Percent Intraexaminer Agreement Before and After Training

Examiner	Before Training	After Training
2	88	81
4	75	94
5	81	94
10	88	100
Mean	**83**	**92**

RESULTS

Percent of Examiners Giving Modal Evaluations Before and After Training

All statistical analysis was performed at the 0.05 level of significance. An indication of interexaminer agreement is the proportion of examiners who are in accord on the modal judgment for the 44 restorations. Perfect agreement would be shown by 100% of the examiners agreeing on a judgment of acceptable or unacceptable. Minimum agreement would occur if the examiners were evenly split with half evaluating a restoration as acceptable and half as unacceptable. To assess whether the proportion of examiners giving the modal judgment increased after training, the direction of change for each restoration was determined. The Sign test was used to evaluate

Table 5. Percent Interexaminer Agreement Before and After Training

Examiner	Before Training	After Training
1	61	73
2	56	68
3	61	67
4	66	73
5	63	70
6	61	66
7	61	71
8	62	72
9	66	71
10	58	68
Mean	**61**	**70**

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Table 6. Kappa Analysis of Examiners by Time

Time = 1										
Examiner	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.00									
2	0.54	1.00								
3	0.17	0.13	1.00							
4	0.38	0.24	0.25	1.00						
5	0.06	0.11	0.11	0.03	1.00					
6	0.28	0.06	0.39	0.21	0.21	1.00				
7	-0.07	-0.10	-0.21	0.21	0.19	0.10	1.00			
8	-0.09	-0.01	0.12	0.07	0.20	0.24	0.33	1.00		
9	-0.17	-0.07	0.16	-0.1	0.16	0.20	0.19	0.32	1.00	
10	0.08	0.04	0.22	0.04	0.27	0.10	0.07	0.11	0.28	1.00
Time = 2										
Examiner	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.00									
2	0.54	1.00								
3	0.17	0.09	1.00							
4	0.59	0.35	0.35	1.00						
5	0.32	0.07	0.05	0.28	1.00					
6	0.09	0.22	-0.10	0.20	0.24	1.00				
7	0.28	0.20	0.04	0.25	0.43	0.29	1.00			
8	0.19	0.12	-0.03	0.13	0.40	0.27	0.53	1.00		
9	0.00	-0.11	0.00	0.01	0.24	-0.03	0.20	0.27	1.00	
10	0.09	-0.06	-0.15	0.07	0.47	0.02	0.33	0.25	0.35	1.00
Time = 1 versus 2										
Examiner	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Kappa	0.46	0.56	-0.01	0.41	0.61	0.58	0.21	0.36	0.63	0.43

Kappa Agreement:
0.81-1.00 Nearly perfect agreement
0.61-0.80 Substantial agreement
0.41-0.60 Moderate agreement
0.21-0.40 Fair agreement
0.00-0.20 Poor agreement

the significance of the findings. The mean modal agreement before and after training is indicated in Table 3. The magnitude of the modal judgment increased after training for 25 restorations, decreased for 8, and did not change for 11. Results show that examiner agreement for the modal judgment is higher after training for a statistically significant number of restorations than for the number of restorations for which agreement on the modal judgment is lower ($z = 2.79, P = 0.0052$).

Intraexaminer Agreement

Following both the initial pretraining and posttraining evaluations, four of the 10 examiners re-evaluated 16 of the restorations to determine intraexaminer agreement pre- and posttraining. In the pretraining session, interaexaminer agreement was determined from the first and second evaluations of the 16 restorations. The same procedure was followed in the posttraining session. Comparisons in intraexaminer agreement before and after training were determined for each examiner and a mean score computed for the four examiners in the two sessions. As shown in Table 4, the overall mean intraexaminer agreement was 83% before training and improved to 92% after training. Three of the four examiners showed improved agreement, while one examiner showed less intraexaminer agreement following training. The difference was not tested statistically due to the small number involved.

Interexaminer Agreement

To evaluate interexaminer agreement, each of the 10 examiners was paired with each of the nine other examiners, and their agreement over all 44 restorations was determined before and after training. Table 5 shows that the mean pretraining interexaminer agreement was 61% and improved to 70% following the training session. The improvement ranged from 5% to 12%, with an average improvement in interexaminer agreement of 8.8%. All 10 examiners showed improved interexaminer agreement posttraining as compared with pretraining. The difference in interexaminer agreement before and after training, as tested by the Sign test was statistically

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significant ($P = 0.002$). Kappa analysis of the intra- and interexaminer agreement was calculated for the pretraining and posttraining evaluation sessions. The linear trend toward higher Kappa scores in the posttraining evaluation (Table 6), and thus improved reliability, was shown to be statistically significant by means of a paired t-test ($P = 0.040$). A nonparametric equivalent analysis of the t-test, the Wilcoxon Signed-Rank test of these same data to assure normality, also showed significantly greater Kappa scores following the training session ($P = 0.015$). Therefore, the training program clearly improved agreement for both intra- and interexaminer reliability.

DISCUSSION

The results show that following limited training, examiners demonstrated improvement in interexaminer agreement when evaluating amalgam restorations using acceptable or unacceptable judgments. Even though training examiners to an acceptable level of agreement is not easy (Hinkelman & Long, 1973; Houpt & Kress, 1973; Poulsen, Bille & Rugg-Gunn, 1980; Weaver & Saeger, 1984; Scruggs & others, 1989), this improvement in examiner reliabiliy following training is consistent with other investigations (Natkin & Guild, 1967; Abou-Rass, 1973; Mjör & Haugen, 1976; Goepferd & Kerber, 1980; Edwards, Morse & Mitchell, 1982). It should be noted, however, that even after training, interexaminer agreement falls short of standards generally accepted in the literature (Cvar & Ryge, 1971; Ryge & Snyder, 1973; Poulson, 1987). The findings are viewed as promising, given the fact that the examiners were only first introduced to the rating scale and criteria during the training session. In addition, the training program, by design, was brief and included only a discussion of the rating scale and criteria. The clinical practice session, where the examiners first had the opportunity to practice using the rating scale and criteria, was also limited.The results might have been more promising had the examiners been allowed time to reach consensus on the criteria used, rather than to accept them as presented.

One might expect that a longer training program, especially one in which disagreement among examiners on samples of restorations could be discussed and consensus reached, and where examiners could check their ratings against a standard for accuracy, would enhance interexaminer agreement. This is consistent with other authors (Ryan, Phillips & Prescott, 1988) who believe interexaminer agreement is enhanced by well-designed training procedures, and by the opportunity to reevaluate the examiners following training. Since the training program in this study included a rating scale, descriptive criteria, instruction in using the scale to make clinical judgments, and color slides and line drawings of the individual criteria, it is not possible to assess independently the contribution of any of the components. However, the success of the present study supports the use of visual comparison standards to improve interexaminer agreement. While this study addressed only examiner agreement and not the accuracy of the examiners' decisions, the use of error models or standardized restorations might be effective for this purpose. The success of this training program may also be partly explained by the fact that, although brief, it contained the following elements deemed important by Weaver and Saeger (1984): (1) an active practice session rating sample products; (2) low levels of pretraining examiner agreement; and (3) clearly defined objectively worded criteria. However, higher agreement following training is no guarantee that examiner reliability won't deteriorate over time. Future studies should address the maintenance level of training necessary to maintain high examiner agreement. The development of standardized criteria to evaluate the serviceability of previously placed restorations, as well as the role of treatment philosophies on the standardization of clinical decisions are also concerns that should be addressed.

CONCLUSIONS

General dentists from diverse educational backgrounds and with varying levels of experience demonstrated a high degree of variability and low interexaminer agreement when rendering clinical decisions as to the serviceability of amalgam restorations. This investigation has shown that a brief training program using a rating scale, well-defined criteria, and visual comparison standards, can improve the reliability of examiners rendering clinical judgments. Although this improvement was not to the level accepted as a standard in the literature, it is a step in the right direction.

Acknowledgment

The authors wish to express their gratitude to Dr Gerald T Charbeneau for his many contributions to this study.

(Received 7 November 1995)

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References

ABOU-RASS M (1973) A clinical evaluation instrument in endodontics *Journal of Dental Education* **37** 22-36.

ALLANDER L, BIRKHED D & BRATTHALL D (1990) Reasons for replacement of class II amalgam restorations in private practice *Swedish Dental Journal* **14** 179-184.

BADER JD & SHUGARS DA (1992) Understanding dentists' restorative treatment decisions *Journal of Public Health Dentistry* **52** 102-110.

BADER JD & SHUGARS DA (1993) Agreement among dentists' recommendations for restorative treatment *Journal of Dental Research* **72** 891-896.

BORGMEYER PJ, ADVOKAAT, JG & AKERBOOM HB (1983) Quality control of amalgam restorations Part II: A comparison of four non-clinical methods of evaluation *Netherlands Dental Journal* **90** 24-43.

BOYD MA (1989) Amalgam replacement: are the decisions based on fact or tradition? In *Quality Evaluation of Dental Restorations Criteria for Placement and Replacement* Anusavice KJ, ed Chicago: Quintessence pp 73-80.

BOYD MA & RICHARDSON AS (1985) Frequency of amalgam replacement in general dental practice *Journal of the Canadian Dental Association* **51** 763-766.

BRYANT RW, MAHLER DB & ENGLE JH (1985) A comparison of methods for evaluating the marginal fracture of amalgam restorations *Dental Materials* **1** 235-237.

CHARBENEAU GT (1975) Rating scales for the clinical evaluation of quality of performance in restorative dentistry In *An Instructional Information Exchange for Dentistry in the United States* **6** 153-178 Mackenzie RS & Harrop TJ, eds Washington: US Govt Printing Office (DHEW Pub No (HRA) 75-78).

CVAR JF & RYGE G (1971) *Criteria for the Clinical Evaluation of Dental Restorative Materials* San Francisco: US Government Printing Office, USPHS Pub No 790-244.

DAVIES JA (1984) The relationship between change of dentist and treatment received in the General Dental Service *British Dental Journal* **157** 322-324.

EDWARDS WS, MORSE PK & MITCHELL RJ (1982) A practical evaluation system for preclinical restorative dentistry *Journal of Dental Education* **46** 693-696.

ELDERTON RJ (1989) Variability in the decision-making process and implications for change toward a preventive philosophy In *Quality Evaluation of Dental Restorations: Criteria for Placement and Replacement* Anusavice KJ, ed Chicago: Quintessence pp 211-219.

ELDERTON RJ & NUTTALL AM (1983) Variation among dentists in planning treatment *British Dental Journal* **154** 201-206.

FRIEDL K-H, HILLER K-A & SCHMALZ G (1994) Placement and replacement of amalgam restorations in Germany *Operative Dentistry* **19** 228-232.

FULLER JL (1972) The effects of training and criterion models on interjudge reliability *Journal of Dental Education* **36** 19-22.

GOEPFERD SJ & KERBER PE (1980) A comparison of two methods for evaluating primary class II cavity preparations *Journal of Dental Education* **44** 537-542.

HINKELMAN KW & LONG NK (1973) Method for decreasing subjective evaluation in preclinical restorative dentistry *Journal of Dental Education* **37** 13-18.

HOUPT MI & KRESS G (1973) Accuracy of measurement of clinical performance in dentistry *Journal of Dental Education* **37** 34-46.

JOKSTAD A & MJÖR IA (1991) Assessment of marginal degradation of restorations on impressions *Acta Odontologica Scandinavica* **49** 15-25.

KLAUSNER LH & CHARBENEAU GT (1985) Amalgam restorations: a cross-sectional survey of placement and replacement *Journal of the Michigan Dental Association* **67** 249-252.

KLAUSNER LH, GREEN TG & CHARBENEAU GT (1987) Placement and replacement of amalgam restorations: a challenge for the profession *Operative Dentistry* **12** 105-112.

KREULEN CM, van AMERONGEN WE, BORGMEIJER PJ & AKERBOOM HB (1993) Comparison of two methods for evaluating the occlusal marginal adaptation of posterior restorations *ASDC Journal of Dentistry for Children* **60** 304-309.

LANDIS JR & KOCH GG (1977) The measurement of observer agreement for categorical data *Biometrics* **33** 159-174.

MACINNIS WA, ISMAIL A & BROGAN H (1991) Placement and replacement of restorations in a military population *Journal of the Canadian Dental Association* **57** 227-231.

MERRETT MC & ELDERTON RJ (1984) An in vitro study of restorative dental treatment decisions and dental caries *British Dental Journal* **157** 128-133.

MJÖR IA (1981) Placement and replacement of restorations *Operative Dentistry* **6** 49-54.

MJÖR IA & HAUGEN E (1976) Clinical evaluation of amalgam restorations *Scandinavian Journal of Dental Research* **84** 333-337.

NATKIN E & GUILD RE (1967) An evaluation of preclinical laboratory performance: a systematic study *Journal of Dental Education* **31** 152-161.

NUCKLES DB, SNEED WD, BAYME JB, COLLINS DE, HOOK CR & WELSH EL (1991) Faculty differences in replacement decisions for amalgam restorations *Quintessence International* **22** 533-540.

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O'CONNOR P & LOREY RE (1978) Improving interrater agreement in evaluation in dentistry by the use of comparison stimuli *Journal of Dental Education* **42** 174-179.

PINK FE, MINDEN NJ & SIMMONDS S (1994) Decisions of practitioners regarding placement of amalgam and composite restorations in general practice settings *Operative Dentistry* **19** 127-132.

POULSON E (1987) A method for training and checking interrater agreement for a patient classification study *Nursing Management* **18** 72-80.

POULSEN S, BILLE J & RUGG-GUNN AJ (1980) Evaluation of a calibration trial to increase interexaminer reliability of radiographic diagnosis of approximal carious lesions *Community Dentistry and Oral Epidemiology* **8** 135-138.

QVIST J, QVIST V & MJÖR IA (1990) Placement and longevity of amalgam restorations in Denmark *Acta Odontologica Scandinavica* **48** 297-303.

RADIKE A (1968) Criteria for diagnosis of dental caries In *Proceedings of the Conference on Clinical Testing of Cariostatic Agents* Chicago: American Dental Association pp 87-88.

RYAN JW, PHILLIPS CY & PRESCOTT PA (1988) Interrater reliability: the underdeveloped role of rater training *Applied Nursing Research* **1** 148-150.

RYGE G (1980) Clinical criteria *International Dental Journal* **30** 347-358.

RYGE G (1989) The California Dental Association Quality Evaluation System: A standard for self assessment In *Quality Evaluation of Dental Restorations, Criteria for Placement and Replacement* Chicago: Quintessence pp 273-286.

RYGE G & SNYDER M (1973) Evaluating the clinical quality of restorations *Journal of the American Dental Association* **87** 369-377.

SCRUGGS RR, DANIEL SJ, LARKIN A & STOLTZ RF (1989) Effects of specific criteria and calibration on examiner reliability *Journal of Dental Hygiene* **63** 125-129.

SMALES RJ, WEBSTER DA, LEPPARD PI & DAWSON AS (1991) Prediction of amalgam restoration longevity *Journal of Dentistry* **19** 18-23.

TVEIT AB & ESPELID I (1992) Class II amalgams: interobserver variations in replacement decisions and diagnosis of caries and crevices *International Dental Journal* **42** 12-18.

WEAVER JR & SAEGER W (1984) A rater training program in removable prosthodontics *Journal of Dental Education* **48** 251-257.

WHITEHEAD SA & WILSON NHF (1992) Restorative decision-making behavior with magnification *Quintessence International* **23** 667-671.

YORK AK & ARTHUR JS (1993) Reasons for placement and replacement of dental restorations in the United States Navy Dental Corps *Operative Dentistry* **18** 203-208.

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Postoperative Pain following Bonded Amalgam Restorations

W D BROWNING • W W JOHNSON • P N GREGORY

Clinical Relevance
This double-blinded clinical trial using OptiBond was unable to substantiate claims that a dentinal adhesive liner used in conjunction with amalgam restorations nearly eliminates postoperative sensitivity to cold.

