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OPERATIVE DENTISTRY

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

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EDITORIAL

A Time of Change, A Time of Constancy

As we begin Volume 18 and 1993, there are some changes in *Operative Dentistry* that may interest you. First, there has been an editor change in the journal. Dr David Bales has stepped down as editor after eight years of superb service. I have replaced him as editor commencing with this first issue of 1993. In reality, I have been performing the duties of the editor for the articles in this issue, since it takes from 10 months to one year's time to move from receipt of an article to its publication.

I have made several small changes to the format of the journal in an effort to allow you, the reader, greater insight into the contents of each article. Each issue has several articles involving the application of dental materials in various clinical situations as well as clinical techniques. However, due to the complex nature of modern research, it is sometimes difficult to distinguish how the research in a particular article might affect your practice of dentistry. To help make that decision, and to help you decide which of the articles you want to read in depth, we have placed a small "wire box" on the first page of each article. It contains one or two sentences that express the author(s) (or editor's) view concerning the "clinical relevance" of the paper.

Another change that has occurred in this first issue of 1993 is that the Academy of Operative Dentistry emblem on the cover has been redrawn by its originator, Dr Ian Hamilton. It now reflects the true picture of the enamel rods and the crystals within. Ian noted the defect in his original design a number of years ago and has graciously redrawn the corrected emblem for the Academy.

These format changes regarding the clinical relevance of an article and the update of the Academy of Operative Dentistry's emblem are symbolic of our trying to keep you accurately informed concerning our areas of interest in what is loosely called operative dentistry.

I strongly urge each reader to consider submitting clinical or technique articles to the journal. The directing boards of both academies continuously request that we publish more clinical articles. Yet we receive very few pure clinical articles in any year. I will publish a short guide for production of a clinical article in the near future. Please consider soliciting your study club members for technique articles for the journal. If each study club were to submit one technique paper, we would have enough for several years of clinical articles.

We have reformulated the editorial board for Volume 18. The board now has many new members. We all owe a great deal of thanks to the previous members who served so selflessly over the years. I am confident that the new members of the board will serve with equal distinction for the next few years. The names of the current board members are listed on the opposite page.

Finally, I want to publicly express my thanks and gratitude to the immediate past editor, Dr David Bales. He has devoted thousands of hours toward making *Operative Dentistry* a quality scientific journal. Both David Bales and Ian Hamilton have served you well. I am confident that the editorial board and I will maintain the quality of your journal in the years to come.

MAXWELL H ANDERSON
Editor

ORIGINAL ARTICLES

Effect of Different Adhesive Systems on Microleakage at the Amalgam/Composite Resin Interface

F HADAVI • J H HEY
E R AMBROSE • H E ELBADRAWY

Clinical Relevance
Some adhesive systems reduce microleakage at the amalgam/composite junction.

SUMMARY

The objective of this study was to evaluate the effect of different bonding systems on the microleakage at the amalgam/composite interface. The microleakage at the amalgam/composite resin interface was evaluated with a quantitative dye penetration method. Amalgam cylinders were made and a 2 mm composite base was added after the application of five different bonding systems to the roughened innerface of the amalgam cylinders. The cylinders were filled with an exact volume of 0.05% fuchsin solution, and the total weight of the sample was measured. The cylinders were placed on a filter paper with the composite base down and evaluated for leakage after 1, 3, 6, and 24 hours. Weight loss and coloring of the filter paper represented microleakage. The results indicated that the application of Prisma Universal Bond 2 adhesive, Cover Up II, or Amalgambond (groups E, F, and G) reduced the amount of microleakage significantly as compared to the groups in which no adhesive system, 3M Porcelain Repair Kit (with and without acid etching of the amalgam surface), or Prisma Universal Bond 2 primer and adhesive (groups A, B, C or D) was applied.

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INTRODUCTION

Clinical situations for placement of composite resin adjacent to existing or freshly placed dental amalgam have been described in several publications (Anglis & Fine, 1982;

Barkmeier & Cooley, 1979; Cardash & others, 1990; Durnan, 1971; Eidelman & others, 1990; Gordon, Laufer & Metzger, 1985; Gourley & Ambrose, 1982; Lambert, Scrabeck & Robinson, 1983; St Arnault & Coury, 1983; Zalkind & others, 1981).

Some laboratory studies, however, demonstrated the presence of microleakage at the junction of amalgam alloy and composite resin (Eidelman & others, 1990; Fuks & Shey, 1983; Hadavi, Hey & Ambrose, 1991a; Kossa, 1987; Leonard & others, 1988; Maroney & others, 1988). Evidence suggests that microleakage, in addition to establishing an environment for the development of caries, may result in pulp pathology and postoperative tooth sensitivity and contributes to corrosion, dissolution, or discoloration of certain dental materials (Trowbridge, 1987). The application of an adhesive system on the amalgam surface prior to placement of composite resin might be a suitable method to decrease or prevent this microleakage.

The purpose of this study was to qualitatively evaluate the influence of four commercial adhesive systems on the microleakage between composite resin and amalgam alloy using a dye penetration test method and to determine whether significant differences exist between these systems.

METHODS AND MATERIALS

The method of measuring microleakage in this study has been described in detail in a previous report (Hadavi & others, 1991a).

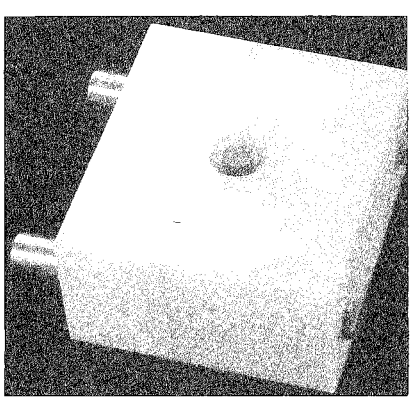

Figure 1. *Mold used to make amalgam cylinders*

Basically, the method consists of quantitative measurement of the amount of leakage between amalgam and composite resin, using a solution of 0.05% fuchsin.

Thirty-five amalgam cylinders (Tytin, Sybron/Kerr, Romulus, MI 48174) with a diameter of 5 mm, height of 10 mm, and wall thickness of 2 mm were fabricated in a mold (Figure 1) by hand condensation and stored at room temperature. After 10 days the lower 2 mm of the inner aspect of the amalgam cylinder was roughened using a low-speed #700 bur (Jet, Beaver Dental Products, Morrisburg, ONT K0C 1X0). The amalgam cylinders were then divided randomly into seven test groups (A to G), each consisting of five samples. In groups B to G, different adhesive systems were applied on the roughened amalgam innerface according to the manufacturers' instructions, while group A did not receive any further treatment and served as a control group (Table 1).

The treated amalgam cylinders were then

Table 1. Treatment Procedures of Roughened Lower 2 mm Innerface of Amalgam Cylinders

Group	Treatment
A	No further treatment
B	3M Porcelain Repair Kit* (acid, primer, and adhesive) was applied according to the manufacturer's instructions.
C	Same as Group B, but the amalgam surface was not acid etched.
D	Prisma Universal Bond 2** (primer and adhesive) was applied according to the manufacturer's instructions.
E	Same as Group D, but no primer was applied.
F	Amalgambond*** (primer and adhesive) was applied according to the manufacturer's instructions.
G	Cover Up II*** (primer and adhesive) was applied according to the manufacturer's instructions.

*3M Dental Products, St Paul, MN 55144
**L D Caulk Co, Dentsply International, Milford, DE 19963
***Parkell, Farmingdale, NY 11735

placed on a positioning rod (Figure 2), and a 2 mm-thick composite resin base (Ful-Fil posterior restorative, L D Caulk) was added in two increments of 1 mm each to the roughened inner surface to close the amalgam cylinders on one side. Each increment was exposed to visible light from a Visilux 2 unit (3M Dental Products) for 40 seconds. The junction of amalgam and composite was polished with 600-grit sandpaper (Buehler Ltd, Evanston, IL 60204), and the weight of each sample was measured on an electronic balance (Sartorius L 2205, Gottingen, Germany) with an accuracy of 0.001 gram.

The amalgam cylinders were immediately filled with an exact volume of 0.05% fuchsin solution, and the weight was remeasured. The open side was carefully covered with wax to prevent any evaporation of the water solution, and the total weight of each sample was determined (Figure 3).

The samples were placed on a filter paper with the composite base down, and the weights were remeasured after time intervals of 1, 3, 6, and 24 hours. After each measurement the cylinders were transferred to a new filter paper. Weight loss and coloring of the filter paper represented the microleakage at the junction of composite and amalgam. The results of the measurements were treated statistically using the Student *t*-test (one tail).

RESULTS

The mean values and standard deviation of weight loss in the different test groups are shown in Table 2 and Figure 4.

After one hour, most leakage was measured

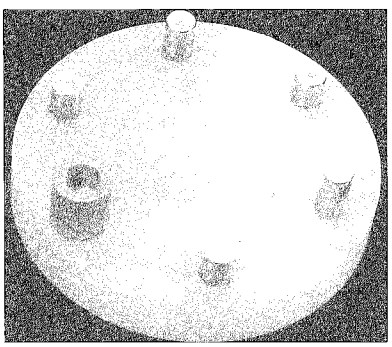

Figure 2. *Positioning rod for amalgam cylinders*

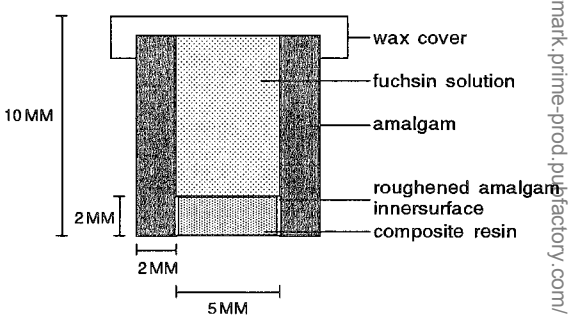

Figure 3. *Cross section of the test sample*

Table 2. Amount of Leakage in the Test Groups

Groups		A	B	C	D	E	F	G
baseline	(grams)	0.116	0.130	0.125	0.123	0.119	0.110	0.121
1 hour	mean	0.015	0.064	0.065	0.001	0	0	0
	stdev	0.015	0.055	0.042	0.002	0	0	0
	%	12.9	49.4	52.0	0.8	0	0	0
3 hours	mean	0.048	0.096	0.100	0.015	0.001	0.001	0.001
	stdev	0.048	0.051	0.013	0.014	0.001	0.001	0.002
	%	41.4	73.6	79.6	12.5	0.7	0.7	1.2
6 hours	mean	0.085	0.115	0.119	0.056	0.004	0.005	0.005
	stdev	0.036	0.032	0.008	0.047	0.003	0.003	0.001
	%	73.5	88.2	94.7	44.7	3.1	4.2	4.2
24 hours	mean	0.108	0.129	0.123	0.074	0.018	0.019	0.017
	stdev	0.018	0.003	0.005	0.046	0.015	0.011	0.004
	%	92.9	98.6	98.3	60.0	15.0	16.9	13.8

in the untreated control group A and both B and C groups treated with the 3M Porcelain Repair kit (with and without acid etching of amalgam surface). The amount of leakage was significantly more than in all the other groups ($P < 0.05$) for this time interval, and it became evident as soon as the amalgam cylinders were filled with the fuchsin solution, indicating lack of adhesion. A minimal degree of microleakage (0.8%) was also measured in some samples of the Prisma Universal Bond (L D Caulk), group D. No microleakage was measured in all remaining groups at the one-hour interval.

The same trend continued for measurements at the 3-, 6-, and 24-hour intervals with groups A, B, and C showing significantly higher microleakage values than all other groups. The one exception was between the untreated control group A and the Prisma Universal Bond 2 (group D), in which the values were not significant.

Group D showed significantly more dye penetration at the three-hour interval than both groups E and F and significantly more than groups E, F, and G at the six- and 24-hour intervals. No significant differences were found within groups E, F, and G and within groups A, B, and C at all different time intervals.

DISCUSSION

A clinically adequate bond should be able to prevent microleakage at the interface. This study demonstrated that microleakage occurred when amalgam and composite resin are placed in contact with each other. It also indicated that the type of bonding agent applied on the amalgam surface significantly affected the amount of leakage.

The manufacturer of the 3M Porcelain Repair Kit recommends that the metal surface be acid etched prior to application of the Scotch-prime Ceramic primer supplied with the kit. However, in a study by Hadavi and others (1991a), it was found that acid etching had a severe adverse effect on the bonding between amalgam and composite resin, therefore a second group of five samples without acid etching of the amalgam surface (group C) was tested. The test results nevertheless showed that in both cases this organosilane repair system failed to prevent microleakage at the amalgam-composite interface and in fact demonstrated no significant difference compared to group A, in which no adhesive system was utilized. It has been reported that the organosilane coupling agents did not bond to a metal surface as they did with porcelain, and it was advised to

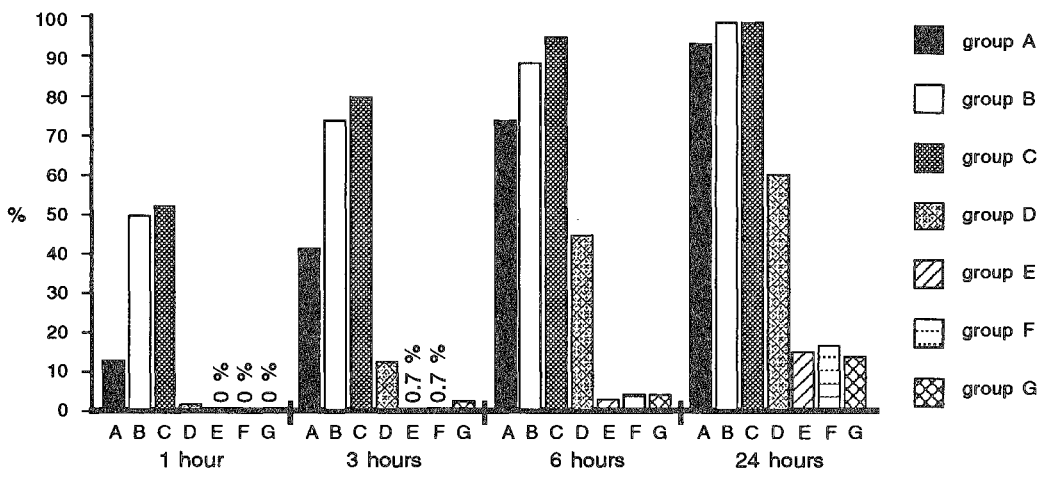

Figure 4. *Percentage of microleakage in the different test groups*

create mechanical retention when a repair involved a large surface of exposed metal (Eames & others, 1977; Bailey, 1989).

Prisma Universal Bond 2 has been advocated for its effectiveness in bonding to enamel and dentin (Hammesfahr, Huang & Shaffer, 1987). In two recent studies it has also been reported to enhance the bonding between amalgam alloy and composite resin (Hadavi & others, 1991a; Hadavi, Hey & Ambrose, 1991b). The application of the primer prior to the application of the adhesive agent (group D) increased microleakage when compared to group E, which was treated with Prisma Universal Bond without prior application of the primer. This implied that when joining amalgam and composite resin, the use of the Prisma Universal primer is not indicated, and that when primer is applied to the dentin surface, contamination of the amalgam surface must be avoided.

Amalgambond and Cover Up II contain monomers with both hydrophilic and hydrophobic groups. Amalgambond is intended to bond amalgam to tooth structure or to amalgam, with secondary use as resin bonding material (Clinical Research Associates, 1990). The present in vitro study demonstrated that the application of Amalgambond as well as Cover Up II reduced the microleakage at the amalgam-composite interface considerably, and there was no significant difference between them. Cover Up II, however, has the advantage of an opaque bonding agent, which masks the silver amalgam surface better than the transparent Amalgambond bonding agent, and it is clinically more convenient to use. In a few studies it has been reported that the use of Cover Up increased the bond strength of composite resin to amalgam (Hadavi & others, 1991b; Murrey & Bailey, 1988; Cooley, McCourt & Train, 1989).

Ful-Fil composite resin has a volumetric polymerization contraction of 2.48% and 2.77% after 30 and 60 seconds of light curing (Walls, McCabe & Murray, 1988). Polymerization shrinkage and lack of adhesion of resin materials to the amalgam surface is an important factor in the magnitude of the dye penetration. In groups E, F, and G (Prisma Universal Bond 2 with no primer, Amalgambond, and Cover Up II respectively), the adhesive systems were able to compensate in part for these shortcomings. This might be due to either establishing a sufficient bond between amalgam and composite resin and/or absorption of water by the unfilled resin, which caused expansion and closure of the marginal gap (Fuks & Shey, 1983; Hadavi & others, 1991a; Koike & others, 1990).

Several authors mentioned the imperfections of dye penetration studies (Trowbridge, 1987; Kidd, 1976; Going, 1972). This present test method allowed us to quantify the amount of leakage; however, we cannot predict whether the dye penetration pattern found with this method can be applied to an in vivo situation. It is also unknown what the precise amount of microleakage is that can be tolerated by the clinical restoration (Phillips, 1988).

CONCLUSION

In this study the application of adhesive systems such as Prisma Universal Bond 2 adhesive, Amalgambond, and Cover Up II reduced the microleakage between amalgam and composite resin significantly. The ultimate solution to the problem of long-term reliability of the bonding agent has to be found through controlled in vitro investigations. In the meantime, laboratory data are appropriate for selecting those products that seem most promising.