SUMMARY

Sixty subjects were randomized into two groups. The time, in seconds, that it took subjects to respond to a standardized cold stimulus was recorded at baseline and again 1 week following treatment. During the intervening week subjects filled out three self-report questionnaires about pain from exposure to cold and several other common sources of postoperative pain. These questionnaires were filled out after 1 day, again 3 days after the first questionnaire, and 3 days after the second. Subjects mailed the questionnaires in immediately to provide three independent reports about cold sensitivity. The group receiving an OptiBond adhesive liner under their amalgam restorations was not found to be any less sensitive to cold, either by timed response to a cold stimulus or by self-report of pain, than the group receiving conventional liners and bases.

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INTRODUCTION

The presence of pain following dental procedures is of concern to patients and has an adverse impact on patient satisfaction. Postoperative pain has been found to be a frequent occurrence following dental restorations (Grover, Hollinger & Lorton, 1984a; Grover, Lorton & Hollinger, 1984b). Mild to moderate pain to cold was reported by one-half of all dental patients following placement of dental restorations that utilized an application of conventional liners and cavity varnishes (Silvestri, Cohen & Wetz, 1977). Concern about the pulpal response to a broad array of operative procedures, liners, bases, and restorative materials and their relation to postoperative pain has led to extensive investigation in this area (Cox, 1992). Brännström and Nordenvall (1978), Torstenson (Torstenson, Nordenvall & Brännström, 1982), Nyborg (Brännström & Nyborg, 1971), and others were among the first to investigate the effects of microleakage on the pulp. Brännström's investigation led him to conclude that: 1) pulpal damage is caused by infection rather than by the procedures or materials used in restoring carious lesions, and 2) dentin is a good insulator, and thick bases are not needed under amalgam restorations (Brännström, 1984). He cites two sources of bacterial contamination responsible for this infection: bacteria in the smear layer and the ingress of bacteria by microleakage. Thus, removal of the smear layer, including the bacteria present there, and placement of a material to seal

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the dentinal tubules to prevent microleakage should greatly reduce or eliminate postoperative sensitivity without the necessity of placing thick, insulating bases.

Studies have demonstrated that: 1) etching dentin removes the smear layer (Pashley, Michelich & Kehl, 1981); 2) dentinal adhesive liners reduce microleakage under amalgam restorations (Ben-Amar & others, 1987); and 3) etching of dentin and placement of dentinal adhesive liners is well tolerated by the pulp (Gilpatrick, Johnson & Moore, 1994).

Miller and Charbeneau (1984) investigated the necessity of basing to reduce postoperative sensitivity to cold and demonstrated that teeth without bases were hypersensitive to cold when compared to those with bases. However, their study design did not provide for the removal of the smear layer or for sealing the dentinal tubules, relying rather on the cementation of amalgam "inlays" with a zinc oxide and eugenol cavity liner.

The purpose of this study was to determine whether patients whose amalgam restorations were placed utilizing a procedure of etching the enamel and dentin and then placing a dentinal adhesive liner had less postoperative sensitivity to cold than patients who had restorations placed utilizing only conventional bases and liners.

METHODS AND MATERIALS

Sixty adult subjects, 18 to 55 years of age, with class 1 or 2 carious lesions were recruited from the University of Tennessee, Memphis and the surrounding community. Potential subjects were screened to confirm the presence of an appropriate lesion on a vital tooth. At an initial appointment, subjects were informed about the nature of the project, including the fact that they would be randomly assigned to receive a silver filling with either conventional bases or an adhesive liner, and gave their written consent to participate. Also at this appointment, an alginate impression was taken. From the ensuing model a custom stint was fabricated in a manner that allowed the investigators to inject cold water around the tooth of interest. First, the subject tooth was blocked out on the model with 28-gauge green wax (Kerr Mfg Co, Romulus, MI 48174). The blockout extended from the mesial to the distal line angles and from the cervical on the facial, across the occlusal and to the cervical on the lingual. Next, the stint was fabricated using Triad VLC Resin (Dentsply, York, PA 17405) and lined with Extrude (Kerr Mrg Co). The use of the green wax blockout created a reservoir for cold water around the subject tooth, while the other teeth were intimately contacted with the impression material. An occlusal opening was made in the stint to allow for injection of cold water into the reservoir.

At the treatment appointment a baseline cold response measurement (CRM) was recorded to the nearest tenth of a second. Water, which had been stored in disposable syringes with a plastic cannula at a constant temperature of 8 °C, was injected through the occlusal opening in the stint to obtain the measurement. The subject was given a digital stopwatch and instructed to start the watch when the operator said "go" and to "stop when you feel a definite cold sensation coming from your tooth." Wording remained consistent throughout the project.

Next the subject was anesthetized and the tooth isolated with rubber dam and prepared. Once the cavity preparation was complete, the operator determined the depth classification of the lesion, and the subject was randomized to either the treatment or control groups. All restorations were done by one operator.

Table 1. Protocol for Depth Classification and Basing

Lesion Depth Classification	Definition	Protocol for Treatment Group	Protocol for Control Group
Classification 1: Minimal Caries	Within 1 mm of ideal depth pulpally and axially	1) Etch enamel and dentin 2) OptiBond Prime 3) OptiBond Dual Cure	1) copal varnish only
Classification 2: Moderate Caries	More than 1 mm past ideal depth axially and/or pulpally	1) Etch enamel and dentin 2) OptiBond Prime 3) OptiBond Dual Cure	1) copal varnish 2) Fleck's cement
Classification 3: Deep Caries	Within 1 mm of the pulp on either the axial or pulpal walls	1) Dycal on area nearest pulp 2) Etch enamel and dentin 3) OptiBond Prime 4) OptiBond Dual Cure	1) Dycal on area nearest pulp 2) copal varnish 3) Fleck's cement

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Table 2. Comparison of Groups at Baseline

	Treatment Group (n=31)	Control Group (n=29)
Type of Tooth Restored		
Bicuspid	22	19
Molar	9	10
Class of Restoration		
Class 1	16	12
Class 2	15	17
Depth of Lesion		
Classification 1	21	19
Classification 2	9	8
Classification 3	1	2
Subject's Sex		
Females	20	18
Males	11	11

Randomization of subjects was accomplished using a block randomization schedule. The schedule was prepared in advance, recorded on cards, and sealed in envelopes. The cards were opened only after the operator had finished preparing the tooth and classified the depth of the lesion (Table 1). Thus, both operator and subject were blinded to group assignment. This blinding was maintained throughout the project as neither subjects, operator, nor evaluators were aware of which treatment had been rendered, and it was successful at producing comparable groups at baseline (Table 2). The protocol for completing the restoration was dependent upon the depth of the lesion and the group assignment (Table 1). Subjects in the treatment group had the enamel etched with 37% phosphoric acid for 20 seconds and the dentin etched with 10% phosphoric acid for 15 seconds. The protocol specified for OptiBond is to gently agitate the primer for 30 seconds, air dry 10 to 15 seconds, and light cure for 20 seconds. The OptiBond dual-cure was placed, light cured for 30 seconds, and then restored with Contour (Kerr Mfg Co). Similarly, the liners and bases for the control group were mixed according to the manufacturer's directions, and restored with Contour. Since bases were placed to return the cavity preparation to ideal depth, the minimum depth of Fleck's cement (Mizzy, Inc, Cherry Hill, NJ 08002) was one millimeter.

Subjects were appointed to return in 1 week, and instructed to fill out a series of three self-report questionnaires in the interim: one after 24 hours, one after 4 days, and the last after 7 days. The questionnaires asked for responses about sensitivity to cold and eight other common postoperative complaints the subject might experience during the week. The questionnaires used a 5-inch, visual analog scale. The analog scale was anchored by the descriptor "no pain" on the left and "severe pain" on the right. Thus, subjects who experienced no pain would mark the far left-hand side of the line, and those with severe pain the far right-hand side of the line. Subjects were instructed to place a check-mark at that spot along the line that described their experience. Included with the questionnaires were three self-addressed, stamped envelopes. Questionnaires were to be filled out at the appropriate time and then immediately mailed. In this manner three independent judgments about postoperative cold sensitivity were obtained. Once again, wording of the instructions was kept consistent throughout the project.

At the 1-week follow-up appointment the final CRM was obtained in exactly the same manner as the baseline CRM and color photographs were obtained.

RESULTS

A priori our intent was to compare the degree of cold sensitivity the treatment and control groups experienced at 1 week postop. The measure used was the final cold response measurement (CRM) expressed as a proportion of the baseline CRM. A shorter CRM indicates a more cold-sensitive tooth, while a longer CRM indicates a less sensitive tooth. Similarly, a subject whose final CRM is a smaller proportion of the baseline CRM would have a more cold-sensitive tooth than a subject where the proportion is larger. The mean proportion for each group was compared using an independent samples *t*-test. There was no statistically significant difference between the two groups. There also was no statistically significant difference between the mean CRM at baseline or 1 week postoperatively (Table 3). Four cases, two from each group, were eliminated from the analyses. These were subjects whose recorded CRMs were extreme, more than two standard deviations above the mean. None of the statistical analyses was affected by removing these data, but removal of the data made the means obtained more representative of the groups as a whole.

When a comparison was made within each group, the mean difference between the CRM at baseline and at 1 week postoperative was statistically

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Table 3. Cold Response Measurements

	Treatment Group	Control Group
Baseline	4.1 seconds	3.0 seconds
Final	2.3 seconds	1.8 seconds
Proportion of Baseline	0.78	0.73
Difference between baseline and final	1.8* seconds	1.2** seconds

*The difference between the CRM at the baseline and final measurements for the treatment group was statistically significant ($P < 0.001$).

**The difference between the mean CRM at the baseline and final measurements for the control group was statistically significant ($P < 0.0005$).

Connecting lines indicate no statistically significant differences.

Table 4. Self-Report of Pain--All Subjects

	Treatment Group	Control Group
24 hours	1.8	0.8
4 days	1.4	1
7 days	1.2	1.2

Self-report of pain from cold sensitivity on a 10-point scale; connecting lines indicate no significant differences.

significant, $P < 0.001$ for the treatment group and $P < 0.0005$ for the control group (Table 3).

Similarly, cold sensitivity as measured by the self-report questionnaires was not significantly different statistically at 1, 4, or 7 days postoperative. At 24 hours the control group reported less pain from cold sensitivity than the treatment group. On a scale of 0 to 10, the mean report of pain for the control group was 0.8, while for the treatment group it was 1.8. Although representing a considerable difference between the groups, it was not significant ($P = 0.08$). The difference lessened at 4 days and 7 days (Table 4). It was also noted that a majority of subjects in both groups reported no pain with exposure to a cold stimulus.

Considering only those subjects who reported pain with cold and adjusting for multiple comparisons, there was no significant difference between the mean response for the two groups at 24 hours, 4 days, or 7 days. There was wide variance in responses, the treatment group reporting responses that ranged between 0.8 to 9.2 and the control group 0.2 to 6.2. Considering scores below 3.3 to be minor, between 3.4 and 6.7 to be moderate, and those above 6.7 to be severe, it is apparent that the great majority of subjects experienced minor or no pain. Table 5 contains the number of subjects who reported no pain, minor pain, the mean for those responding positively in each group, and the standard deviation.

DISCUSSION

Christensen's (1994) opinion is that "the state-of-the-art procedure appears to be bonding amalgam into tooth structure." He cites the near elimination of postoperative pain, an empirical observation, and increased fracture resistance as advantages (Christensen

Table 5. Self-Report of Pain for Those Subjects Reporting Pain

	24 Hours				4 Days				7 Days			
	No Pain	Pain <3.3	SD	Mean Response	No Pain	Pain <3.3	SD	Mean Response	No Pain	Pain <3.3	SD	Mean Response
Treatment Group (n=30)	18	4	2.5	4.5	20	4	2.2	4.2	20	5	2.5	3.6
Control Group (n=28)	18	8	2.1	2.1	18	5	1.4	2.8	16	7	1.8	2.9

Self-report of pain from cold sensitivity on a 10-point scale for those subjects reporting no pain or minor pain; connecting lines indicate no statistically significant differences.

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& others, 1991). Our results do not support the idea that bonded amalgams nearly eliminate postoperative sensitivity. This project investigated a different bonding agent (OptiBond) than the one he recognized as being the most popular (Amalgambond Plus, Parkell Products, Farmingdale , NY 11735). While the differences could be product-related, other possibilities need to be considered as well.

Findings based on empirical observation alone are prone to misinterpretation and bias. Our study showed that, for both groups, a majority of subjects reported no pain with exposure to a cold stimulus and, even among those subjects experiencing some pain, many reported minor pain. Thus, practitioners asking patients about postoperative sensitivity are, more often than not, going to get a report of no pain or very little pain. Since placing bonded amalgam restorations is a new modality and copal varnish is not, our empirical observations are prone to reporting bias. Since we fail to ask those receiving conventional therapy about their postoperative experiences, we fail to find that this group has experienced very little postoperative pain as well.

Christensen and others (1991) reported that teeth restored with Amalgambond and amalgam had cusp fracture resistance values almost 50% higher than unprepared teeth. The same study also found no significant difference in cusp fracture resistance between unprepared teeth and teeth with an unrestored MOD preparation. By contrast, Santos and Meiers (1994) did not find bonded amalgams to be more fracture resistant than conventional amalgam restorations, and a study measuring microstrain rather than tooth fracture found uncut teeth to be significantly more resistant to flexure than teeth with unrestored MOD preparations (Lopes, Leitao & Douglas, 1991).

Researchers are also reporting that the advantage in decreasing microleakage demonstrated by the use of adhesive liners under amalgam restorations dissipates with increased aging (Saiku, St Germain & Meiers, 1993; Moore, Johnson & Kaplan, 1995). So there seems to be no clear-cut evidence in the literature that bonded amalgam restorations are superior to conventional basing and lining practices.

When compared to present practices, the routine placement of an adhesive liner under amalgam restorations is more time consuming and costly with no clear-cut reason to expect a superior clinical result. While recognizing the difficulties inherent in generalizing studies about specific products to a class of products and of predicting clinical success or failure from in vitro data, it seems premature to establish the use of adhesive liners under amalgam restorations as the standard of care. Amalgam restorations with and without copal varnish liners have a long history of clinical success. Unfortunately, there is a paucity of clinical data that are not empirical in nature on the long-term success of bonded amalgam restorations.

The finding, as measured by the self-report questionnaire, that the control group experienced less than half as much pain to cold as the treatment group was surprising. Compared to copal varnish, one would expect initially a superior seal against microleakage from an adhesive liner. Accordingly, the observed result seems opposite to what would be expected. At 4 days and 7 days the groups are virtually identical. It would seem that the initial report of pain, while nearly reaching statistical significance, was an aberrant observation, and at 4 and 7 days we simply see a regression to a mean which was common to the two groups.

CONCLUSIONS

The cold response measurements (CRM) for the treatment and control groups were not significantly different before treatment or at 1 week following treatment. Both groups, however, were found to have a statistically significant shorter CRM, indicating more sensitivity to cold, 1 week following treatment. Therefore, it can be concluded that both groups experienced postoperative sensitivity to cold, and that the use of an OptiBond liner under the amalgam restorations did not eliminate postoperative sensitivity to cold. Furthermore, OptiBond did not offer any advantage over the use of Fleck's cement and copal varnish in minimizing postoperative cold sensitivity. The results and conclusion are further supported by similar findings from the subjects' self-report of pain at 1 day, 4 days, and 7 days postoperative.

(Received 14 November 1995)

References

BEN-AMAR A, NORDENBERG D, LIBERMAN R, FISCHER J & GORFIL C (1987) The control of marginal microleakage in amalgam restorations using a dentin adhesive: a pilot study *Dental Materials* **3** 94-96.