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Interfacial Structure between Dentin and Seven Dentin Bonding Systems Revealed Using Argon Ion Beam Etching

S INOKOSHI • H HOSODA
C HARNIRATTISAI • Y SHIMADA

Clinical Relevance
All systems tested use the hybrid layer for some portion of their bonding.

SUMMARY

The interfacial structure of seven dentin adhesive systems was studied morphologically. Argon ion beam etching of an undecalcified section clearly revealed the resin-impregnated demineralized dentin at the adhesive interface of the seven systems when observed under the scanning electron microscope.

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Choltacha Harnirattisai, DDS, graduate student

Yasushi Shimada, DDS, graduate student

INTRODUCTION

Bonding to dentin has become one of the most interesting and challenging topics in restorative dentistry. The high organic content and tubular structure of dentin as well as odontoblastic processes and the outward flow of fluid make dentin bonding difficult to attain (Pashley, 1990).

Nakabayashi (1982) first described the presence of a hybrid layer of 4-META/MMA-TBB resin and surface-demineralized dentin at the adhesive interface. This layer was disclosed using a scanning electron microscope by partially decalcifying a polished section of the resin-dentin interface with 6 N HCl for 30 seconds. It was acid-proof like resin but demonstrated a tubular structure similar to that of dentin. Nakabayashi (1982, 1985, 1989) explained that this layer was produced by the impregnation of the resin component into the demineralized superficial dentin, and that it was an essential part of dentin adhesion. Although extensive studies have been done on the adhesive interface between 4-META/MMA-TBB resin and dentin morphologically and spectroscopically (Fukushima & Horibe, 1990; Wang & Nakabayashi, 1991; Kato,

Wakumoto & Suzuki, 1986; Suzuki, Kato & Wakumoto, 1991), limited information is available in relation to the other dentin bonding systems (Nakajima, 1985; Eick & others, 1987, 1989; Watson, 1989).

Morphological analysis of the adhesive interface has been performed using the scanning electron microscope, transmission electron microscope (Eick & others, 1987, 1989; Nakabayashi, 1985; Sugizaki, 1991), and confocal optical microscope (Watson, 1989), with the scanning electron microscope being the simplest method among them. However, a technique is necessary to enhance the structural differences at the tooth-resin adhesive interface. Although an acid has been used for this purpose (Nakabayashi, 1982; Nakajima, 1985; Fukushima & Horibe, 1990), it is sometimes difficult to identify the hybrid layer, which is extremely thin. Then an alternative technique for specimen preparation to view this region more clearly is desirable. The authors have previously reported that argon ion beam etching was useful to reveal the resin-impregnated demineralized dentin (hybrid layer) at the adhesive interface between phosphoric acid-treated dentin and an adhesive resin (Inokoshi & others, 1990).

In the present study, the interfacial structure between dentin and seven different adhesive resins was examined under scanning electron microscopy using the argon ion beam etching technique.

METHODS AND MATERIALS

The table shows dentin conditioners and adhesive resins used in the present study.

Dentin Bonding Systems Used

Dentin Bonding System	Batch #	Manufacturer
Clearfil Photobond System		Kuraray Ltd Osaka, Japan
K-etchant	EG014	
10-20 Ca conditioner		
Clearfil Photobond	U: 206 C: 102	
Superbond C&B System		Sun Medical Kyoto, Japan
10-3 solution	91001	
PMMA powder	01001	
Liquid	00704	
Catalyst	008021	
Scotchbond 2 Dentin Adhesive System		3M Dental Products St Paul, MN 55144
Scotchprep	9CK	
Scotchbond 2	8BE	
Tenure Solution Dentin Adhesive System		Den-Mat Corp Santa Maria, CA 93456
Tenure Dentin Conditioner	231019	
Tenure Solution A	431014	
Tenure Solution B	462019	
Visar Seal	13945	
Mirage Bond Dentin-Enamel Bonding System		Chameleon Dental Products Kansas City, KS 66101
Conditioner		
Bonding resin		
Gluma Bonding System		Bayer Dental Leverkusen, Germany
Gluma 2	4108S	
Gluma 3	4104S	
Gluma 4	4110S	

Figure 1 shows a schematic illustration of a specimen prepared and an area observed. In order to minimize separation or gap formation at the interface due to dehydration during specimen preparation, the adhesive resin was made as thin as possible by bonding a pair of dentin disks together without placing a resin composite.

Twenty-one pairs of dentin disks were prepared from 21 freshly extracted human third molars. Half of the dentin surface was covered by a varnish (Masking Varnish, G-C Industrial Corp, Tokyo, Japan) to create a reference surface without dentin conditioning. One surface of each pair was treated with a conditioner. Although the conditioning time of 30 seconds for Gluma and Superbond systems, 40 seconds for Clearfil, and 30 to 60 seconds for Tenure and Mirage systems are recommended, the time was fixed at 60 seconds for all the dentin bonding systems in order to make a direct comparison of the depths of demineralization. The treated surfaces of each pair were then bonded together with the accessory adhesive resins (table) according to the manufacturers' instructions. The bonding resins were light-cured for 60 seconds from both sides of the disk except for the chemically cured resin, Superbond C&B. Three pairs of dentin disks were used for each bonding system. The procedures for bonding of each system are as follows.

1) Clearfil Photobond System: Dentin surfaces were treated with either K-etchant (37% phosphoric acid gel) or 10-20 Ca conditioner (10% citric acid, 20% calcium chloride in water) for 60 seconds, washed, and air dried. Clearfil Photobond was mixed and applied, using a small pellet, to the surfaces, which were then bonded together with the same adhesive resin.

2) Superbond C&B System: Dentin surfaces were treated with 10-3 solution (10% citric acid, 3% ferric chloride in water) for 60 seconds, washed, and air dried. The PMMA powder was dispensed into a small dish, and the MMA liquid with 4-META and Catalyst (TBB-O) were mixed in another dish. These were then applied to the surfaces using the bead technique. The surfaces were subsequently bonded together.

3) Scotchbond 2 Dentin Adhesive System: Scotchprep (55% HEMA, 5% maleic acid in

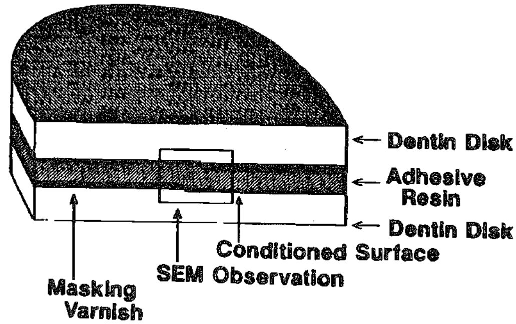

Figure 1. *A schematic illustration of the specimen used.*

water) was applied to the dentin surfaces and continuously agitated with a small brush for 60 seconds. The surfaces were air dried without washing and bonded together with Scotchbond 2.

4) Tenure Solution Dentin Bonding System: Dentin surfaces were treated with Tenure Dentin Conditioner (aluminum oxalate) for 60 seconds, washed, and dried. A mixture of Tenure Solution A (5% NTG-GMA in acetone) and Solution B (10% PMDM in acetone) was applied to the surfaces. Ten seconds later, the surfaces were gently air dried and then bonded together with Visar Seal.

5) Mirage Bond Enamel-Dentin Bonding System: The conditioner (2.5% HNO_3, 4% NPG in water) was applied to the dentin surfaces and continuously agitated with a small brush for 60 seconds. The surfaces were then air dried without washing. The bonding resin (10% PMDM in acetone) was applied to the surfaces. Forty seconds later, the surfaces were air dried and bonded together with Visar Seal.

6) Gluma Bonding System: Dentin surfaces were treated with Gluma 2 (0.5 M EDTA in water) for 60 seconds, washed, and air dried. Gluma 3 (5% glutaraldehyde, 35% HEMA in water) was then applied to the surfaces. Thirty seconds later, the surfaces were air dried and bonded together with Gluma 4.

The bonded dentin disks were stored in 10% neutral buffered formalin for 12 hours, then washed in running tap water before being sectioned perpendicular to the bonded surfaces through the center of the disks with a diamond saw microtome under copious water lavage. The two halves of each saw-cut specimen were embedded in epoxy resin,

then ground and polished using wet silicon carbide papers and diamond pastes of decreasing abrasiveness down to 0.25 μm. The polished surfaces were sputter coated with gold and observed under a scanning electron microscope (JXA 840, JEOL Ltd, Tokyo, Japan). Each specimen was subjected to argon ion beam etching (EIS-1E, Elionix Ltd, Tokyo, Japan) for the different time periods of 1.5, 4.5, and 10 minutes. Operating conditions for the argon ion beam etching were an accelerating voltage of 1 kV and an ion current density of 0.2mA/cm^2, with the ion beam directed perpendicular to the polished surface. These specimens were again sputter coated and observed using the scanning electron microscope.