BRÄNNSTRÖM M (1984) Communication between the oral cavity and the dental pulp associated with restorative treatment *Operative Dentistry* **9** 57-68.

BRÄNNSTRÖM M & NORDENVALL K-J (1978) Bacterial penetration, pulpal reaction and the inner surface of Concise enamel bond. Composite fillings in etched and unetched cavities *Journal of Dental Research* **57** 3-10.

BRÄNNSTRÖM M & NYBORG H (1971) The presence of bacteria in cavities filled with silicate cement and composite resin materials *Swedish Dental Journal* **6** 149-155.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via free access

CHRISTENSEN GJ (1994) Should we be bonding all tooth restorations? *Journal of the American Dental Association* **125** 193-194.

CHRISTENSEN GJ, HUNSAKER KJ, BANGERTER V & CHRISTENSEN R (1991) Influence of Amalgambond on molar cusp fracture resistance *Journal of Dental Research* **70** *Abstracts of Papers* p 300 Abstract 279.

COX CF (1992) Effects of adhesive resins and various dental cements on the pulp *Operative Dentistry* **Supplement 5** 165-176.

GILPATRICK RO, JOHNSON WW & MOORE DS (1994) Histology of human pulp after etching with 10% phosphoric acid *Journal of Dental Research* **73** *Abstracts of Papers* p 407 Abstract 2442.

GROVER PS, HOLLINGER J & LORTON L (1984a) A review of the incidence of pain after an operative treatment visit: Part I *Journal of Prosthetic Dentistry* **51** 224-225.

GROVER PS, LORTON L & HOLLINGER J (1984b) A clinical study of the incidence of pain after an operative treatment visit: Part II *Journal of Prosthetic Dentistry* **51** 369-71.

LOPES LM, LEITAO JG & DOUGLAS WH (1991) Effect of a new resin inlay/onlay restorative material on cuspal reinforcement *Quintessence International* **22** 641-645.

MILLER BC & CHARBENEAU GT (1984) Sensitivity of teeth with and without cement bases under amalgam restorations: a clinical study *Operative Dentistry* **9** 130-135.

MOORE DS, JOHNSON WW & KAPLAN I (1995) A comparison of amalgam microleakage with 4-Meta liner and copal varnish *International Journal of Prosthodontics* **8** 461-466.

PASHLEY DH, MICHELICH V & KEHL T (1981) Dentin permeability: Effects of smear layer removal *Journal of Prosthetic Dentistry* **46** 531-537.

SAIKU JM, ST GERMAIN H Jr & MEIERS JC (1993) Microleakage of a dental amalgam alloy bonding agent *Operative Dentistry* **18** 172-178.

SANTOS AC & MEIERS JC (1994) Fracture resistance of premolars with MOD amalgam restorations lined with Amalgambond *Operative Dentistry* **19** 2-6.

SILVESTRI AR Jr, COHEN SH & WETZ JH (1977) Character and frequency of discomfort immediately following restorative procedures *Journal of the American Dental Association* **95** 85-89.

TORSTENSON B, NORDENVALL K-J & BRÄNNSTRÖM M (1982) Pulpal reaction and microorganisms under Clearfil Composite Resin in deep cavities with acid etched dentin *Swedish Dental Journal* **6** 167-176.

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Five-Year Treatment Outcomes for Teeth with Large Amalgams and Crowns

J A MARTIN • J D BADER

Clinical Relevance
Large amalgams (four and five surfaces) exhibited more favorable 5-year outcomes than generally assumed.

SUMMARY

For 4735 posterior complex amalgams and crowns placed in adults with continuous dental HMO coverage, all additional treatment received over the subsequent 5 years was determined. The restorations were placed under routine clinical conditions by 74 different dentists among a broad spectrum of insured dental patients. Treatment outcomes were described in terms of a hierarchical classification of additional treatments. At the extremes, a successful outcome was defined as no additional treatment or an additional one- or two-surface restoration on the same tooth, and a catastrophic outcome as extraction or endodontic treatment. Due to clinical protocols, teeth with guarded to poor prognosis prior to treatment are overrepresented in the five-surface amalgam cohort. Successful outcomes characterized 72% of four-surface amalgams, 65% of five-surface amalgams, 84% of gold crowns, and 84% of porcelain crowns. Catastrophic outcomes occurred for 10% of four-surface amalgams, 15% of five-surface amalgams, 8% of gold crowns, and 9% of porcelain crowns.

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INTRODUCTION

While large amalgams are often believed to be less durable than cast restorations, current knowledge about the life history of a tooth following a restorative treatment is limited, particularly in a general dental population. Reasons for restoration replacement have been documented (Allender, Birkhed & Bratthal, 1990; Bader & Shugars, 1996; Boyd, 1989; Cheetham, Makinson & Dawson, 1991; Mjör & Medina, 1993; Qvist, Qvist & Mjör, 1990), but we know very little about the effect amalgam or crown placement has on a tooth's health status. This information is needed for clinicians and their patients to make appropriate treatment decisions based on an understanding of the likely outcomes for alternative treatments.

A treatment outcome is not a simple determination of success or failure. Outcomes can be considered along four dimensions (Bader & Shugars, 1995). A physical

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dimension includes considerations of whether pathology, pain, or functional limitations ensue or remain after treatment. A psychological dimension addresses patient perception and satisfaction. Economic and longevity dimensions include considerations of costs as well as survival (evaluated in terms of the tooth, pulp, and restoration). With the exception of the survival of the restoration, almost no information is available to describe the outcomes of restorative treatment along these dimensions. Yet patients are interested in what will happen to their teeth, not just their restorations. Indeed, Mjör and Medina (1993) noted that "...data from patients' records in general practice is, therefore, urgently needed to assess the cost-benefit of different types of restorative treatment."

A lack of knowledge about the relative effectiveness of treatment options has been cited as a cause of dentists' variation in treatment planning (Shugars & Bader, 1992). General dentists are uncertain about restoration longevity. Their estimates of the minimum acceptable longevity, and how long restorations actually last are extremely variable. Maryniuk and Kaplan (1986) found that large amalgams were believed to last on average 6.1 years, although a minimally acceptable length of service was noted as 4 years. An average cast gold restoration was expected to last 13 years, with the minimally acceptable length of service estimated to be 8.4 years.

More information is needed for both providers and patients to make informed choices about treatment alternatives. At present, a treatment selection often is based primarily on economics. If patients are offered a choice between two alternative treatments, the implication is that the more costly treatment is better, although in most instances including amalgam and crown decisions, there are few, if any, data to support such an assumption. While one school of thought regards large amalgams as a "false economy," Maryniuk, Schweitzer, and Braun (1988) developed a computer model of restorative needs over the life of a tooth, and found that replacing a failed amalgam with another amalgam may be more cost-effective than replacement with a crown. From the patient's perspective, a cast restoration costs approximately 500% more than a complex amalgam, and initially requires twice the number of visits as well. Patients (and payors) may want to know what they are buying for the additional cost, and their interest extends beyond simple restoration survival data to include the survival of the tooth and pulp as well as related maintenance requirements.

Restoration longevity is essentially the only kind of outcome data available for operative treatment, and it has substantial shortcomings. Many longitudinal studies of restoration longevity have been done in settings unlike a routine private general dental practice (Allan, 1977; Bentley & Drake, 1986; Crabb, 1981; Doglia & others, 1986; Robinson, 1971; Rytomaa & others, 1984), yet Jokstad and Mjör (1991) demonstrated the importance of patient variables in a restoration's survival pattern. Survival patterns differed significantly depending upon the patient's age and caries activity. While selecting patients for longevity studies who are likely to be available over several years is important to minimize the number of restorations lost to follow-up, it is possible that the ability to generalize is weakened. Patients both willing and likely to return for follow-up differ from the general population in ways that may maximize the life of their restorations. Understandably then, much less is known about the longevity of restorations placed in a general population.

The dentist operator has long been believed to be an important determiner of a restoration's longevity, although studies rarely report the longevity of restorations placed under routine clinical conditions by general practitioners (Allan, 1977; Bentley & Drake, 1986; Crabb, 1981; Doglia & others, 1986; Robinson; 1971; Smales, 1991; Smales & Webster, 1993). The outcomes of restorations placed in a routine practice environment will be easier to generalize for practicing dentists than those restorations placed under rigorous experimental protocols.

Size has been shown to have an effect on amalgam restoration longevity, with the expected length of service decreasing as the amalgam size increases (Bentley & Drake, 1986; Qvist & others, 1990; Crabb, 1981), although Jokstad and Mjör (1991) found no differences between MO, DO, and MOD amalgam survival rates. Some studies of longevity of smaller amalgam restorations (Robinson, 1971; Allan, 1977) restricted their retrospective analysis to patients who regularly received dental care. Robinson (1971) found 75% of the amalgams still present after 5 years, 50% after 10 years, and 25% intact after 20 years. Allan (1977) found 50% of the restorations were intact after 8 years. Only two restorations with more than two surfaces were analyzed by Robinson, and Allan did not describe restoration size. Crabb (1981) retrospectively evaluated patients who had regularly attended a teaching hospital dental service for 10 years and found that 50% of the two- and three-surface amalgams had failed by the 8-year mark. Jokstad and Mjör (1991) followed two- and three-surface amalgams placed by a dentist in a school clinic, two dentists in a public health clinic, and three dentists in private practice. At 9.5 years, 81% of the restorations were intact, but almost half the studied teeth were lost to follow-up, and a disproportionate number of restorations were replaced in those who dropped out of the study when compared to patients who remained available for follow-up. Further, the mean ages of the two groups that accounted for most of the loss to follow-up, 12 and

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16 years, were substantially different than the mean ages of the groups with little loss to follow-up, 36 to 40 years. Letzel and others (1989) described a series of studies where class 1 or 2 restorations were placed by dental school faculty in patients selected for their availability for long-term follow-up, acceptable oral hygiene, and tissue health. The patients included many dental students. In the first trial completed, 84% of the restorations were still in place after 7 years. In the second, 85% were intact at 5 years.

Unfortunately, there is less information describing the longevity of four- and five-surface amalgams, which would seem to be a likely outcome for any tooth restored several times (Brantley & others, 1995). Robbins and Summitt (1988) analyzed posterior amalgams replacing at least one cusp and found a 75% survival rate at 5.7 years and a 50% survival rate at 11.5 years. Their study population received complex restorations (n=128) in a large military dental clinic, but more than half the identified patients were lost to follow-up. Smales found a 72% survival of cusp-covered amalgams (n=124) at 15 years, although it appears that only those patients available for follow-up over the 15-year study period were eligible for analysis. No information was presented about either the number of teeth lost to follow-up, or how the group analyzed may have differed from those who were excluded from the analysis.

Length of service estimates for crowns also exhibit variation, although still less information on crown longevity is available (Mjör, Jokstad & Qvist, 1990; Mjör, 1992) than for amalgams. Walton, Gardner, and Agar (1986) found a mean length of service for single full-coverage metal and ceramometal crowns of 6.1 and 6.5 years respectively. Glantz's 1989 study of crown and bridge prostheses includes too many different types of restorations to generalize his results to single-unit crowns.

The study reported here adds to the relatively small amount of literature describing the outcomes of complex amalgams and crowns. In so doing, it expands the range of outcomes considered by including information describing the survival of the tooth and pulp, as well as information on maintenance requirements for the tooth such as re-restoration, patching, and miscellaneous additional operative treatment received. Further, the study is based on restorations placed among a large group of unselected patients by a large group of unselected general dentists, thereby permitting increased confidence in generalizing the findings.

METHODS AND MATERIALS

All treatment procedures performed in the Kaiser Permanente Dental Program are recorded electronically. All four- and five-surface amalgams and porcelain and gold crowns ("target restorations") placed in posterior teeth during 1988 were identified and evaluated for inclusion in the study. They were included if the patient was classified as an enrolled adult, i e, was both a plan member and at least 21 years old on 31 December 1988. Enrollees receiving target restorations who had continuous year-end dental plan coverage during 1988-1993 became the eligible population for analysis, while those without continuous eligibility were the ineligible, or lost to follow-up population. Members have an annual opportunity to disenroll, and the prepaid HMO practice does not reimburse for any care delivered outside the HMO, except for emergency treatment while traveling. Members who retain their membership for the entire 5-year period are therefore unlikely to have gone outside the plan for dental care.

Restorations were placed under usual clinical conditions by 74 general dentists in 12 clinics. Program protocols preclude placing cast restorations in the presence of untreated periodontal disease, poor oral hygiene, or questionable pulp health. Thus, teeth with questionable or poor prognosis would have had amalgams placed instead of crowns, and would be particularly overrepresented in the five-surface amalgam category. In 1988, the amalgam in use in the dental program was Valiant PhD (L D Caulk, Milford, DE 19963). Gold crowns were fabricated with Midas (Jelenko Dental Health Products, Armonk, NY 10504) and ceramometal crowns with Legacy (Jelenko).

Amalgam target restorations replaced by crowns within 120 days of the amalgam placement (and placed in 1988) were classified as crown restorations for the analyses. If crown placement occurred within 120 days of amalgam treatment in 1989, the tooth was not included in any analysis (38 teeth were thus excluded from any analysis). We selected 120 days as a conservative time interval between the placement of an amalgam foundation and the preparation of the crown. While many of the build-ups were crowned within 30 days, it is common in the dental program to place a stable amalgam, then wait until the next available routine appointment to prepare the crown. How soon that visit would occur varies, but the 120-day window allows for both patient and provider scheduling flexibility.

In 1988, a total of 7687 target restorations were placed in 5901 enrolled adult patients. Of these, 4735 restorations were placed in 3655 members whose eligibility was continuous from 1988 to 1993. Thus, we were able to follow 62% of both the patients and eligible target restorations placed in 1988 for 5 years. Possible bias introduced through the 38% loss to follow-up was examined in two ways. First, differences in the distribution of demographic and restoration characteristics between patients with and without

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Percent Distribution of Restored Teeth across Outcomes after 5 Years, by Type of Restoration

Outcome	4-Surface Amalgam			5-Surface Amalgam			Porcelain Crown			Gold Crown		
	all* 2038	mol* 1382	pre* 656	all 1626	mol 1145	pre 481	all 555	mol 191	pre 364	all 516	mol 422	pre 94
Extraction	3	3	3	7	6	7	2	0	3	4	4	4
Endodontic treatment	7	6	9	8	7	8	6	7	5	7	6	7
Restoration replacement:												
same restoration	9	9	8	8	8	9	4	4	4	2	1	5
crown for amalgam	7	5	11	10	9	11	--	--	--	--	--	--
Miscellaneous treatment	3	3	3	3	3	2	4	5	3	5	5	3
Restoration repair	10	11	9	10	11	7	2	2	2	4	4	2
No further treatment	62	63	58	55	55	56	82	83	82	80	80	78

all* = all molars and premolars; mol* = all molars; pre* = all premolars. Columns may not add up to 100% due to rounding.

continuous enrollment were examined through bivariate analyses. Second, survival functions of restorations in these two patient groups were compared.

The classification of outcomes was constructed such that categories were mutually exclusive and exhaustive, i e, a target restoration could have only one outcome. Treatment outcomes were hierarchical, with the tooth assigned the most severe outcome category experienced. The hierarchy of outcomes was: extraction, endodontic treatment, amalgam replacement with a crown, replacement of the initial restoration with a similar type of restoration, miscellaneous (all treatment not included in other categories, e g, periodontal treatment, three-surface amalgam), a one- or two-surface additional restoration, and no further treatment received. The first qualifying restoration received by a tooth in 1988 became the target restoration and was followed through the end of 1993.