RESULTS

Figures 2 and 3 show the interface between Clearfil Photobond and phosphoric acid-treated dentin. Cracking through the adhesive resin frequently occurred due to the dehydration during gold coating, scanning electron microscopy observation, and argon ion beam etching, but gap formation between the resin and dentin was seldom observed. Before argon ion beam etching, the bonding resin was poorly demarcated from the underlying dentin with no special structure at the resin-dentin interface being visible (Figure 2a). However, argon ion beam etching of the same specimen for 10 minutes revealed a transitional layer with apparent tubule structure at the superficial part of the dentin (Figure 2b). The width of the layer was about 10 μm and was noted to be at a lower level (small arrow) compared with the unconditioned reference surface (large arrow). Demineralization of the dentin surface with 37% phosphoric acid applied for 60 seconds was found to penetrate to about a 15 μm depth when compared with the unconditioned reference dentin surface, and was noted to be the deepest of all groups examined.

Figures 3a and 3b show higher magnification of the same interface of another specimen, which was argon ion etched for 1.5 and 4.5 minutes respectively. It was clear that the intertubular dentin and resin

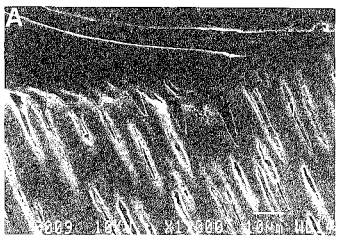

Figure 2a. *Before ion etching, the adhesive resin and dentin interfacial zone shows no special features.*

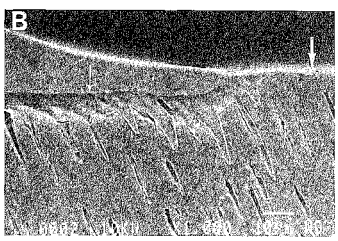

Figure 2b. *After ion etching for 10 minutes, an intermediate layer with an apparent tubular structure appears between the adhesive resin and underlying dentin. The conditioned surface (small arrow) lies at a lower level than the unconditioned reference surface (large arrow).*

Figure 2. *Identical interfaces between phosphoric acid-treated dentin and Photobond prior to (A) and after (B) argon ion beam etching (X90)*

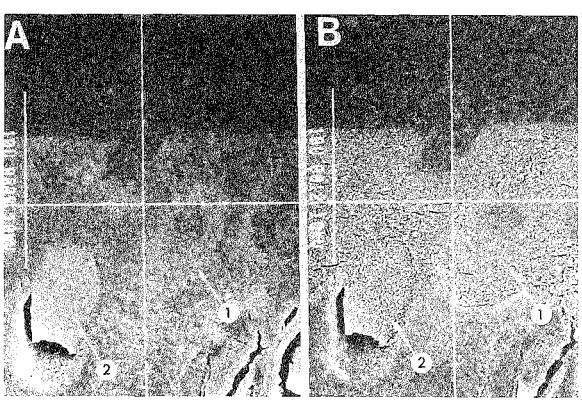

Figure 3. *Identical interfaces between phosphoric acid-treated dentin and Photobond after argon ion beam etching for 1.5 (A) and 4.5 (B) minutes. High power magnification (X750) reveals a gradual roughening of intertubular dentin and resin tags (1 & 2) at the superficial part of the dentin as etching time increases. A vertical bar on the left side indicates 10 μm.*

tags of the superficial part of the dentin were gradually roughened as the time of the argon ion beam etching was extended.

Figure 4 shows the interface between 10-20 Ca-conditioned dentin and Photobond. The conditioner demineralized the dentin to a depth of approximately 5 μm, leaving a hybrid layer 2 μm thick. The demineralized layer was about one-third of that produced by the 37% phosphoric acid gel.

Figure 5 shows the interface between Superbond and 10-3-treated dentin. Although demineralization of the dentin surface was about 10 μm deep, the demineralized layer remained at the original level, unlike that of the phosphoric acid gel.

Figure 6 shows the interface between Scotchprep-treated dentin and Scotchbond 2. The hybrid layer was about 2 μm thick. The demineralized surface remained at the original level of the unconditioned dentin.

Figure 7 shows the resin-dentin interface of the Tenure Solution Dentin Bonding System. Although the hybrid layer was slightly thicker (about 4 μm) than Scotchbond 2, the demineralized surface also remained at the original

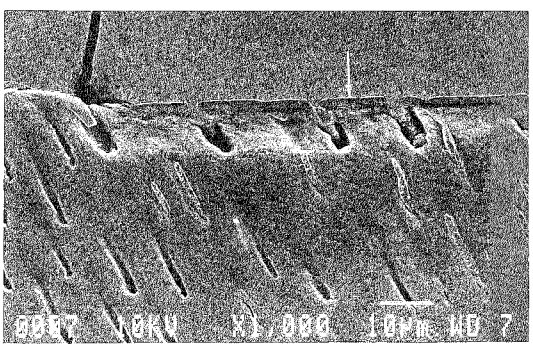

Figure 4. *The interface between 10-20 Ca-treated dentin and Photobond after ion etching for 10 minutes. Large and small arrows indicate unconditioned and conditioned surfaces respectively. (X250)*

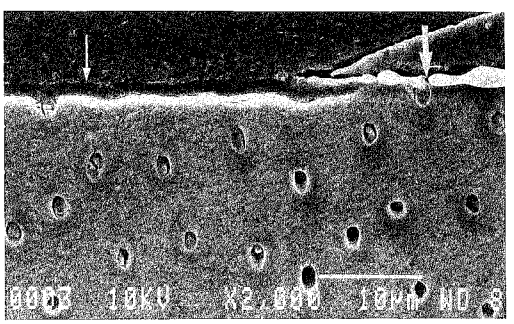

Figure 6. *The interface between Scotchprep-treated dentin and Scotchbond 2 after ion etching for 10 minutes. Large and small arrows indicate unconditioned and conditioned surfaces respectively. (X500)*

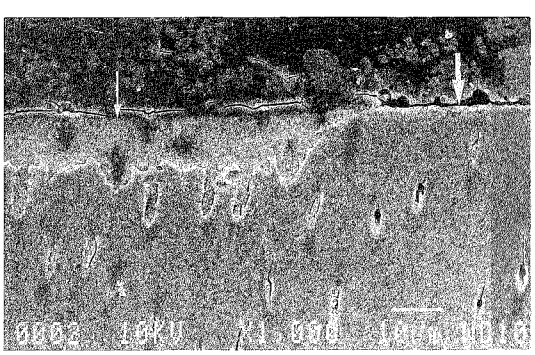

Figure 5. *The interface between 10-3-treated dentin and Superbond C&B after ion etching for 10 minutes. Large and small arrows indicate unconditioned and conditioned surfaces respectively. (X2500)*

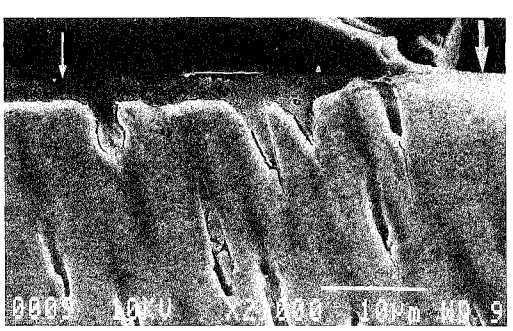

Figure 7. *The resin-dentin interface of Tenure Solution Dentin Adhesive System after ion etching for 10 minutes. Large and small arrows indicate unconditioned and conditioned surfaces respectively. (X500)*

level like Scotchbond 2.

Figure 8 shows the resin-dentin interface of the Mirage Bond Dentin-Enamel Bonding System. This system produced demineralization of about 8 μm deep and a hybrid layer of a 4 μm thickness.

Figure 9 shows the resin-dentin interface of the Gluma Bonding System. The hybrid layer was as thin as 1 μm.

DISCUSSION

Argon ion beam etching has long been used by metallurgists for etching metal surfaces in order to disclose their structure. It is now widely used as a milling method in the semiconductor industry and as a cleaning method for electron spectroscopy for chemical analysis (ESCA). As early as 1962, Boyde and Stewart (1962) used argon ion beam etching to erode dental tissues and found it useful for accentuating the differences in structural composition at the surface of mineralized tissues. During argon ion beam etching, accelerated argon ions attack and remove atoms at the specimen surface. The resistance of the material components against argon ion beam etching is related to the composition of the material.

In the present study, seven dentin bonding systems were used that contained acidic conditioners and chelating agents to remove or alter the smear layer. Argon ion beam etching of polished section surfaces clearly revealed the hybrid layer at the resin-dentin interface of these systems. The hybrid layer was noted to range from as thin as 1 μm in the Gluma system up to a thickness of 10 μm for the H_3P0_4 system. The hybrid layer is demineralized dentin impregnated by an adhesive resin (Nakabayashi, 1982, 1985, 1989). Roughening of the hybrid layer through argon ion beam etching seems to be produced by selective removal of the resin component impregnated into the demineralized dentin and exposure of the collagen fibers of the demineralized dentin. Due to the edge effect of the roughened surface, this layer was clearly distinguished through the secondary electron image of the scanning electron microscope.