Analyses of these classifications were performed for all posterior teeth combined, and separately for molars and premolars. The calculation of survival distribution functions used the product-limit (Kaplan-Meier) method, with observations censored as of the last day of 1993. Comparison of functions used the likelihood ratio test, as these distributions were approximately exponential. For the analyses comparing restorations in eligible and ineligible patients, observations were considered to be censored on the last day of the most recent year in which the patient was enrolled for the full year.

RESULTS

Ineligible patients, i e, those who were lost to follow-up, were not different with respect to gender: 57% male vs 56% female (x^2=0.94, df=1, $P > 0.05$), but they were significantly younger: 41 years vs 47 years (t=26.6, $P < 0.01$). The disenrollment rate was relatively steady at approximately 10% of remaining enrolled patients each year. Among those patients whose enrollment was discontinued, a significantly smaller proportion of the original restorations comprised crowns: 20% vs 23% (x^2=6.91, df=1, $P < 0.01$). Comparisons of survival distributions for eligible and ineligible patients showed that tooth loss experience was not different between groups. When failure was defined as either tooth loss or endodontic treatment (i e, pulp death), the two groups' experiences were not different for crowns, but ineligible patients were less likely to encounter this outcome for amalgam restorations (x^2=4.53, df=1, $P < 0.05$).

A total of 4735 teeth were followed for the 5-year period: 2038 four-surface amalgams, 1626 five-surface amalgams, 555 porcelain crowns, and 516 gold crowns (table). Successful restorations were those that needed either no further treatment or only an additional one- or two-surface restoration. At the end of 5 years, 72% of four-surface amalgams, 65% of five-surface amalgams, 84% of porcelain crowns, and 84% of gold crowns were successful. Catastrophic outcomes (either extraction or endodontic treatment required) ranged from 8% for the porcelain crowns to 15% for the five-surface amalgams, with

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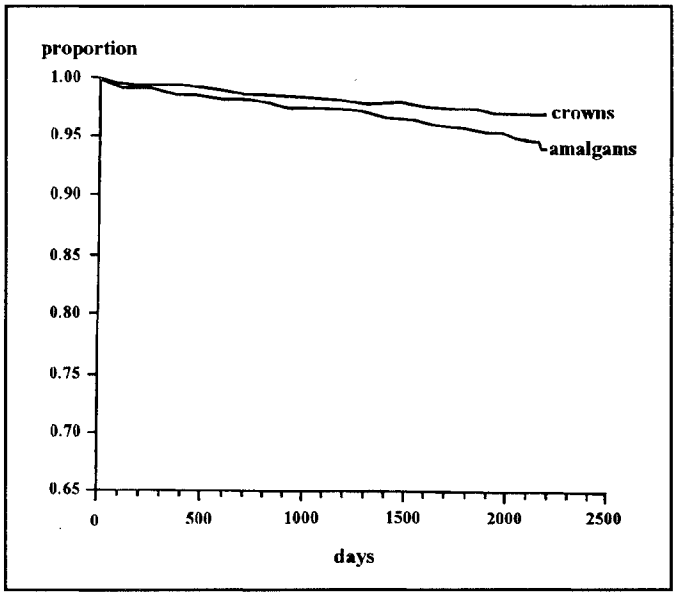

Figure 1. *Survival curves for crowns and complex amalgam. Failure is defined as loss of the tooth.*

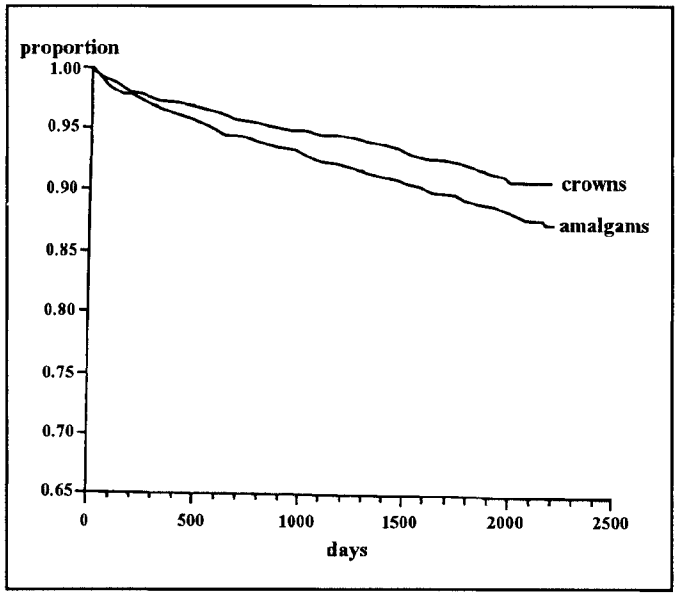

Figure 2. *Survival curves for crowns and complex amalgam. Failure is defined as loss of the tooth or receipt of endodontic treatment.*

gold crowns at 11% and four-surface amalgams 10%.

Survival distribution functions for three outcomes (extraction only; extraction or endodontic treatment; and extraction, endodontic treatment, or restoration replacement, including crowns for amalgam restorations), are shown for crown and amalgam restorations in Figures 1-3. In all instances, the distributions are significantly different (Figure 1, $x^2=6.96$, df=1, $P < 0.01$; Figure 2, $x^2=7.41$, df=1, $P < 0.01$; Figure 3, $x^2=115.1$, df=1, $P < 0.01$). Figure 3 suggests that after an early period of approximately 4 months in which both restoration types experienced relatively frequent failure, rate of failure moderated more quickly and substantially for crowns. This more rapid early failure for crowns may be due in part to the dental plan's classification of crowns requiring a new impression at the cementation appointment as replacement restorations.

DISCUSSION

This first study utilizing this database is primarily descriptive. More information is available about a broader spectrum of patients, because the population studied was not as narrowly selected as those in many other longitudinal studies. Essentially all adults receiving a target restoration were included, although they did need to have continuous HMO membership for the 5 years if the restorations were to be included in the 5-year outcome classification. Further, possible bias introduced through loss to follow-up does not appear to be substantial, and in any event would lead to more conservative outcome estimates in the one instance where survival functions differed between eligibles and noneligibles, because the noneligibles had better noncatastrophic outcomes. Thus, the results of this study could be generalized to other insured adult populations.

We defined as successful any restoration that either needed no further treatment over the 5-year period or required only maintenance, defined as receiving only a one- or two-surface restoration after the target restoration was placed. This category would include

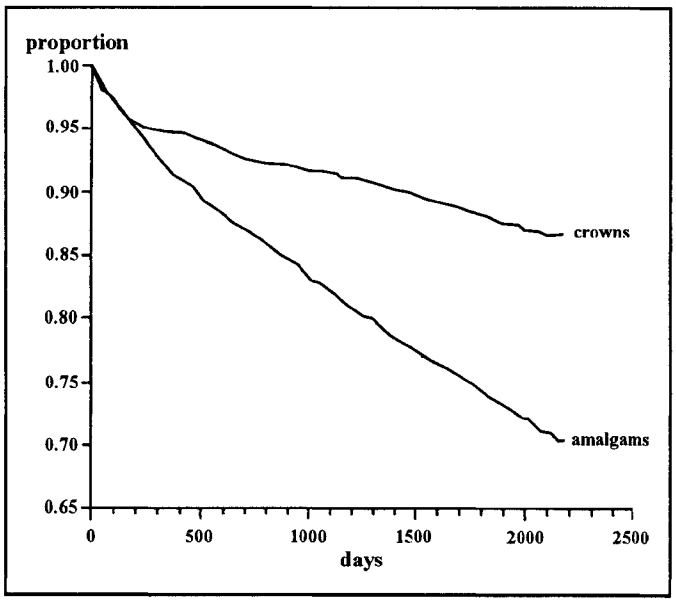

Figure 3. *Survival curves for crowns and complex amalgam. Failure is defined as loss of the tooth, receipt of endodontic treatment, or restoration replacement.*

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patches actually abutting the existing restoration (Cowan, 1983), as well as those restoring a noncontiguous area. A more traditional definition of success might not include teeth that receive any further treatment, although others might classify those teeth that required restoration replacement as successful. A definitive judgment about whether an outcome that includes an additional restoration constitutes success must await the collection and analysis of additional data that measure outcomes along the psychosocial and economic dimensions.

There are several circumstances that may affect the 5-year outcomes seen in the table. The question of when a tooth needs a crown is one of continued uncertainty. In this study, we did not collect reasons for restorative treatment. Given the dental profession's tendency to replace amalgam restorations with crowns for preventive reasons (Bader & Shugars, 1996), the amalgam restorations in this study may be underrepresented in the "no further treatment needed" category.

Kaiser dental program treatment protocols do not recommend cast restorations in the presence of untreated periodontal disease, poor oral hygiene, uncertain pulpal health, or a poor long-term prognosis for the tooth. The adverse selection bias for large amalgam restorations due to these clinical protocols may explain a substantial proportion of the difference in catastrophic outcomes (extraction or endodontic treatment) between crowns and amalgams. As it is, the proportions of successful 5-year outcomes for four- and five-surface amalgams belie the opinions of many dentists that amalgams are impermanent (Maryniuk & Kaplan, 1986).

Unfortunately, this study could not include information about a tooth prior to 1988, so we are unable to discuss what effects prior treatments might have had on our measured outcomes. An unknown proportion of the teeth analyzed had received endodontic therapy prior to the placement of the target restoration. As a consequence, the incidence of endodontic treatment is artificially low, but we do not know the magnitude of the underestimation. Our rate of endodontic treatment ranged between 69%. Given that some of the extracted teeth were likely lost due to the presence of a nonvital pulp, the incidence of pulpal death following treatment is larger than our measured 6-9%. Our data, therefore, are in the range of that reported by Felton and others (1989) of a 13.3% incidence of pulpal necrosis associated with full-coverage restorations, although these data are published in abstract form only.

Finally, we have only partial information about the accuracy of the electronic treatment records upon which the study is based. From informal inspection of records, the most frequent type of error that would affect our results is the entry of erroneous tooth numbers. In the only formal study of this phenomenon, an error rate of <0.5% (4/888) was found when computer-generated extraction codes were compared with written entries in the paper chart (Phipps & Stevens, 1995). The effect of such miscoding is difficult to predict. While subsequent treatment on target teeth might be missed, treatment of teeth not in the study is equally likely to be erroneously assigned to target teeth.

When analyzing survival, the definition of restoration success and failure remains an area of variability in the literature and tends to consider only the restoration, often ignoring the tooth or patient. While Robinson (1971) classified restorations as failures if present in a tooth that is extracted, that criterion was considered "fairly severe" by Robbins and Summitt (1988), reinforcing the focus on the restoration. Others have considered as failures restorations that continue to function in the mouth but that are judged to have an unacceptable clinical appearance (Robbins & Summitt, 1988). We agree with Smales and Webster's (1993) request "to define unsatisfactory restorations in terms of actual adverse effects on dental health, rather than merely in terms of restoration deterioration," and have made a first attempt to judge a restoration's success or failure based on all the follow-up treatment received by the tooth after restoration placement.

CONCLUSIONS

Population-based studies are needed to evaluate treatment option effectiveness if dentists and patients are to base their treatment decisions on information about real-world treatment outcomes. Outcomes beyond restoration replacement need to be addressed, particularly taking into account those dimensions that are important to the patient. Complications of treatment, including tooth loss and endodontic needs, must be studied in addition to restoration replacement and maintenance, to allow both patients and dentists to make careful choices among alternative treatment options. These results support generally held beliefs about length of service for cast restorations and suggest that large amalgams may have more favorable 5-year outcomes than generally assumed.

Acknowledgments

We thank Paul Cheek and Siu-King Ngan for their contributions to the data analyses. This study was supported by Permanente Dental Associates, Portland, Oregon and Kaiser Permanente Center for Health Research, Portland, Oregon. Additional support was provided by a W R Keenan Jr leave from the University of North Carolina.

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(Received 28 November 1995)

References

ALLAN DN (1977) A longitudinal study of dental restorations *British Dental Journal* **143** 87-89.

ALLANDER L, BIRKHED D & BRATTHAL D (1990) Reasons for replacement of Class II amalgam restorations in private practice *Swedish Dental Journal* **14** 179-184.

BADER JD & SHUGARS DA (1995) Variation, treatment outcomes, and practice guidelines in dental practice *Journal of Dental Education* **59** 61-95.

BADER JD & SHUGARS DA (1996) Using crowns to prevent tooth fracture *Community Dentistry and Oral Epidemiology* **24** 47-51.

BENTLEY C & DRAKE CW (1986) Longevity of restorations in a dental school clinic *Journal of Dental Education* **50** 594-600.

BOYD M (1989) Amalgam replacement: Are decisions based on fact or tradition? In *Quality Evaluation of Dental Restorations: Criteria for Placement and Replacement* ed Anusavice K pp 73-80 Chicago: Quintessence.

BRANTLEY CF, BADER JD, SHUGARS DA & NESBIT SP (1995) Does the cycle of rerestoration lead to larger restorations? *Journal of the American Dental Association* **126** 1407-1413.

CHEETHAM JD, MAKINSON OF & DAWSON AS (1991) Replacement of low copper amalgams by a group of general dental practitioners *Australian Dental Journal* **36** 218-222.

COWAN R (1983) Amalgam repair—a clinical technique *Journal of Prosthetic Dentistry* **49** 49-51.

CRABB HS (1981) The survival of dental restorations in a teaching hospital *British Dental Journal* **150** 315-318.

DOGLIA R, HERR P, HOLZ J & BAUME LJ (1986) Clinical evaluation of four amalgam alloys: a five-year report *Journal of Prosthetic Dentistry* **56** 406-415.

FELTON D, MADISON S, KANOY E, KANTOR M & MARYNIUK G (1989) Long term effects of crown preparation on pulp vitality *Journal of Dental Research* **68** 1009.

GLANTZ P (1989) The clinical longevity of crown-and-bridge prostheses In *Quality Evaluation of Dental Restorations: Criteria for Placement and Replacement* ed Anusavice K pp 343-354 Chicago: Quintessence.

JOKSTAD A & MJÖR IA (1991) Analyses of long-term clinical behavior of class-II amalgam restorations *Acta Odontologica Scandinavica* **49** 47-63.

LETZEL H, VAN'T HOF M, VRIJHOEF M, MARSHALL G & MARSHALL S (1989) Failure, survival and reasons for replacement of amalgam restorations In *Quality Evaluation of Dental Restorations: Criteria for Placement and Replacement* ed Anusavice K pp 83-92 Chicago: Quintessence.

MARYNIUK GA, SCHWEITZER SO & BRAUN RJ (1988) Replacement of amalgams with crowns: a cost-effectiveness analysis *Community Dentistry and Oral Epidemiology* **16** 263-267.

MARYNIUK GA & KAPLAN SH (1986) Longevity of restorations: survey results of dentists' estimates and attitudes *Journal of the American Dental Association* **112** 39-45.

MJÖR IA (1992) Long-term cost of restorative therapy using different materials *Scandinavian Journal of Dental Research* **100** 60-65.

MJÖR IA, JOKSTAD A & QVIST V (1990) Longevity of posterior restorations *International Dental Journal* **40** 11-17.

MJÖR IA & MEDINA JE (1993) Reasons for placement, replacement, and age of gold restorations in selected practices *Operative Dentistry* **18** 82-87.

PHIPPS KR & STEVENS VJ (1995) Relative contribution of caries and periodontal disease in adult tooth loss for an HMO dental population *Journal of Public Health Dentistry* **55** 250-252.

QVIST J, QVIST V & MJÖR IA (1990) Placement and longevity of amalgam restorations in Denmark *Acta Odontologica Scandinavica* **48** 297-303.

ROBBINS JW & SUMMITT JB (1988) Longevity of complex amalgam restorations *Operative Dentistry* **13** 54-55.

ROBINSON D (1971) The life of a filling *British Dental Journal* **130** 206-208.

RYTOMAA I, MURTOMAA H, TURTOLA L & LIND K (1984) Clinical assessment of amalgam fillings *Community Dentistry and Oral Epidemiology* **12** 169-172.

SHUGARS DA & BADER JD (1992) Appropriateness of care. Appropriateness of restorative treatment recommendations: a case for practice-based outcomes research *Journal of the American College of Dentists* **59** 7-13.

SMALES RJ (1991) Longevity of cusp-covered amalgams: survivals after 15 years *Operative Dentistry* **16** 17-20.

SMALES RJ & WEBSTER DA (1993) Restoration deterioration related to later failure *Operative Dentistry* **18** 130-137.

WALTON JN, GARDNER FM & AGAR JR (1986) A survey of crown and fixed partial denture failures: length of service and reasons for replacement *Journal of Prosthetic Dentistry* **56** 416-421.

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Strength Properties of Visible-Light-cured Resin-modified Glass-Ionomer Cements

R E KERBY • L KNOBLOCH • A THAKUR

Clinical Relevance
The strength properties of various brands of light-cured resin-modified glass-ionomer cements depend greatly upon their curing conditions and chemistry.

SUMMARY

A new generation of glass ionomers containing polymerizable methacrylate monomers and/or prepolymers are now available for use as direct esthetic restorative materials. Proper clinical application of these new resin-modified glass ionomers requires an understanding of their benefits and limitations. The purpose of this investigation was to compare the compressive and diametral tensile strength at 1 hour, 24 hours, and 7 days of three visible-light-cured glass-ionomer cements, a polyacid-modified composite resin, and a composite resin core build-up material under both light-cure and dark-cure conditions. Statistical analysis indicated significant differences between several of the cements tested for both compressive and diametral tensile strengths at all three testing times ($P > 0.05$). Prosthodent composite resin and Vitremer tricure visible-light-cured glass-ionomer cement are significantly greater in both compressive and diametral tensile strength than any of the other materials tested after 7 days.

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INTRODUCTION

Glass-ionomer (polyalkenoate) cements possess certain properties that make them useful as a multipurpose restorative material. These properties include the release of fluoride ions into adjacent tooth structure (Swartz, Phillips & Clark, 1994), a low coefficient of thermal expansion (McLean & Gasser, 1985; Craig, 1989), biocompatibility with dental tissues (Tobias & others, 1978; Heys & others, 1987), and physicochemical bonding to both enamel and dentin (Hotz & others, 1977; Lacefield, Reindl & Relief, 1985). Unfortunately, conventional glass-ionomer cements have also been shown to be susceptible to fracture (Goldman, 1985) as well as moisture contamination and dehydration, especially during the initial stages of the setting reaction (Mount & Makinson, 1982). In view of these shortcomings, attention has been directed at improving the physical properties and handling characteristics of glass ionomers by the addition of polymerizable free-radically active methacrylate monomers and/or prepolymers (McKinney &

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Antonucci, 1986; Mathis & Ferracane, 1989).

Advantages of these resin-modified glass ionomers include a shortened setting time, decreased early moisture sensitivity, extended working time, and greater strength properties when compared to conventional glass-ionomer cements (McKinney & Antonucci, 1986; Rusz & others, 1992). However, questions remain as to whether these resin-modified glass ionomers have sufficient strength properties to make them adequate for use in high stress-bearing areas. Therefore, the purpose of this investigation was to compare the compressive and diametral tensile strength of three commercially available resin-modified glass-ionomer cements and a polyacid-modified composite resin with a composite resin core build-up material at 1-hour, 24-hour, and 7-day set times under both light-cure and dark-cure conditions in order to evaluate both free-radical polymerization and glass-ionomer (acid-base) setting reaction.

METHODS AND MATERIALS

Five restorative materials were tested in the study (Table 1). These materials included three visible-light-cured (VLC) resin-modified glass-ionomer cements, a polyacid-modified composite resin, and a composite resin core build-up material. The preparation and testing of specimens was carried out in accordance with ANSI/ADA Spec 21 for resin-based filling materials and Spec 96 for water-based cements.

Five cylindrical specimens of each cement type were made utilizing silicone-lubricated Teflon split molds. Manufacturer specifications as to proper mixing time, paste-to-paste, and powder-to-liquid ratios were carefully followed. Only those materials with the same batch numbers were tested. The visible-light-activated glass ionomers were prepared in both light-cure (40-second exposure) and dark-cure (no light activation) conditions in order to evaluate both light-cure and chemical-cure free-radical polymerization as well as the glass-ionomer (acid-base) set. The encapsulated VLC glass ionomer Photac-Fil was mechanically triturated for 10 seconds at 4300 cycles per minute in an amalgamator (CAPMIX, ESPE-Premier, Norristown, PA 19404). Mixing of all cements was carried out at 23 °C in an atmosphere of 60% relative humidity. After mixing, cement specimens were allowed to bench set for 10 minutes and were then transferred to an oven at 37° ± 2 °C and 100% RH. Specimens were removed from the split molds after 1 hour and fine sanded with 600-grit silicon-carbide paper and water to produce cylindrical specimens measuring 4 mm (outside diameter) x 6 mm for both the composite resin and VLC glass ionomers. All specimens were maintained in distilled water at 37 °C ± 2 °C until the time of testing.

Testing of specimens was performed at 1 hour, 24 hours, and 7 days on a Universal Testing Machine (Instron, Model 4204, Canton, MA 02021). At the time of testing, specimens were loaded either uniaxially (compressive test) or diametrically (tensile test) between two steel platens with a cross-head displacement rate of 1.0 mm/min for the compressive strength test and 0.5 mm/min for the diametral tensile strength test. To help prevent areas of localized stress concentration, wet blotting paper was placed between the specimens and the platens during load application. The diametral tensile test was included in this study because glass-ionomer cements have been shown to be weak in tensile strength (Wilson & McLean, 1988). In

Table 1. Polyacid-modified Composite Resin and Glass-Ionomer Cements

Cement [code]	Manufacturer	Type	Powder/Liquid Ratio (g/g)
Vitremer [VI]	3M Dental Products, St Paul, MN 55144	tricure* resin-modified glass ionomer	2.5
Variglass [VG]	L D Caulk/Dentsply, Milford, DE 19963	photocure** polyacid-modified composite resin	4
Fuji II LC [FL]	GC America, Chicago, IL 60658	tricure* resin-modified glass ionomer	3
Photac-Fil [PH]	ESPE-Premier, Norristown, PA 19404	dual-cure† resin-modified glass ionomer	5
Prosthodont [PD]	Lee Pharmaceuticals USA, South El Monte, CA 91733	autocure‡ composite resin	1.1

*tricure = visible-light- and chemical-cure free-radical methacrylate polymerization and glass-ionomer set.

**photocure = visible-light-cure only.

†dual-cure = visible-light-cure free-radical methacrylate polymerization and glass-ionomer set.

‡autocure = chemical-cure free-radical methacrylate polymerization only.

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addition, hydrolytic degradation at the surface of the cement specimen should greatly affect the results of this test (Cho, Kopel & White, 1995; Wilson, Paddon & Crisp, 1979; White & Yu, 1993). A one-way analysis of variance procedure (ANOVA) followed by Tukey's Studentized Multiple Range Test was then performed on all data.

RESULTS

The results of the compressive and diametral tensile strength tests are presented in Tables 2 and 3 respectively. The ANOVA ($P < 0.001$) and Tukey's test indicated significant differences between several of the cements tested for both compressive and diametral tensile strengths at all three testing times ($P < 0.05$).

The composite resin core build-up material, Prosthodont, was significantly greater (20%) in compressive strength at both 1 and 24 hours than any of the other cements tested. No significant difference was noted between the compressive strength of the Vitremer tricure VLC glass-ionomer cement and the Fuji II light-cured glass ionomer at the 24-hour set time ($\alpha = 0.05$). However, at 255 MPa, the Vitremer tricure glass ionomer was more than 23% greater in compressive strength at 7 days than any of the other VLC cements tested.

The dark-cure mean compressive strength of the Fuji II LC cement was significantly greater than that of the Vitremer tricure cement at the 1-hour set time. In addition, no significant difference was noted between the Fuji II LC and Vitremer diametral tensile strengths at 1 hour under dark-cure conditions. The dark-cure Variglass VLC polyacid-modified composite resin specimens exhibited an incomplete set even after the 7-day set time, which prevented further testing. The mean diametral tensile strength of the Prosthodont composite resin was significantly greater than any of the materials tested at both the 1- and 24-hour set time.

DISCUSSION

The results from this study show the mean compressive strength of several of the VLC resin-modified glass-ionomer cements to nearly approach that of composite resin and amalgam at the 7-day set time (Craig, 1989). In addition, nearly all of the resin-modified cements as well as the polyacid modified composite possessed tensile strengths between two and three times that of conventional Type II glass ionomers as reported in the literature (Wilson & McLean, 1988; Kerby & Knobloch, 1992). However, results from this study also showed that the initial strength properties (1 hour) of the resin-modified cements and polyacid-modified composite may make them inadequate for use in high occlusal stress-bearing areas when compared to other more conventional materials such as composite resin or amalgam (Craig, 1989).

The Variglass polyacid-modified composite resin

Table 2. Mean Values for Compressive Strength with Standard Deviations

	Mean Compressive MPa [SD]		
Cement	**1 Hour**	**24 Hours**	**7 Days**
VI (LC)	154.3 [6.7] C	208.4 [12.3] B	254.6 [17.4] A
VI (DC)	132.1 [11.1] D	160.9 [9.4] C	192.1 [10.9] B
VG (LC)	195.9 [9.7] B	158.5 [4.8] C	152.3 [10.1] C
VG (DC)	0	0	0
FL (LC)	178.9 [13.3] C,B	210.3 [12.1] B	206.0 [13.9] B
FL (DC)	167.2 [6.7] C	193.1 [17.1] C	194.2 [19.5] B
PH (LC)	148.2 [7.2] D	176.5 [10.9] D	191.1 [12.3] D
PH (DC)	52.7 [11.1] E	65.2 [5.7] D	115.8 [15.0] B
PD	233.1 [11.1] A	244.2 [11.1] A	245.3 [9.3] A

Mean values marked with the same letter denote no statistically significant difference ($\alpha = 0.05$).
LC = light-cure conditions (40-second exposure).
DC = dark-cure conditions (no light activation).

Table 3. Mean Values for Tensile Strength with Standard Deviations

	Mean Tensile MPa [SD]		
Cement	**1 Hour**	**24 Hours**	**7 Days**
VI (LC)	27.4 [1.6] C,D	38.8 [1.8] B	42.8 [3.1] B
VI (DC)	23.2 [1.6] D	27.1 [3.1] D	30.3 [3.1] D
VG (LC)	35.3 [1.7] B	23.7 [1.1] E	25.4 [1.9] E
VG (DC)	0	0	0
FL (LC)	29.0 [0.4] C	35.9 [1.1] B,C	37.1 [1.7] C
FL (DC)	25.1 [3.2] D	29.9 [3.9] D	32.8 [0.7] D
PH (LC)	26.4 [0.9] C,D	33.7 [0.6] C	36.2 [1.7] C
PH (DC)	1.2 [0.4] F	20.1 [1.1] E	29.0 [2.1] D
PD	48.8 [2.2] A	56.4 [1.7] A	54.2 1.9] A

Mean values marked with the same letter denote no statistically significant difference ($\alpha = 0.05$).
LC = light-cure conditions (40-second exposure).
DC = dark-cure conditions (no light activation).

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dark-cure specimens exhibited an incomplete set even after the 7-day set time. Furthermore, the Variglass light-cure samples showed a 24% and 46% decrease respectively in the mean compressive and diametral tensile strengths from the 24-hour to 7-day set times. This is due to a poor glass-ionomer acid-base setting reaction. Carboxylic and phosphoric acid groups within the cement matrix, which do not undergo metal salt bridge formation, will remain highly hydrophilic. Water penetration at the cement surface and resultant hydrolytic degradation can then lead to a decrease in the physical properties of the cement (Wilson & others, 1979; White & Yu, 1993). Although the relatively high initial strength properties of the Variglass light-cure specimens indicate a strong free-radical cure, the cement contains insufficient water and/or polycarboxylic acid to develop sufficient hardening via a glass-ionomer acid-base reaction under dark-cure conditions. Although Variglass has some chemical similarities to a resin-modified glass-ionomer cement, its failure to undergo any significant acid-base dark-cure setting categorizes it as a polyacid-modified composite resin (McLean, Nicholson & Wilson, 1994). The mean compressive and diametral tensile strength values of the Photac-Fil VLC glass-ionomer (light-cure) specimens were not significantly different from those of the other resin-modified glass-ionomer cements tested. However, as with Variglass but to a lesser extent, the dark-cure samples exhibited relatively poor strength characteristics during the first 24-hour set time. Results such as these strongly warrant the careful layering of these two materials in 2 to 3 mm increments as recommended by the manufacturer to ensure complete light penetration and polymerization. Bonding between increments is facilitated by unreacted methacrylate groups within the bulk of the cement and oxygen-inhibited surface layer. Increments of more than 3 mm may result in unpolymerized free monomer and polyacid within the deeper portions of the material, which could lead to failure of the restoration as well as pulpal irritation (Langeland, Dogon & Langeland, 1970; Stanley & others, 1972).

The Vitremer tricure resin-modified glass-ionomer cement utilizes a microencapsulated water-soluble ascorbic acid/potassium persulfate redox catalyst system in order to obtain a chemical-cure free-radical methacrylate setting reaction in addition to its light-cure and glass-ionomer setting modes (Mitra & Mitra, 1992). It is interesting to note, however, that the Fuji II tricure VLC resin-modified glass-ionomer cement, which contains the more conventional peroxide/tertiary amine (or sulfinic salt) catalyst accelerator system (Akahane & others, 1991), exhibited a 24-hour compressive strength that was significantly greater than that of the Vitremer cement. In addition, no significant differences were noted between their diametral tensile strengths at the 24-hour set time. Apparently, the conventional peroxide-based system can be modified to produce a sufficient free-radial polymerization even in the presence of water and acid.

Clinically, the results of this study suggest that when placing light-cured resin-modified glass ionomers in larger than 2 mm increments, the tricure cements such as Vitremer and Fuji II VLC should be considered. Cements that exhibit poor dark-cure setting characteristics should be placed in increments that ensure visible-light penetration and polymerization. These increment thicknesses will vary according to manufacturer specifications, depending largely on material shade and chemistry.

Further studies to investigate other physical properties such as fracture toughness and wear resistance as well as chemical composition and biocompatibility are now needed to better understand the physical properties of these resin-modified glass-ionomer cements, under both dark-cure and light-cure conditions.

CONCLUSIONS

1. Prosthodent composite resin and the Vitremer tricure VLC glass-ionomer cement are significantly greater in both compressive and diametral tensile strength than any of the other materials tested after 7 days.
2. Variglass polyacid-modified composite resin and Photac-Fil VLC glass-ionomer cement demonstrated relatively poor dark-cure setting reactions.
3. The glass-ionomer cements tested in this study may be inadequate for use in high occlusal stress-bearing areas when compared to amalgam or composite resin.

Acknowledgments

The authors acknowledge the expert analysis and assistance of William M Johnston, PhD, Department of Restorative Dentistry, Prosthodontics and Endodontics; Connie S Mason, administrative secretary to the department, for her valued assistance in manuscript preparation; and Paul Herman, for his expert technical assistance.

(Received 12 December 1995)

References

AKAHANE S, TOSAKI S, KUSAYANAGI Y & KUSAKAI S (1991) Dental glass ionomer cement compositions United States Patent 5,063,257.

CHO E, KOPEL H & WHITE SN (1995) Moisture susceptibility of resin-modified glass-ionomer materials *Quintessence International* **26** 351-358.

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CRAIG RG (1989) *Restorative Dental Materials* 8th ed, St Louis: Mosby, pp 236, 265.