In the hybrid layer of the phosphoric acid-treated dentin and Photobond, the resin tags

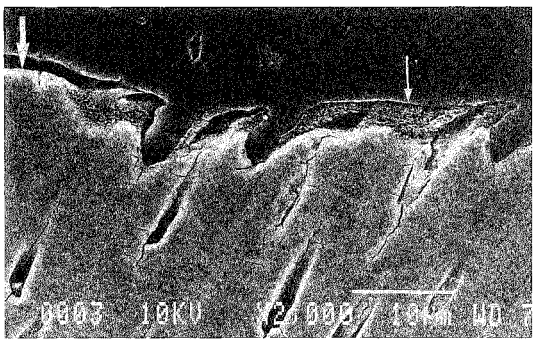

Figure 8. *The resin-dentin interface of Mirage Bond Dentin-Enamel Bonding System after ion etching for 10 minutes. Large and small arrows indicate unconditioned and conditioned surfaces respectively. (X500)*

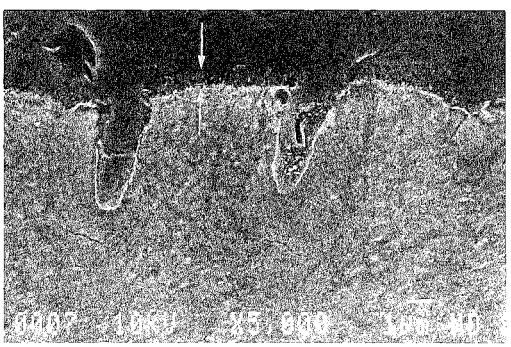

Figure 9. *A resin-dentin interface of Gluma Bonding System after ion etching for 10 minutes, showing a resin-impregnated demineralized layer of 1 μm thickness at the top surface of intertubular dentin (between small arrows). (X1250)*

became much rougher than the adhesive resin layer over the dentin through the argon ion beam etching. This may suggest limited polymerization of the adhesive resin that has penetrated into the dentinal tubules. The reason for this is probably due to the presence of oxygen and water in the dentin. Polymerization of the adhesive resin impregnated into the demineralized intertubular dentin may also be poor. Hence improvement of the polymerization of the resin impregnating the demineralized dentin might lead to much more stable dentin bonding (Imai & others, 1991).

The dentin surface demineralized with the phosphoric acid gel was noted to be at a

lower level than the original unconditioned dentin surface. This is due to shrinkage of the collagenous layer that loses its support from the hydroxyapatite during demineralization. This shrinkage possibly prevents bonding resins from penetrating into the demineralized layer, thus leading to poor micromechanical interlocking. Several dentin primers showing improved dentin bonding like SA (3% N-methacryloyl 5 aminosalicylic acid in 80% ethanol) (Hosoda & others, 1988), 35% HEMA aqueous solution (Itoh, Hasimoto & Wakumoto, 1985), Gluma 3 (Munksgaard & Asmussen, 1984), GM (35% glyceryl methacrylate aqueous solution) (Chigira & others, 1989), and MTYA (35% HEMA + 3% o-methacryloyl tyrosine amide) (Hayakawa & others, 1989) were reported to prevent this shrinkage (Sugizaki, Inokoshi & Hosoda, 1990; Sugizaki, 1991).

10-20 Ca is a new enamel and dentin conditioner for Clearfil Photobond (Hosoda, Hirasawa & Fujitani, 1989) and has been shown to be less harmful to dentin than phosphoric acid. Since the conditioner causes shrinkage of the demineralized layer, the associated use of primers should be recommended to obtain higher bond strengths to the dentin (Hosoda & others, 1988; Sugizaki, 1991).

10-3 solution was developed especially for 4-META/MMA-TBB resin to remove the smear layer and enhance bonding to dentin (Nakabayashi & others, 1981). Nakabayashi (1989) speculated that $FeCl_3$ stabilizes the collagen-lined porous channels in the demineralized intertubular dentin, thereby retaining their dimensional stability during the etching/rinsing/drying/resin-infiltration procedures. The result of this study seems to suggest that this speculation is true.

Scotchprep contains maleic acid and HEMA. Although it demineralized the superficial dentin, the demineralized dentin remained at the original level, suggesting that HEMA prevents the collagenous layer from shrinking (Sugizaki, 1991). This may partly explain the stability of the dentin bonding of the Scotchbond 2 system (Tsai & others, 1990).

Tenure Solution Dentin Conditioner demineralized the dentin to 4 μm deep. The demineralized dentin remained at the original level, like Scotchbond 2, suggesting that shrinkage of the demineralized dentin surface was prevented. The aluminum ions in the conditioner may act as a stabilizing cation for the collagenous layer during surface-demineralization.

The Mirage system showed deep demineralization of the dentin next to 10-3 solution and shrinkage of the demineralized surface like phosphoric acid gel. Although the Tenure and Mirage systems have the same conceptual origin (Bowen & others, 1987), their effect on the organic component of dentin seems to be different.

The Gluma system showed the least demineralization. This is a reasonable result, considering the composition of the conditioner (Munksgaard & Asmussen, 1984). Although Gluma 3 was reported to prevent shrinkage of the demineralized dentin surface with phosphoric acid (Sugizaki, 1991), it was impossible to detect its effect on the EDTA-treated dentin surface morphologically, due to the extremely thin demineralized layer.

Figure 10 shows a schematic illustration of the formation of the interface between the surface-demineralized dentin and adhesive resin. The original cut dentin surface is covered with a smear layer, and the acidic conditioner superficially demineralizes the dentin and exposes collagen fibers, which usually shrink by losing support from the hydroxyapatite. The shrinkage seems to be prevented through the use of primers containing HEMA like Scotchprep or conditioners containing cations like 10-3 solution. A dentin adhesive

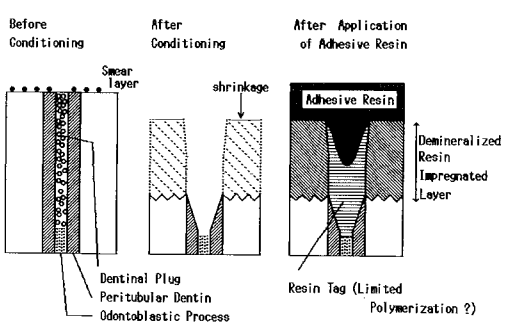

Figure 10. *A schematic illustration of the formation of the interface between surface-demineralized dentin and dentin adhesive*

resin applied to the surface penetrates not only into the dentinal tubules, but also into spaces between the exposed collagen fibers, and then polymerizes. Polymerization of the impregnated resin may be inhibited to some extent by oxygen and water present in the demineralized layer. All of the seven dentin adhesive systems used in the present study showed varying degrees of demineralization of the superficial dentin and created a resin-dentin hybrid layer at the interfaces. The bonding mechanism of these systems seems to be explained by the same protocol of entanglement between collagen fibers and adhesive resins (Nakabayashi, 1982, 1985, 1989; Douglas, 1989).

Clinicians should bear in mind that the dentin bonding systems used in this study demineralized the dentin surface. They should therefore strictly follow the instruction manuals to achieve the maximum efficacy of the products, because failure of the adhesive interface may expose the demineralized dentin surface to oral bacteria and fluids, possibly leading to an accelerated progression of tooth decay.

CONCLUSIONS

The interfacial structure of seven dentin adhesive systems was studied morphologically. Argon ion beam etching of undecalcified sections clearly revealed the resin-impregnated demineralized dentin at the resin-dentin interface when observed under the scanning electron microscope in all the dentin bonding systems used. This technique is, therefore, a useful method to disclose the interfacial structure between the dentin adhesives and dentin. It is also suggested that the bonding mechanism of these systems seems to follow the same protocol of entanglement between the collagen fibers and adhesive resin.

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The Glass-Ionomer-lined Cervical Composite Restoration: an in Vitro Investigation

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M A COCHRAN • R W PHILLIPS

Clinical Relevance
Thickness of etched glass-ionomer bases makes a difference in microleakage.

SUMMARY

The marginal adaptation and microleakage of the glass-ionomer-lined composite resin restoration in simulated erosion and conventional class 5 preparations were evaluated. The most common site of leakage for all restorations was the gingival margin. In erosion lesion restorations, the etched thick liners were superior to the etched thin liners with respect to marginal leakage. Acid-etched and unetched liners in both the erosion lesion and the conventional class 5 restorations were comparable.

Under the SEM a gap was often found in the liner rather than at the liner-resin interface in restorations with etched liners.