GOLDMAN M (1985) Fracture properties of composite and glass ionomer dental restorative materials *Journal of Biomedical Materials Science* **19** 771-783.

HEYS RJ, FITZGERALD M, HEYS DR & CHARBENEAU GT (1987) An evaluation of a glass ionomer luting agent: pulpal histological response *Journal of the American Dental Association* **114** 607-611.

HOTZ P, McLEAN JW, SCED I & WILSON AD (1977) The bonding of glass ionomer cements to metal and tooth substrates *British Dental Journal* **142** 41-47.

KERBY RE & KNOBLOCH L (1992) Strength characteristics of glass-ionomer cements *Operative Dentistry* **17** 170-174.

LACEFIELD WR, REINDL MC & RETIEF DH (1985) Tensile bond strengths of a glass-ionomer cement *Journal of Prosthetic Dentistry* **53** 194-198.

LANGELAND K, DOGON LI & LANGELAND LK (1970) Pulp protection requirements for two composite resin restorative materials *Australian Dental Journal* **15** 349-360.

MATHIS RS & FERRACANE JL (1989) Properties of a glass-ionomer/resin-composite hybrid material *Dental Materials* **5** 355-358.

McKINNEY JE & ANTONICCI JM (1986) Wear and microhardness of two experimental dental composites *Journal of Dental Research* **65** *Abstracts of Papers* p 848 Abstract 1101.

McLEAN JW & GASSER O (1985) Glass-cermet cements *Quintessence International* **16** 333-343.

McLEAN JW, NICHOLSON JW & WILSON AD (1994) Proposed nomenclature for glass-ionomer dental cements and related materials *Quintessence International* **25** 587-589.

MITRA SB & MITRA S (1992) Universal water-based medical and dental cement United States Patent 5,154,762.

MOUNT GJ & MAKINSON OF (1982) Glass-ionomer restorative cements: clinical implications of the setting reaction *Operative Dentistry* 7 134-141.

RUSZ JE, ANTONUCCI JM, EICHMILLER F & ANDERSON MH (1992) Adhesive properties of modified glass-ionomer cements *Dental Materials* **8** 31-36.

STANLEY HR, MYERS CL, HEYDE JB & CHAMBERLAIN J (1972) Primate pulp response to an ultraviolet light cured restorative material *Journal of Oral Pathology* **1** 108-114.

SWARTZ ML, PHILLIPS RW & CLARK HE (1984) Long-term F release from glass ionomer cements *Journal of Dental Research* **63** 158-160.

TOBIAS RS, BROWN RM, PLANT CG & INGRAM DV (1978) Pulpal response to a glass ionomer cement *British Dental Journal* **144** 345-350.

WHITE SN & YU Z (1993) Compressive and diametral tensile strengths of current adhesive luting agents *Journal of Prosthetic Dentistry* **69** 568-572.

WILSON AD & McLEAN JW (1988) *Glass-Ionomer Cement* Chicago: Quintessence Pub Co p 68.

WILSON AD, PADDON JM & CRISP S (1979) The hydration of dental cements *Journal of Dental Research* **58** 1065-1071.

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A Comparison of Antimicrobial Activity of Etchants Used for a Total Etch Technique

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Clinical Relevance
Intentional treatment with disinfectants or antimicrobials may not be necessary in light of the antimicrobial activity of phosphoric acid etchants.

SUMMARY

The purpose of this study was to determine the antimicrobial activity of eight commercially available etchant materials and positive and negative controls as they came into contact with bacteria commonly found within the oral cavity. The following bacteria were used in this study: *Streptococcus mutans*, *Streptococcus salivarius*, and *Actinobacillis actinomycetocomitans*. The study was conducted in two parts: Part I—Etchants and controls placed within wells in agar plates; Part II—Enamel-dentin disks saturated with the etchants for 20 seconds and placed on the agar plates with the controls. Zones of microbial inhibition were measured in millimeters after 48 hours. The results of the study indicate that all of the etchants demonstrated antimicrobial activity against the bacteria tested.

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INTRODUCTION

Since Buonocore (1955) and Buonocore, Wileman, and Brudevold (1956) reported the use of acid pretreatment of both enamel and dentin to increase adhesion of acrylic resin to tooth structure, researchers have attempted to improve on these techniques for sealing cavity preparations, reducing microleakage, and improving retention of composite resin restorations. The acid-etch pretreatment of enamel to facilitate adhesion of composite resin to enamel has been shown to microscopically roughen the enamel surface, allowing the resin to flow into the enamel microporosities and retain composite resin restorations (Jordan & others, 1977). Current adhesive bonding systems to enamel and dentin use an acid conditioner/etchant to alter, penetrate, or remove the dentin smear layer so that hydrophilic monomers can penetrate the dentin to form a resin-modified zone (Pashley, 1991; Prati & Pashley, 1992). Penetration and saturation of monomeric resins on acid-pretreated dentin surfaces cause copolymerization with the resin adhesive component of the bonding system. This has been referred to as the hybrid layer (Nakabayashi, Kojima & Masuhara, 1982; Goracci & others, 1994).

There have been numerous investigations into dentin and enamel bonding with etchants that have focused on comparing different concentrations, viscosities, and etch times of phosphoric acid to improve the bond strengths of adhesives to tooth structure (Swift, Denehy & Beck, 1993; Baharav & others, 1988; Perdigao, Denehy & Swift, 1994; Barkmeier, Shaffer & Gwinnett, 1986; Shay & others, 1988). At the same time, it has increasingly become

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accepted that past concerns about acid etching dentin and the histologic response of the pulp were unfounded (White & others, 1994). Pulpal inflammation in most cases has been demonstrated to be due to bacterial etiology with a de-emphasis on the theory of material toxicity per se (Douglas, 1989). With the implication of bacteria contributing to pulpal inflammation, recommendations have been made to use an antimicrobial cavity cleanser after tooth preparation and before tooth restoration (Brännström & others, 1980). Several researchers have also investigated the residual antimicrobial action of phosphoric acid etchants that contain antimicrobial additives (Chan & Hui, 1992; Farley, Chan & Lam, 1993; Chan & Lo, 1994). In this regard, one manufacturer has recently incorporated an antibacterial agent (benzalkonium chloride) into its phosphoric acid etchant (UniEtch 32% with benzalkonium chloride, Bisco Dental Products, Itasca, IL 60143). The purpose of this study, therefore, was to determine the antimicrobial activity of a number of commercially available etchant materials on bacteria commonly found within the oral cavity.

METHODS AND MATERIALS

The zones of bacterial inhibition (inhibition halo effect) produced by the following phosphoric acid etchants (followed by percent of concentration) and two control substances were measured and compared:

1. Tooth Conditioner Gel Etch (L D Caulk/Dentsply, Milford, DE 19963), 34%,
2. UniEtch 32% (Bisco), 32%,
3. UniEtch 32% with benzalkonium chloride (Bisco), 32%,
4. Etch N'Seal (Den-Mat Corp, Santa Maria, CA 93456), 27%,
5. Etchant (Den-Mat Corp), 27%,
6. Etchant (3M Dental Products, St Paul, MN 55144), 35%,
7. UltraEtch (Ultradent Products, Inc, South Jordan, UT 84095), 35%,
8. Kerr Gel (Kerr Mfg Co, Romulus, MI 48174), 37.5%,
9. Penicillin G (2 units)—positive control, and
10. Sterile enamel and dentin disks—negative control.

The following bacteria, provided by the New York University College of Dentistry, Division of Basic Medical Sciences, Department of Microbiology, were utilized in this study:

1. *Streptococcus mutans* (HS-6)
2. *Streptococcus salivarius* (Mid-West Culture Service)
3. *Actinobacillis actinomycetocomitans* (Mid-West Culture Service)

Although *Streptococcus mutans* is the only cariogenic organism of the three tested, the other bacteria tested also provide a spectrum of bacteria that may be found in the oral cavity, since *Streptococcus salivarius* stains gram positive, and *Actinobacillus actinomycetocomitans* stains gram negative.

All bacteria were cultured in yeast-glucose broth overnight at 37° C.The next morning the broth culture was diluted 10-fold, and grown as above until a density of 10^6 cells/milliliter was determined by optical density using a Klett-Summerson photometer. Assays were performed on Brain-Heart Infusion Agar sterile Petri dishes (Fisher Scientific Co, Ottawa, Canada). The study was conducted in two parts:

Part I: Etchants and controls placed within wells in the agar plates;

Part II: Enamel-dentin disks were treated with the etchants and placed on the agar plates with the controls.

As a result of this division into two parts, the etchants were tested against the bacteria on their own as well as on tooth structure. In the latter case, the enamel-dentin disks were created to approximate

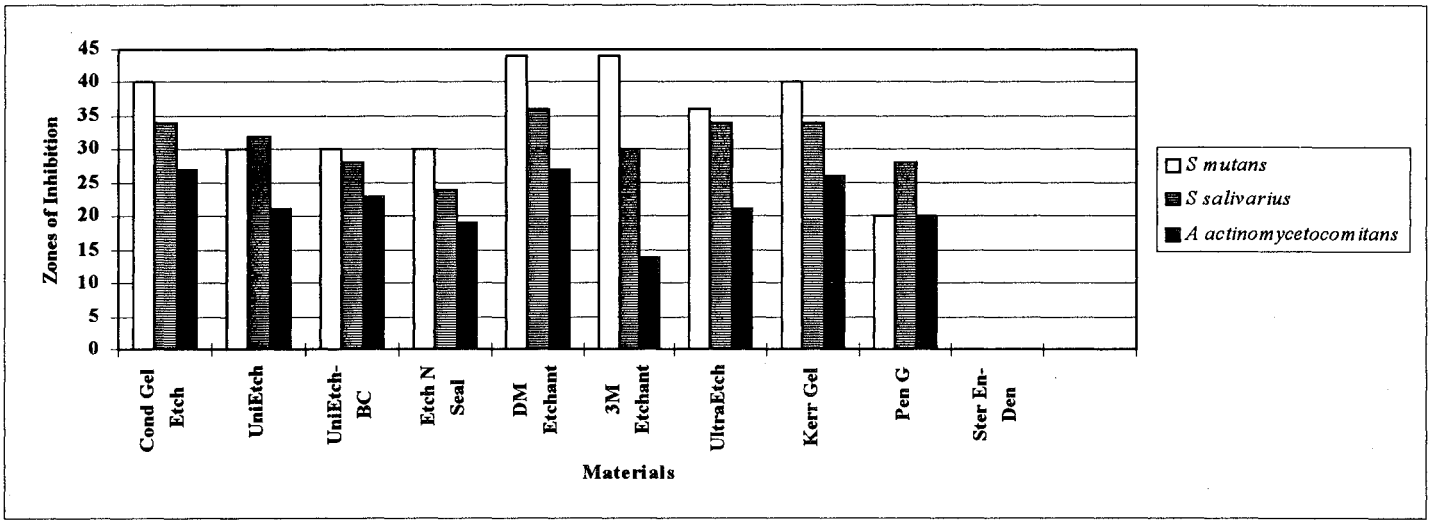

Figure 1. *Zones of inhibition—Part I*

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the size of the wells and were therefore within a constant diameter.

Part I

Wells 4.0 mm in diameter were prepared with a sterile steel punch in the agar plates. The bacteria were swabbed over the surfaces of the agar plates in two directions. Each material was placed in a well with its own sterile applicator under a laminar flow hood. Immediately after the inoculation of the plates, the materials to be tested were placed into the prepared wells. All wells were filled to the surface with the material being tested. In addition, positive control antibiotic disks, Penicillin G (2 units), and negative controls composed of sterile enamel-dentin disks were also placed on the prepared plates. It was felt that sterile enamel-dentin disks provided a better negative control than water. These enamel-dentin disks were previously sectioned from human molars, gas sterilized, and degassed. Three samples of each material and the controls were placed on one plate at a time. Thus, each material and the controls were tested three times and the average of the zones of inhibition against each bacteria reported.

Part II

Sterile enamel-dentin disks prepared in the same manner as Part I were then treated with each etchant for 20 seconds, washed for 20 seconds, and air dried. The bacteria were swabbed over the surfaces of the agar plates in two directions. Immediately after the inoculation of the plates, the acid-treated enamel-dentin disks to be tested were placed on the prepared plates along with the controls as in Part I.

Streptococcus mutans and *Streptococcus salivarius* were incubated aerobically at 37° C; *Actinobaccillis actinomycetocomitans* was grown anaerobically. Each Petri dish was evaluated after 48 hours, and zones of microbial inhibition measured in millimeters with a caliper (Mitutoyo Mfg Co, Ltd, Tokyo, Japan). As stated previously, every attempt was made to fabricate the enamel-dentin disks as the same size of the well. If there were any discrepancies, measurements were taken at the most symmetrical diameter of the disk.

RESULTS

The results of this study are summarized in Figures 1 and 2. All of the etchants used demonstrated antimicrobial activity against all three bacteria. It should be noted that greater zones of inhibition were observed when the etchants were placed alone in the prepared wells in Part I.

DISCUSSION

Concerns have been expressed about residual bacteria in cavity preparations (Brännström, 1987). Not only do residual bacteria reside in the dentinal tubules and can therefore be a source of infection to the pulp, but bacteria are also present at the area of the contraction gap between tooth and composite resin. Brännström (1987) characterizes cavity infection by bacteria as being due to multiple sources: (1) invasion from the tooth surface via marginal gaps between tooth and restorative material; (2) bacteria present in the smear layer; (3) bacteria present in the dentinal tubules; (4) bacteria at the gap at the dentinoenamel junction; and (5) microbes recontaminating the surface after cleaning. After cavity preparation, assessment of residual caries and bacteria has in most cases been a subjective assessment (Charbeneau & others, 1988). A number of different

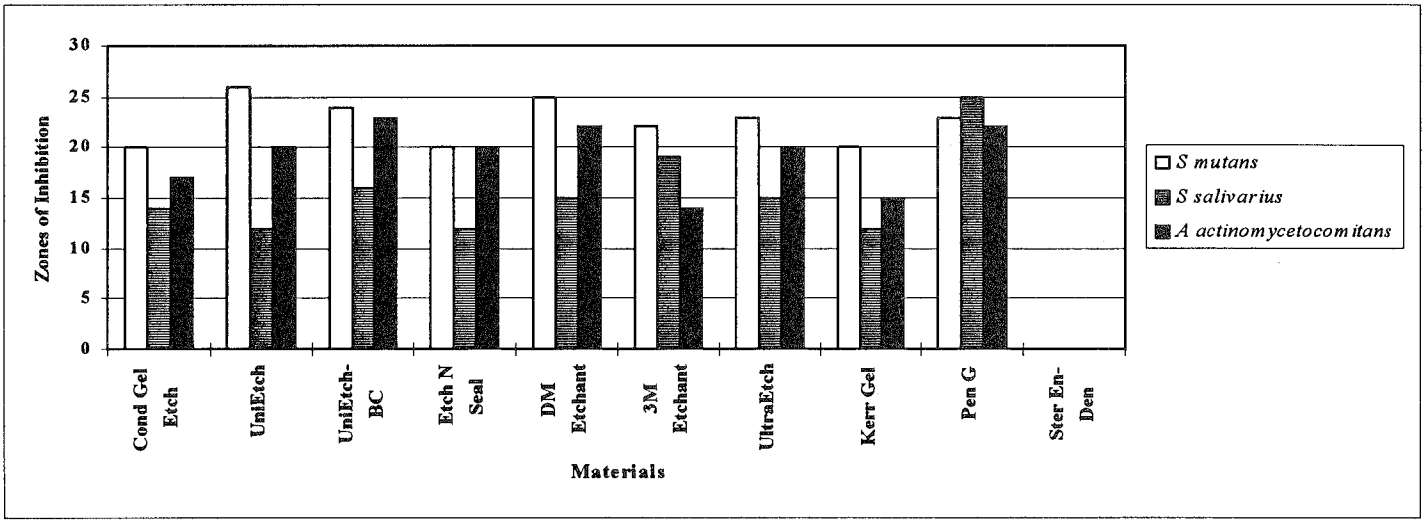

Figure 2. *Zones of inhibition—Part II*

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investigators have described procedures for the detection of carious dentin using dyes that assist visual detection (Franco & Kelsey, 1981; Kidd & others, 1989; Maupomé & others, 1995). Anderson and Charbeneau (1985) compared digital and optical assessment criteria for detecting carious dentin and found that even when the dentinoenamel junction was cleared of all discoloration attributable to caries and was judged by tactile discrimination with an explorer to be sound, when using fuchsin stain to disclose caries, 59% of the teeth demonstrated staining at the dentinoenamel junction. Based upon this evidence, the use of an antibacterial cavity cleanser has been recommended after cavity preparation as a treatment for residual bacteria. With this in mind, investigations into removing residual bacteria-infected dentin have been undertaken. Chan and Hui (1992), Chan and Lo (1994), and Farley and others (1993) have demonstrated the residual antibacterial effects of additives such as chlorhexidine and benzalkonium chloride on a phosphoric acid etchant.

Therefore, is it necessary to use an adjunctive antibacterial agent before acid etching and adhesive placement with composite resin restorations? The results of this study demonstrated that all the etchants produced zones of inhibition against the three bacteria used. Two of the bacteria, *Streptococcus mutans* and *Streptococcus salivarius*, stain gram positive and stain in a similar manner to other bacteria associated with the caries process such as *Streptococcus sobrinus*, *Lactobacillis casei* or *acidophilus*. *Actinobacillis actinomycetocomitans* stains gram negative and has been regarded as a periodontal anaerobe. Thus, the bacteria used demonstrated a wide range of activity, and may be representative of bacteria commonly found in the oral cavity.

The zones of inhibition obtained in Part I were greater than those obtained in Part II. However, this should not be surprising, as the etchant may have diffused into the agar itself and allowed the bacteria to come in direct contact with a more acidified agar medium. In Part II, the bacteria came into contact with the etched enamel-dentin disks and further supported the evidence of demonstrated antimicrobial activity. These disks more closely simulated what may take place in the oral cavity compared to the agar alone. However, it is interesting to note that antimicrobial activity was indeed apparent in both parts of this study and further support the antimicrobial nature of etchants. It is interesting to note that the etchant with benzalkonium chloride did not exhibit significantly larger zones of inhibition compared to the other etchants used in the study. The results therefore question the necessity of placing additional disinfectants within etchant materials, or whether it is even necessary to treat dentin surfaces with separate antimicrobials prior to the placing of restoratives. If the newer bonding systems hybridize the dentin, and provide an enhanced seal to limit microleakage, nutritional requirements for bacteria would be lacking, since the bacteria would not be able to exploit microleakage between the restorative and the cavity wall. Thus, the issue of bacterial entry or residual bacteria within a cavity preparation may diminish in importance, especially if the restoration is able to maintain its seal.

CONCLUSION

1. All phosphoric acid etchant materials tested demonstrated antimicrobial activity against several bacteria commonly found in the oral cavity.
2. The addition of antimicrobial agents to etchants or cavity preparations may not be necessary, given the antimicrobial activity of the etchants, if the current bonding systems can provide and sustain a sealed tooth-restorative interface.

(Received 27 December 1995)

References

ANDERSON MH & CHARBENEAU GT (1985) A comparison of digital and optical criteria for detecting carious dentin *Journal of Prosthetic Dentistry* **53** 643-646.

BAHARAV H, CARDASH HS, PILO R & HELFT M (1988) The efficacy of liquid and gel acid etchants *Journal of Prosthetic Dentistry* **60** 545-547.

BARKMEIER WW, SHAFFER SE & GWINNETT AJ (1986) Effects of 15 vs 60 second enamel acid conditioning on adhesion and morphology *Operative Dentistry* **11** 111-116.

BRÄNNSTRÖM M (1987) Infection beneath composite resin restorations: can it be avoided? *Operative Dentistry* **12** 158-163.

BRÄNNSTRÖM M, GOLA M, NORDENVALL K-J & TORSTENSON B (1980) Invasion of microorganisms and some structural changes in incipient enamel caries. A scanning electron microscropic investigation *Caries Research* **14** 276-284.

BUONOCORE MG (1955) A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces *Journal of Dental Research* **34** 849-853.

BUONOCORE MG, WILEMAN W & BRUDEVOLD F (1956) A report on a resin composition capable of bonding to human dentin surfaces *Journal of Dental Research* **35** 846-851.

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CHAN DCN & HUI EYW (1992) Antimicrobial action of chlorhexidine incorporated in an etchant *Journal of Dental Research* **71** *Abstracts of Papers* p 141 Abstract 284.

CHAN DCN & LO WW (1994) Residual antimicrobial action of benzalkonium chloride-containing etchant *Journal of Dental Research* **73** *Abstracts of Papers* p 226 Abstract 995.

CHARBENEAU GT, CARTWRIGHT CB, COMSTOCK FW, KAHLER FW, SNYDER DT, DENNISON JB & MARGESON RD (1988) *Principles and Practices of Operative Dentistry* 3rd edition, Philadelphia: Lea & Febiger.

DOUGLAS WH (1989) Clinical status of dentine bonding agents *Journal of Dentistry* **17** 209-215.

FARLEY DW, CHAN DCN & LAM YWF (1993) Chlorhexidine uptake after treatment with a chlorhexidine-containing etchant *Journal of Dental Research* **72** *Abstracts of Papers* p 384 Abstract 2246.

FRANCO SJ & KELSEY WP (1981) Caries removal with and without a disclosing solution of basic fuchsin *Operative Dentistry* **6** 46-50.

GORACCI G, BAZZUCCHI M, MORI G & CASA de MARTINIS L (1994) In vivo and in vitro analysis of a bonding agent *Quintessence International* **25** 627-635.

JORDAN RE, SUZUKI M, GWINNETT AJ & HUNTER JK (1977) Restoration of fractured and hypoplastic incisors by the acid etch resin technique: a three-year report *Journal of the American Dental Association* **95** 795-803.

KIDD EA, JOYSTON-BECHAL S, SMITH MM, ALLAN R, HOWE L & SMITH SR (1989) The use of a caries detector dye in cavity preparation *British Dental Journal* **167** 132-134.

MAUPOMÉ G, HERNÁNDEZ-GUERRERO JC, GARCÍA-LUNA M, TREJO-ALVARADO A, HERNÁNDEZ-PÉREZ M & DÍEZ-DE-BONILLA J (1995) In vivo diagnostic assessment of dentinal caries utilizing acid red and povidone-iodine dyes *Operative Dentistry* **20** 119-122.

NAKABAYASHI N, KOJIMA K & MASUHARA E (1982) The promotion of adhesion by the infiltration of monomers into tooth substrates *Journal of Biomedical Materials Research* **16** 265-273.

PASHLEY DH (1991) Dentin bonding: overview of the substrate with respect to adhesive material *Journal of Esthetic Dentistry* **3** 46-50.

PERDIGAO J, DENEHY GE & SWIFT EJ Jr (1994) Silica contamination of etched dentin and enamel surfaces: a scanning electron microscopic and bond strength study *Quintessence International* **25** 327-333.

PRATI C & PASHLEY DH (1992) Dentin wetness, permeability and thickness and bond strength of adhesive systems *American Journal of Dentistry* **5** 33-38.

SWIFT EJ Jr, DENEHY GE & BECK MD (1993) Use of phosphoric acid etchants with Scotchbond Multi-Purpose *American Journal of Dentistry* **6** 88-90.

SHAY K, LLOYD PM, PANHANS MA & BATES DM (1988) The absence of an age effect on enamel solubility in phosphoric acid *Journal of Prosthetic Dentistry* **60** 531-540.

WHITE KC, COX CF, KANKA J III, DIXON DL, FARMER JB & SNUGGS HM (1994) Pulpal response to adhesive resin systems applied to acid-etched vital dentin: Damp versus dry primer application *Quintessence International* **25** 259-268.

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CLINICAL ARTICLE

A Technique for Fabrication of a Cast Post and Core

S DOUKOUDAKIS

INTRODUCTION

The restoration of endodontically treated teeth with cast posts and cores is a routine procedure in restorative dentistry. The successful fabrication of a cast post and core provides the necessary retention and resistance form for the fixed prosthesis. The preparation of the remaining tooth structure, the casting procedures, and the final cementation are based on principles that have been established for many years and are extensively reported in the literature (Bartlett, 1968; Dewhirst, Fisher & Shillinburg, 1969; Baraban, 1970). Variations exist in the techniques for the fabrication of the pattern that will be used to produce the casting (Hudis & Goldstein, 1986).

The standard technique incorporates a standardized plastic post that is fitted in the prepared canal, and then self-cured acrylic resin is used to provide an accurate fit of the post in the canal, forming the post portion of the pattern. Recently the fabrication of a post and core using a combination of light- and chemically activated resins was reported (Waldmeier & Grasso, 1992). These resins were only used for the core portions, because the depth of polymerization of light-activated systems could not exceed 3 mm, which prohibited the use of light-activated resins for the post portion.

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CLINICAL TECHNIQUE

The introduction of clear plastic posts (Luminex, Weissman Technology International, Inc, New York, NY 10016) provides the opportunity to use light-activated resins for the post portion, since the polymerization light penetrates the clear post and polymerizes the resin inside the canal (Lui, 1994). This article describes a technique in which the entire post and core is fabricated using a clear plastic pattern and light-activated resin according to the following procedures:

1. The root canal and the remaining tooth structure are prepared using the principles of preparation for an endodontically treated tooth, ensuring that no undercuts are present in the canal (Figure 1).
2. A clear plastic post with undercuts is selected and placed in the canal. The post should fit loosely.
3. The depth is measured and the clear post modified so it will seat at the bottom of the prepared root canal, leaving adequate length to fabricate the core portion.
4. The canal is lubricated using separating material from the Coltène Brilliant kit (Coltène Inc East,

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Figure 1. *The preparation of the tooth is completed for the application of the cast post.*

Hudson, MA 01749) (Figure 2).

5. Using a Lentulo spiral file (L D Caulk, Milford, DE 19963) and slow-speed handpiece, the thin, light-activated material from the Palavit GLC (Heraeus Kulzer, Wehrheim, Germany) or Triad Burn Out (Dentsply International Inc, York, PA 17405) kit is transferred into the root canal (Figure 3).

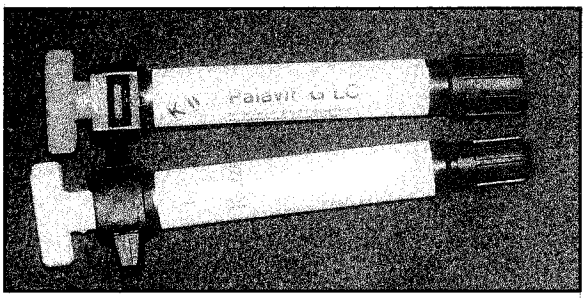

Figure 3. *The light-activated resin*

6. The clear plastic post is fitted in the canal, and unnecessary excess of resin is removed from around the core portion.

7. The resin is initially polymerized with a polymerization light for 1 minute (Figure 4).

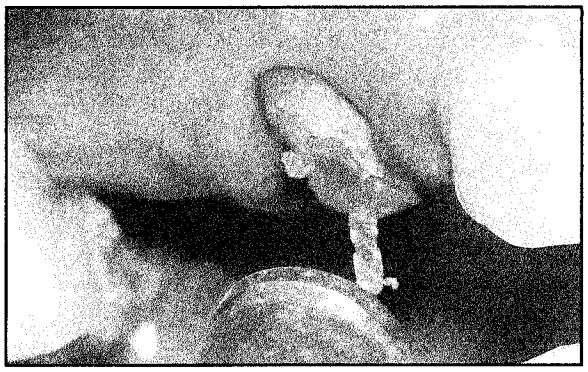

Figure 4. *Polymerization of the light-activated resin after the insertion and fit of the clear plastic post*

Figure 2. *The lubricant*

8. The post with the resin that is not completely polymerized is removed and examined for inaccuracies. In this way we avoid locking the post into existing undercuts. At this stage, it can be further polymerized outside the mouth.

9. The polymerized post is placed back in the root canal, and adequate retention and fit are verified.

10. The core is built using the thick portion of the system and polymerized using light polymerization.

11. The core portion is finally shaped using an additional resin or removing resins with the help of burs and/or disks (Figure 5).

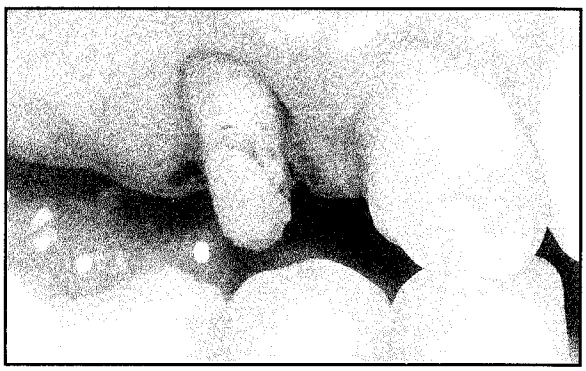

Figure 5. *The acrylic pattern is completed.*

12. The morphology and fit of the completed pattern is examined, and if it meets all the necessary requirements, it is sent to the laboratory to be cast (Figure 6 and 7). The final restoration is shown in Figure 8.

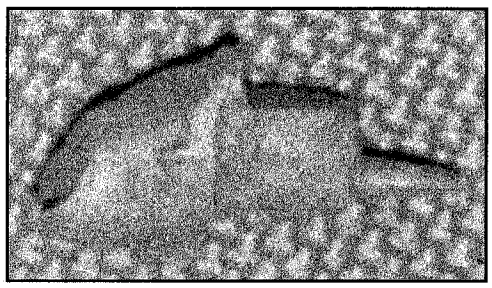

Figure 6. *The casting*

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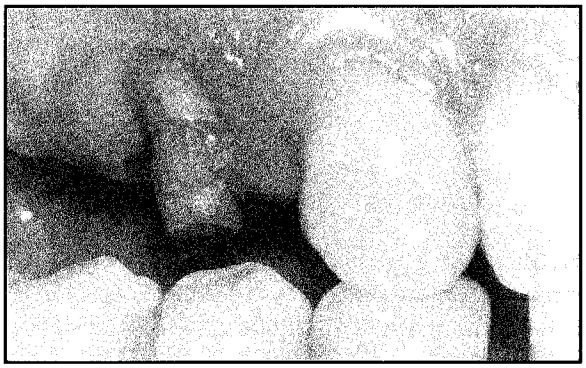

Figure 7. *The post is fitted on the prepared tooth structure.*

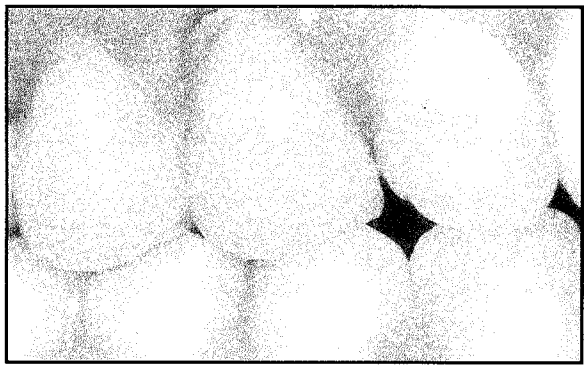

Figure 8. *The final restoration*

CONCLUSION

The advantages of the described technique are:

1. It is an easy method for the fabrication of the post and core pattern;
2. The core portion is easily fabricated, since the light-activated resin is easier to place and shape to the necessary form; and
3. Although the cost with this technique may be higher, the post and core pattern may be quickly and easily fabricated.