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INTRODUCTION

The glass-ionomer cements have a number of properties that recommend them for use in restorations of class 5 cavities as well as cervical lesions without cavity preparation. They bond chemically to enamel and dentin and possess anticariogenic properties. However, the esthetic and wear characteristics of the glass-ionomer cement are inferior to those of composite resin. In order to overcome these shortcomings, a combined restoration

has been suggested, whereby the glass-ionomer cement is used as a liner and the composite resin as an overlying veneer. In this way the advantages of both materials are realized. While the combination technique has been described and recommended, there has been little research to prove the efficacy of this procedure and to elucidate the variables associated with it (McLean & others, 1985; Quiroz & Swift, 1985; Bitter, 1986; Brackett & Robinson, 1986).

The purpose of this in vitro investigation was to evaluate two of these variables: 1) the effect of liner thickness and 2) acid etching of the cement surface on marginal adaptation. The adaptation of the restoration to the cavity and the cement-resin interface was examined by means of scanning electron microscopy in sectioned teeth.

METHODS AND MATERIALS

Preliminary Study of Effect of Etch Time

Before the restorations were placed, a preliminary study was conducted to determine the effect of etch time on two commercial glass-ionomer lining cements. Ketac Bond (ESPE, Seefeld/Oberbay, Germany) and G-C Liner (G-C Dental Industrial Corp, Tokyo, Japan) were mixed according to the manufacturers' directions. The cement mix was transferred to a Teflon ring between two glass slides to create a cement disk with a diameter of 8 mm and a thickness of 1 mm. The cement specimens were allowed to set between the glass slides for seven minutes. Half the disk was protected by adhesive tape. The exposed half immediately was etched with 37% phosphoric acid gel (Scotchbond Etchant, 3M Dental Products, St Paul, MN 55144) for designated time periods of 10, 15, 20, 25, 30, and 60 seconds followed by a 40-second rinse with water. In addition to the etched specimens, specimens were prepared in which the cement was patted into the mold and not covered by a glass slab. This was done in order to obtain a surface simulating that which would exist clinically on cement liners. Replicas of the surface of the disks were prepared by taking an impression with light body addition polyvinylsiloxane impression material (President, Coltene Inc, Hudson, MA 01749). The impressions were poured with an epoxy resin (Stycast, Roy E Davis Co, Peabody, MA 01960). The resin replicas were cleaned and metallized by sputter coating for SEM examination.

A second replica was made from each impression. These replicas were sectioned at a 90° angle to the demarcation line between the etched and unetched halves and mounted so as to expose the cross sections. The replicas were sputter coated and examined by the scanning electron microscope. The loss of material resulting from the etching procedure was determined on the cross sections by measuring the height of the step formed at the junction of the etched and unetched portions of the specimens on the photomicrographs.

Marginal Seal

Marginal leakage of the glass-ionomer-lined restorations both in erosion lesions and conventional class 5 preparations was evaluated using an isotope technique (Swartz & Phillips, 1961).

Ketac Bond was employed as the liner in each case and Silux (3M Dental Products), a microfilled light-cured composite, was the restorative resin.

Cavity Preparations

Human canines and premolars that had been stored in water since extraction were employed. Simulated erosion lesions were produced at the cementoenamel junction by means of a green stone operated at slow speed under running water. The occlusal half of the lesions was in enamel and the gingival portion in cementum and/or dentin. Once cut, the simulated erosion lesions were brushed in a mechanical toothbrush machine for 15 minutes with a nonfluoridated dentifrice (Pepsodent, Lever Brothers, New York, NY 10022, 0.6 g/ml) in order to produce a surface that microscopically appeared to be analogous to a

natural erosion lesion (Figures 1a & b). After the lesions were brushed, the enamel margins were beveled.

The conventional class 5 preparations were cut with a #330 carbide bur operating at high speed with water-air coolant. The mesial and distal walls extended to the line angles. Again the occlusal margin was placed in enamel and the gingival margin in cementum and/or dentin. The cavosurface margins had a 90° angle except for the enamel bevel. A retention groove was placed in the gingival wall with a 1/4 round bur.

Restorative Procedures

The adaptation of the restorations as influenced by liner thickness and the absence or presence of etching on the liner was examined. There were eight test groups, each of which consisted of six canines and six premolars. The various groups were restored in the following manner:

Erosion Lesions:

Group A—thin glass-ionomer liner, etched;

Group B—thin glass-ionomer liner, unetched;

Group C—thick glass-ionomer liner, etched; and

Group D—thick glass-ionomer liner, unetched.

Class 5 Preparations:

Group E—thin glass-ionomer liner, etched;

Group F—thin glass-ionomer liner, unetched;

Group G—thick glass-ionomer liner, etched; and

Group H—thick glass-ionomer liner, unetched.

The erosion lesions were first cleaned with a pumice-water slurry. Both the erosion lesions and the class 5 preparations were washed with a 3% solution of hydrogen peroxide and water to help remove any pumice particles lodged in the dentin tubules. The dentin surface was first treated with a 20% solution of polyacrylic acid for 15 seconds, then rinsed with water for 40 seconds, and dried with compressed air. The Ketac Bond cement was mixed according to the manufacturer's recommendation and inserted into the preparation with a small ball burnisher. The liner covered all of the dentin surfaces, and it was extended to the gingival margin.

For the "thin liner specimens" the cement was applied to the cavity in as thin a layer as possible, although there was a tendency for the material to accumulate at the axiogingival line angle. Measurement of liner thickness on the sectioned teeth indicated the thickness of liners designated as "thin" to be in the 200 to 400 μm range. The thickness of the thick liners ranged from 500 to 700 μm. The cement liners were allowed to harden for six minutes.

The surface of the liners of the etched Groups (A, C, E, and G) were treated for 20 seconds with a 37% phosphoric acid gel, followed by a 20-second rinse with water. The

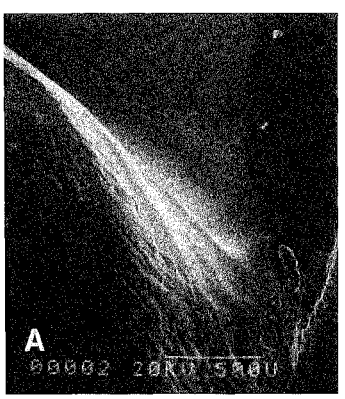

Figure 1a. Photomicrograph of a natural erosion lesion

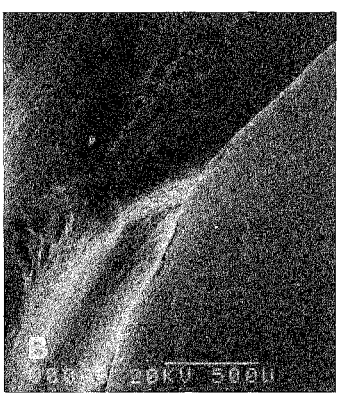

Figure 1b. Artificial erosion lesion

unetched Groups (B, D, F, and H) were rinsed with water. The beveled enamel margins of all cavities were etched for 60 seconds with phosphoric acid gel and then rinsed for 40 seconds with water. The surfaces were dried with a gentle stream of compressed air. Excessive desiccation was avoided. The chemically cured bonding agent, Scotchbond, was mixed according to the manufacturer's recommendations and applied to both the cement liner and the enamel. This was followed by insertion of the composite resin in one increment. The resin was held in place by a transparent matrix and step-cured by applying light to the mesial, distal, and center of the restoration. Each light exposure was 40 seconds in length. Five minutes after placement of the restorations, the restored teeth were immersed in water. The restorations were finished shortly thereafter using abrasive disks (Sof-Lex, 3M Dental Products) to finish. The restored teeth were stored in water at 37 °C for five weeks before they were tested for marginal leakage. During the last week of storage, the restored teeth were thermostressed by cycling them between two water baths with a temperature differential of 40° (10 and 50 °C) for 5000 half-cycles. The dwell time in each bath was 30 seconds.

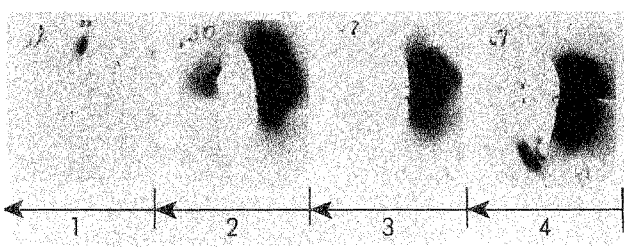

Figure 2. *Autoradiographs of specimens with various degrees of penetration serving as standards for evaluation of marginal leakage of the erosion lesion restorations*

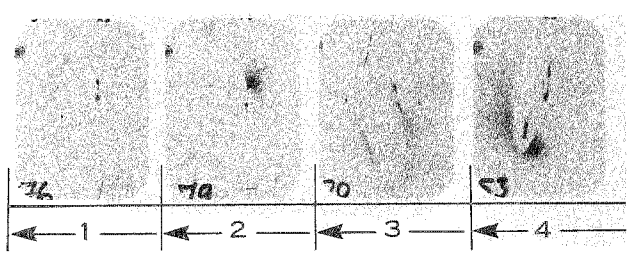

Figure 3. *Autoradiographs of specimens with various degrees of penetration serving as standards for evaluation of marginal leakage of the class 5 restoration*

Microleakage Test

Microleakage was tested according to the method of Swartz and Phillips (1961), using ^{45}Ca as the tracer. The teeth were covered with nail polish and foil except for the restoration and the tooth structure immediately surrounding it. Specimens were immersed for two hours in a solution of $^{45}CaCl_2$ with an activity of 0.1 mCi/ml, rinsed for one hour in running water, and scrubbed with detergent and water. A tray resin was placed around the tooth in order to retain the restoration during sectioning. The teeth were sectioned longitudinally through the restoration by means of a hard sectioning machine that employed a diamond saw with water.