(Received 16 January 1996)

References

BARABAN D J (1970) A simplified method for making posts and cores *Journal of Prosthetic Dentistry* **24** 287-297.

BARTLETT S O (1968) Construction of detached core crowns for pulpless teeth in only two sittings *Journal of the American Dental Association* **77** 843-845.

DEWHIRST R B, FISHER D W & SCHILLINBURG H T Jr (1969) Dowel-core fabrication *Journal of the Southern California Dental Association* **37** 444-449.

HUDIS S I & GOLDSTEIN G R (1986) Restoration of endodontically treated teeth: a review of the literature *Journal of Prosthetic Dentistry* **55** 33-38.

LUI J L (1994) Depth of composite polymerization within simulated root canals using light-transmitting posts *Operative Dentistry* **19** 165-168.

WALDMEIER M D & GRASSO J E (1992) Light-cured resin for post patterns *Journal of Prosthetic Dentistry* **68** 412-415.

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DEPARTMENTS

ABSTRACTS

The editor wishes to thank the second-year Comprehensive Dentistry Residents at the Naval Dental School in Bethesda, MD, for their assistance in the preparation of these abstracts.

Effectiveness of occlusal fissure cleansing methods and sealant micromorphology. *Pope BD Jr, García-Godoy F, Summitt JB & Chan DCN (1996) *Journal of Dentistry for Children* 63 175-180.

(*University of Texas Health Science Center at San Antonio, Department of Pediatric Dentistry, San Antonio, TX 78284-7888)

The purpose of this study was to evaluate the effectiveness of different methods for cleansing and preparing occlusal fissures before placing pit and fissure sealants and to evaluate the sealant morphology in respect to the method used. Fifty extracted mandibular human molars were divided into five groups of 10 teeth and treated as follows: One group was cleaned with flour of pumice and a rubber cup, one group cleaned with a low-speed dry bristle brush, one group had the occlusal fissures opened with a ¼ round bur, one group was cleaned with a Danville Microprophy unit, and one group with a Danville Microetcher. All teeth were then conductively coated and examined under a scanning electron microscope. Another group of 25 teeth were separated into five groups of five, treated with the same fissure cleaning/preparation methods as above, then acid etched, rinsed, and Helioseal sealant material was applied to all occlusal fissures and light cured. Results for the SEM examination of fissure cleaning and preparation methods suggested that a rubber cup and pumice was the least effective method, as all samples showed evidence of pumice in the fissures. Results of the sealant applications showed less evidence of penetration of sealant onto enamel prisms for the rubber cup and pumice or bristle brush suggesting the etchant was not able to penetrate the fissures as well as for the other treatment methods. The results of this study suggest that a rubber cup and pumice or bristle brush should not be the method of choice for preparing teeth for sealants. It would appear that opening fissures with a ¼ round bur, or cleaning the fissures with an air-abrasive unit are preferable methods for preparing teeth for sealant applications.

Effect of a surface sealant on microleakage of Class V restorations. *May KN, Swift EJ, Wilder AD & Futrell SC (1996) *American Journal of Dentistry* 9(3) 133-136.

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Carious or abrasion-type lesions in the cervical areas of teeth are usually restored with either resin composite or glass-ionomer cement. Despite the improvements in bond strengths of dentin adhesives and resin-modified glass ionomers, the marginal seal of cervical restorations remains a concern. Microleakage at poorly sealed margins can result in staining, postoperative sensitivity, pulpal irritation, and recurrent caries.

Fifty extracted human teeth had box-shaped class 5 preparations made in the facial and lingual surfaces. Occlusal margins were in enamel and gingival margins were in dentin/cementum. Preparations were restored with the following five systems: Dentin Conditioner + Fuji II LC; ProBond primer + Variglass VLC; OptiBond +XRV Herculite; Scotchbond Multi-Purpose + Silux Plus; and Scotchbond Multi-Purpose + Restorative Z100. Half of the restorations in each group were randomly selected and sealed with Fortify resin immediately after finishing and polishing. Specimens were thermocycled 500 times between 5° and 55°C and subjected to a silver nitrate microleakage test. The teeth were sectioned faciolingually through the center with a slow-speed diamond saw. The sections were examined with an optical microscope at X15 to determine the extent of microleakage. Penetration of the silver nitrate in the form of precipitated silver ions was evaluated and recorded using a 0-4 ordinal scale. Data were analyzed using nonparametric statistical tests.

All of the restorative systems had very little leakage at enamel margins, regardless of whether the resin sealant was used. Each of the systems except VariGlass had minimal leakage at unsealed dentin margins also. Application of the resin significantly reduced leakage at the interface between VariGlass and dentin or cementum, but had no effect on the other restorative systems.

Effectiveness of the current enamel-dentinal adhesives: A new methodology for its evaluation. *Pagliarini A, Rubini R, Rea M, Campese C & Grandini R (1996) *Quintessence International* 27(4) 265-270.

(*University of Ferrara, School of Dentistry, Department of Conservative Dentistry, Ferrara, Italy)

The purpose of this study was to investigate an alternative method for evaluating adhesive systems

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by measuring microleakage at the dentin-material gap rather than bond strength to dentin.

Ten extracted third molar teeth were prepared with two class 2 box preparations, one each on the mesial and distal surfaces. The dentinal adhesives Syntac, Gluma 2000, Scotchbond Multi-Purpose, and All-Bond 2 were applied to five boxes each and restored incrementally with the photopolymerizing resin composite material Z100. The crowns of the teeth were then placed in cylindrical containers and filled with epoxy resin. A microtome was used to create 20 disks, each of which was composed of a ring of epoxy resin that contained an axial section of the crown crossed in all its thickness by the composite resin restoration. Each disk was then fixed to a preformed epoxy resin washer and inserted into a permeability cell for microleakage evaluation. The amount of physiologic solution able to permeate between the cavity walls and the resin was measured, and the flux of the liquid over time was calculated.

Of the four adhesive systems evaluated, All-Bond 2 was the only one capable in three of the five disk samples of making the dentin impermeable to the physiologic solution and forming an intimate seal between the resin composite and the underlying dentin surface. Syntac allowed the greatest amount of microleakage, which can be explained by the presence of a smear layer creating more of a potential gap between adhesive and dentin surface.

The in vitro results of this study should not be considered absolute values for what may happen in clinical situations. This study provides a methodology of comparing, in standard and repeatable conditions, the amount of microleakage in four dentin adhesive systems.

The effect of a vital bleaching technique on enamel surface morphology and the bonding of composite resin to enamel. Josey AL, *Meyers IA, Romaniuk K & Symons AL (1996) *Journal of Oral Rehabilitation* 23 244-250.

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

The purpose of this in vitro study was (1) to examine the effect of a nightguard vital bleaching technique on the enamel surface; (2) to evaluate the effect of acid etching on bleached enamel surfaces; and (3) to evaluate the effect of vital bleaching on the shear bond strength of a composite resin luting cement to enamel.

Ninety-six extracted human teeth were divided equally into experimental and control groups. Half of the teeth were bleached for 1 week according to the manufacturer's recommendations using Rembrandt Lighten (Den-Mat Corp, Santa Maria, CA 93456), while the control teeth were stored in an artificial saliva solution. After 1 day or 12 weeks of storage, 32 teeth were examined under light microscopy. An additional 24 teeth had a thin groove placed to divide the facial surface in half, and one half was etched for 60 seconds with 37% phosphoric acid, followed by SEM examination. The remaining 40 teeth were selected for shear bond strength testing using orthodontic brackets and a low-viscosity composite resin luting cement (Comspan, Caulk/Dentsply, Milford, DE 19963) after post-bleaching storage intervals of 1 day, 1 week, 6 weeks, and 12 weeks.

Light microscopy investigation suggested the bleaching process resulted in a loss of mineral from enamel. SEM showed a definite change in the surface texture of the bleached enamel surface, with a loss of prismatic form and an overetched appearance. The mean shear bond strength tended to be lower for the bleached enamel surfaces, with the lowest bond strengths observed 24 hours after the bleaching process and the maximum shear strength reached after 6 weeks of storage, suggesting that perhaps veneers should not be placed immediately following bleaching. However, analysis using ANOVA indicated there was no significant difference ($P > 0.05$) between control and experimental groups. The results suggest that although bleaching does result in changes to the enamel surface topography, the shear bond strength of composite resin luting cement to etched bleached enamel appeared to be clinically acceptable.

Effects of hydrogen peroxide-containing bleaching agents on the morphology of human enamel. *Ernst C-P, Marroquin B & Willershausen B (1996) *Quintessence International* 27(1) 53-56.

(*Johannes Gutenberg-University Mainz, Department of Operative Dentistry, Mainz, Germany)

This study utilized SEM observations to evaluate the effects of four bleaching agents on the enamel surface of human incisors. To accomplish this, 10 freshly extracted maxillary incisors were sectioned into six specimens each and treated as follows: (1) 10% carbamide peroxide (Opalescence) for 6 hours, (2) 30% hydrogen peroxide (HiLite) for 10 minutes, (3) 30% hydrogen peroxide for 30 minutes, (4) a 1:1 mixture of 30% hydrogen peroxide and sodium perborate for 30 minutes, (5) 37% phosphoric acid for 30 seconds as positive control, and (6) left untreated as negative control.

Resulting SEM images of the first four groups showed either no or very slight enamel surface alterations as compared to the negative control. The specimens treated with 37% phosphoric acid showed severe surface alteration. Thus, the application of these vital bleaching agents did not significantly affect the enamel surfaces of human incisors and can be recommended for clinical use.

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The overwet phenomenon: A scanning electron microscopic study of surface moisture in the acid-conditioned, resin-dentin interface. Tay F, *Gwinnett A & Wei S (1996) *American Journal of Dentistry* 9 109-114.

(*State University of New York at Stony Brook, School of Dental Medicine, Stony Brook, NY 11794-8702)

The purpose of this study was to examine the effects of various amounts of moisture on the resin-dentin interface when using acetone-based adhesives on conditioned dentin.

Twenty-four dentin disks were made from 24 separate teeth and divided into three groups of eight based on the treatment of surface moisture. Group 1 was air dried for 3 seconds, Group 2 was blotted dry with the dentin remaining glossy, and Group 3 was blotted dry, followed by deliberate rewetting of the surface. They were then primed, a DBA utilized to bond sections together, and the bonded specimens were sectioned and prepared for SEM evaluation.

Group 1 exhibited a hybrid layer with solid resin tags extending through the hybrid layer and into the dentinal tubules. Group 2 exhibited this along with globules and droplets on the surface of the hybrid layer and spherical voids within the primer layer itself. Group 3 exhibited large blister-like spaces and large droplets often exceeding 100 microns in diameter along the surface of the resin-impregnated dentin. Too much water was shown to produce a surface with the same characteristics of incomplete wetting.

The results of this study indicate that bonding to wet or moist dentin should not be loosely interpreted but should be better defined. The spaces evident in this study clearly indicate areas of inadequate dentinal seal and could possibly, though not specifically tested in this study, have a detrimental affect on the bonding strength of the resin. The water already in acetone-based primers may be sufficient to rewet desiccated dentin without the risk of the overwet phenomenon. The authors felt that more specific directions for use should be developed and determined by the amount of water that is in the adhesive primer.

The prosthodontic management of endodontically treated teeth: A literature review. Part I. Success and failure data, treatment concepts. Goodacre CJ & Spolnik KJ (1994) *Journal of Prosthodontics* 3 243-250; Part II. Maintaining the apical seal. Goodacre CJ & Spolnik KJ (1995) *Journal of Prosthodontics* 4 51-53; Part III. Tooth preparation considerations. *Goodacre CJ & Spolnick KJ (1995) *Journal of Prosthodontics* 4 122-128.

(*Loma Linda University School of Dentistry, Loma Linda, CA 92350)

This three-part article concerning the prosthodontic management of endodontically treated teeth addresses some of the most difficult questions concerning this area by reviewing more than 25 years of dental literature and offers a summary opinion.

Part I reviews the incidence of endodontic treatment required after teeth are prepared for single crowns and fixed partial dentures. It found that the incidence of endodontic treatment after tooth preparation ranged from 3% to 23%, with FPD's and complex prostheses having a higher occurrence than single crowns. Many pulpal problems occurred several years later rather than in the first few years after treatment. It concluded that crowns should generally be used on endodontically treated posterior teeth, but are not necessary if an anterior tooth is relatively sound. Posts do not reinforce endodontically treated teeth, but instead have the primary purpose of retaining a core that can be used to retain the definitive restoration. The most common types of post and core failures are either loosening of the post or tooth fracture, with loosening occurring more frequently. From a retention standpoint, threaded posts are the most retentive, followed by cemented, parallel-sided posts. Serrations were found to increase post retention. Although threaded posts were the most retentive, they also were the most likely to cause root fracture, while cemented posts produced less root stress.

In Part II, it was concluded that adequately condensed gutta percha can be removed immediately after endodontic treatment and post space prepared. Both rotary and heated hand instruments can be used without disturbing the apical seal. Four to 5 mm of gutta percha should be retained apically to ensure an adequate apical seal. The importance of placing the definitive restoration as soon as possible after endodontic treatment was emphasized. Also, if zinc oxide eugenol provisional restorations are placed over the obturated canal for periods longer than 3 months, leakage can occur and compromise the gutta percha seal.

In Part III, the optimal post length was determined to be three-fourths of the root length, but in teeth where this is not clinically feasible, the post should be as long as possible, while maintaining 4-5 mm of apical gutta percha. Post diameters should not exceed one-third of the root diameter at any location and the post tip should not exceed 1 mm. To avoid root perforations, posts should not extend more than 7 mm apical to the canal orifice of molars. Safe post

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diameters range from 0.6 mm to 1.2 mm. Peeso rotary instruments #5 and 6, Gates-Glidden #6, round burs greater than size 2, and Parapost drills #6 and 7 should be avoided because their diameters exceed 1.2 mm. The use of a cervical bevel or ferrule was shown to increase a tooth's resistance to fracture in some cases and may be appropriate. The amount of tooth structure present is more important than the material from which the post and core is fabricated. Finally, cervical tooth structure should be retained or the finish line should be extended to engage a minimum of 1 to 2 mm of tooth structure.

BOOK REVIEW

1997 Dental Drug Reference

Tommy W Gage and Frieda Atherton Pickett

Published by Mosby, St Louis, 1997. 658 pages, softbound, $32.95.

This book is an inexpensive, small reference book containing most of the medications that dentists will encounter in their practices. As the authors point out in the preface of the text, the book is based on the 200 most-prescribed medications and is intended to be small enough to be easily used chairside during a review of the patient's medical history.

The text is well organized, indicating the drug classification, effects, uses, and usual doses, along with routes of administration. Each entry is syllabified, with phonetic spelling and accented syllable shown in parentheses. There is also a subheading of dental considerations for each medication, which is written in bold green type. A complete index in the back of the text helps you to cross-reference a drug's product name with its generic name. Another area of the text found to be of benefit to the reader are the appendices on xerostomia and commonly used medical abbreviations.

While this book cannot be used as a reference to obtain extensive drug information, I believe that it does satisfy the purpose as intended by the authors. Major improvements have been made in the 1997 edition to make the text more complete and up-to-date without dramatically increasing its size. After being displeased with previous editions, finding them to be far less than complete, it was a pleasant surprise to find the *1997 Dental Drug Reference* to be complete, easily read, and very well organized. The dental practitioner needs a small and concise drug book that can be easily referenced as an adjunct to a more in-depth drug text.

Restorative dentists need a reliable, up-to-date, concise reference book such as this to be used in their practices. This book, as well as the *Drug Information Handbook for Dentistry* by Richard L Wynn, would be excellent choices for all practitioners who deal with patients and their medications.

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MARCH-APRIL 1997 • VOLUME 22 • NUMBER 2 • 49-96

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