After cleaning, the cut surface of one section of each tooth was placed directly on the emulsion of a dental x-ray film. The film was exposed for 17 hours and then developed. The second half of the tooth was stored in a humidor. Metallized replicas were prepared of representative sections for SEM examination.

Evaluation of Marginal Leakage

Four experimental autoradiographs depicting different degrees of leakage, for each of the two types of cavities, were selected to serve as standards for evaluation of leakage in the autoradiographs. Each of the reference autoradiographs was assigned a number on the basis of the increasing amount of leakage. The standards for the erosion lesions appear in Figure 2 and those for the class 5 cavities in Figure 3.

Erosion lesion restorations:

1. No evidence of penetration,
2. Slight penetration at the cavosurface margin,
3. Penetration of the cavity to the dentin, and
4. Penetration to the deepest portion of the cavity.

Class 5 restorations:

1. No evidence of penetration,
2. Slight penetration at the cavosurface margin,
3. Penetration to the axial wall, and
4. Penetration along the axial wall.

Each test autoradiograph was compared to the set of standards and scored according to the extent of leakage using the following criterion: If the leakage was no more severe than that depicted in autoradiograph 3 but was greater than that in autoradiograph 2, the specimen was assigned a value of 3. Notations also were made with respect to the site of the leakage, gingival and/or occlusal. Autoradiographs were scored by each of three individuals working independently, with each individual evaluating the autoradiographs on three separate occasions.

Statistical Analysis

The intra- and interexaminer agreement with respect to ranking of the marginal leakage as depicted by the autoradiographs was determined by applying the Pearson *r* test. Since there were no significant differences in either the intra- or interevaluator agreement, the data were combined. Ridit analysis and analysis of variance were performed on the data. The Newman-Keuls test was employed for multiple comparison of the test groups.

Scanning Electron Microscopy Examination

The marginal adaptation of the restorations was examined by scanning electron microscopy of replicated sections of selected restorations. Three specimens with varying degrees of leakage were selected from each group for the SEM examinations.

RESULTS

Preliminary Test of Effect of Etching

The data obtained with respect to the thickness of cement liner removed by application of a 37% phosphoric acid for various time periods are presented in Figure 4. Cross sections of disks of Ketac Bond and G-C Liner treated with the acid for 10, 30, and 60 seconds are shown in Figure 5. The superficial layer of Ketac Bond appears to be more vulnerable to attack by the acid than does the G-C Liner in that the 10-second etch resulted in removal of a 12 μm layer of Ketac Bond and only a 3 μm layer of the G-C Liner. However, once this superficial layer was removed, the rate at which both cements were attacked appears to be about the same. The surface morphology of specimens etched for

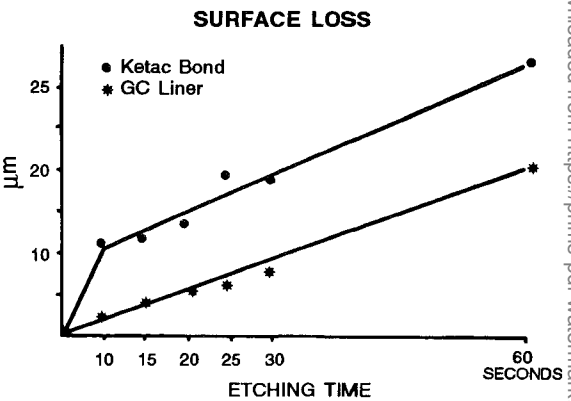

Figure 4. *Surface loss of Ketac Bond and G-C Liner cement surfaces as related to time of etching with 37% phosphoric acid*

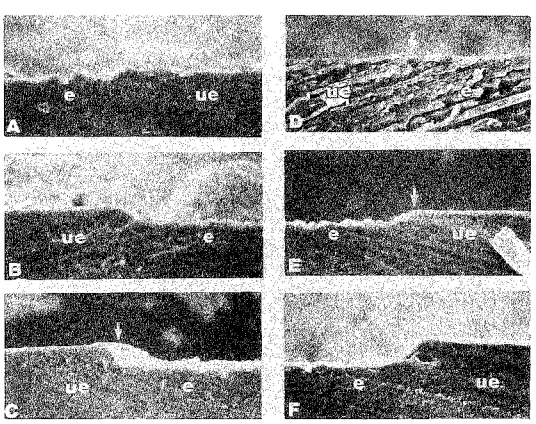

Figure 5. *Etched cement liners, cross-sectional views. Replicas X200. A is a 10-, B a 30-, and C a 60-second etch of Ketac Bond. D is a 10-, E a 30-, and F a 60-second etch of G-C Liner.*

10, 30, and 60 seconds appears in Figure 6. The Ketac Bond specimens reveal fairly uniform etching of the surface. The surface roughness with 10- to 30-second etching appears to be similar, but examination of specimens etched for 60 seconds indicated a more severe attack of the matrix. It was on the basis of this data that the 20-second etching time was selected for use in the leakage study.

With respect to G-C liner specimens, a 10-second etch did not produce a uniformly etched surface. However, etch times of 20 to 60 seconds did result in uniform etching with no detectable differences in surface morphology with increased etch time. More voids were noted in G-C Liner specimens than in Ketac Bond specimens.

The surface morphology of specimens that were patted into the mold but unetched are shown in Figure 7. The surfaces of these specimens were relatively rough. Again voids were apparent in G-C specimens.

Marginal Leakage

The data obtained in leakage tests for the restored erosion lesions along with the summary of the statistical analysis of that data are represented in Table 1. The data obtained with respect to class 5 preparations are summarized in Table 2.

Effect of Liner Thickness

The data indicate a difference in the leakage of erosion lesion restorations that favor the thick liner. The thicker liners, when etched, were superior to etched thin liners in reducing marginal leakage. Although the difference in ridit values between the unetched liner groups was not significant, there were fewer specimens with no leakage in the thinly lined group.

In the case of the class 5 preparations, no significant difference in marginal leakage was observed between restorations with thick and thin liners (Table 2).

Effect of Etching the Liner

There were no significant differences in marginal leakage in erosion lesion restorations between etched and unetched groups (Table 1). The same was true for class 5 preparations (Table 2).

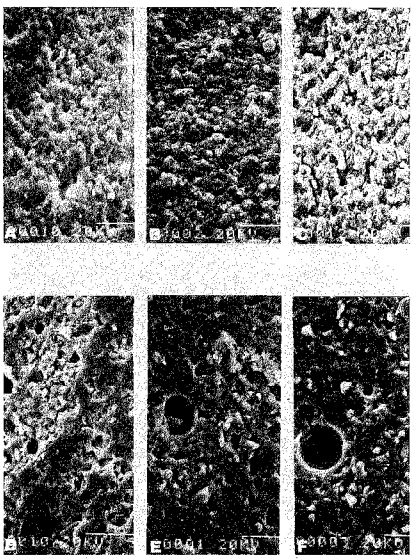

Figure 6. *Etched surfaces of cement liners: A is a 10-, B a 30-, and C a 60-second etch of Ketac Bond; D is a 10-, E a 30-, and F a 60-second etch of G-C Liner.*

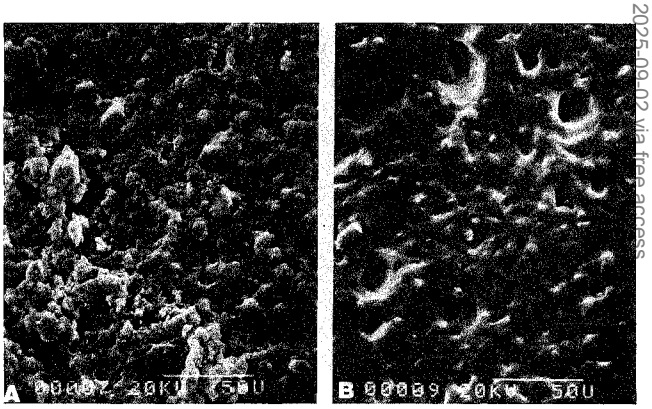

Figure 7. *Scanning electron micrograph of unetched glass-ionomer liners. A is Ketac Bond, B is G-C Liner. Replicas X250.*

Table 1. Erosion Lesions: Microleakage Distribution, Ridit Means, and Standard Deviations

Group	Leakage Categories 1	2	3	4	N	Ridit Mean	SD
C—thick liner, etched	8	3	0	0	11	0.34	0.185
D—thick liner, unetched	7	2	1	0	10	0.37	0.237
B—thin liner, unetched	4	4	0	2	10	0.54	0.293
A—thin liner, etched	1	5	5	1	12	0.72	0.200

Ridit values: 1 = 0.23; 2 = 0.63; 3 = 0.86; 4 = 0.97.
Products connected by vertical lines are not significantly different at 0.05 probability level.

Table 2. Class 5 Preparations: Microleakage Distribution, Ridit Means, and Standard Deviations

Group	Leakage Categories 1	2	3	4	N	Ridit Mean	SD
F—thin liner, unetched	4	6	0	0	10	0.41	0.197
E—thin liner, etched	5	2	2	1	10	0.47	0.338
H—thick liner, unetched	4	3	3	0	10	0.50	0.304
G—thick liner, etched	2	6	4	0	12	0.60	0.244

Ridit values: 1 = 0.18; 2 = 0.56; 3 = 0.87; 4 = 0.98.
Products connected by vertical lines are not significantly different at 0.05 probability level.

Table 3. Location of Marginal Leakage

Erosion Lesion Groups	Location G	O	GO	N
A—thin liner, etched	7	0	4	12
B—thin liner, unetched	4	0	2	10
C—thick liner, etched	1	2	0	11
D—thick liner, unetched	2	0	1	10
Class 5 Preparation Groups				
E—thin liner, etched	2	2	1	10
F—thin liner, unetched	4	1	1	10
G—thick liner, etched	8	0	2	12
H—thick liner, unetched	3	2	1	10

G = gingival margin
O = occlusal margin
GO = occlusal and gingival margin

The sites of marginal leakage are listed in Table 3. By far, the most common site of isotope penetration was at the gingival margin, but penetration at the occlusal margin also occurred in some instances.

Penetration between the liner and resin was observed in the thickly lined restorations in both erosion and class 5 restorations. This was particularly true in etched class 5 restorations, where eight out of 12 specimens exhibited isotope penetration at the cement-resin interface.

Scanning Microscopy

In the erosion lesion restorations, all the specimens in Group A showed a gap between the dentin and resin, where the dentin was not completely covered by the liner.

This was the only type of adaptation defect

detected in this group. Figures 8a and b are micrographs of one replica from Group B (thin liner, unetched). It was noted that two out of three specimens showed a major gap between the liner and resin, particularly at the most pulpal portion of the restoration. However, gaps at the margin were not detected. A third specimen was intact. Figure 8b is a high magnification of the area in the square in Figure 8a. The smooth edge of the resin and cement liner at the gap is apparent.

The micrographs in Figures 8c and d are of one specimen from Group C (thick liner, etched). This specimen exhibited only minor gaps between the composite resin and dentin. The micrograph in Figure 8d is a higher magnification of an area in Figure 8c, depicting a tight junction between dentin and liner.

One specimen in Group D (thick liner, unetched) exhibited a gap along the entire interface between the dentin and glass-ionomer liner. A second specimen had a gap at the liner-resin interface and the third a gap between the dentin and the resin.

In the case of class 5 restorations, the pattern is somewhat different. One specimen in Group E (thin liner, etched) exhibited a close adaptation in all areas, while another specimen showed a separation at the axiogingival line angle. The third specimen, Figure 9a, shows a large gap along the entire length of the liner resin interface. The micrograph in Figure 9b is a higher magnification of the same area. There were only minor to moderate gaps between liner and resin in the specimens of Group F (thin liner, unetched). Figures 9c and d are micrographs of restorations in Group G (thick liner, etched). Large discrepancies along the gingival margin and the liner-resin interface were noted in two of the three specimens. Note in the high magnification micrographs (9b and d) the roughness of the edges of the resin and the cement liner. The fracture has occurred in the cement rather than at the interface. Figures 10a and b are another specimen in Group G. Figures 10c and d show micrographs of one specimen in Group H (thick liner, unetched). Note in Figure 10b that the gap is not entirely between the tooth and the liner, but it also occurred in the liner itself.

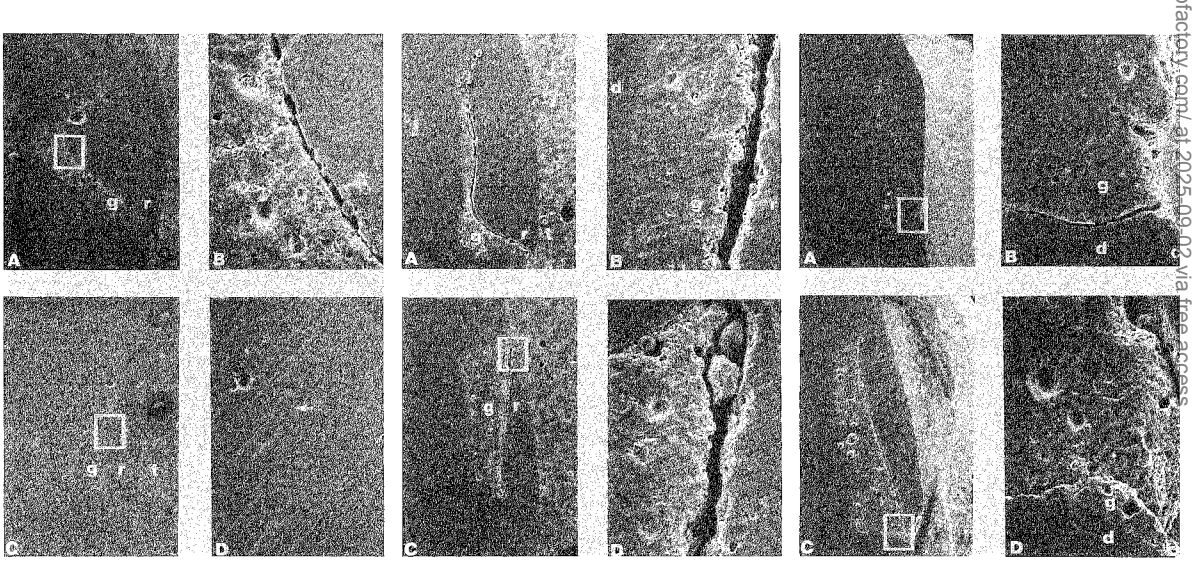

Figure 8. *Scanning electron micrograph of replicas of sectioned restorations: Group B (micrographs A, B) and Group C (micrographs C, D). Replicas X12.5 and X125.*

Figure 9. *Scanning electron micrographs of replicas of sectioned restorations: Group E (micrographs A, B) and Group G (micrographs C,D). Replicas X12.5 and X125.*

Figure 10. *Scanning electron micrograph of replicas of sectioned class 5 restorations from Group H. Magnification X12.5 and X125. e = enamel; d = dentin; g = glass-ionomer liner; r = composite resin; c = cementum.*

DISCUSSION

Preliminary Study of Etching of Cement Liner

The original recommendation (McLean & others, 1985) of etching the glass-ionomer liner for a full 60 seconds has been questioned. Earlier morphological and bond-strength studies have indicated that a 30-second etch period is sufficient (Smith, 1986; Quiroz & Lentz, 1987). It has been suggested that an even shorter period of 10 seconds would be preferable to prevent acid dissolution of the liner. The results obtained here indicated that an etching period of 10 seconds does not produce a uniformly rough surface. With one liner, a 60-second etching period appeared to be too destructive. The more rapid attack of the Ketac Bond as compared to the G-C Liner was somewhat surprising in that Ketac Bond appears to set faster. The more rapid dissolution of the Ketac Bond may have been due to formation of a matrix-rich surface layer against the cover glass.

Since a 30-second etch procedure with 37% phosphoric acid resulted in only an 8 μm loss of G-C Liner and an 18 μm loss for Ketac Bond, it appears doubtful that the etching procedure would lead to the loss of liner and subsequent exposure to the dentin. However, many voids both large and small were observed in the sectioned restorations. These voids could increase the chance for acid penetration into the dentin.

Marginal Leakage

Previous in vitro studies on the glass-ionomer-lined composite restoration in cervical lesions have all shown some marginal leakage as measured by isotope and silver nitrate penetration (Gordon & others, 1985; Roulet & Rosansky, 1986; Crim & Shay, 1987). The marginal leakage seen in this study was slightly higher than in some of the studies, since many specimens were ranked in categories 2 and 3. The discrepancies seen are probably not due to differences in testing methodology. Earlier investigators found little difference when comparing various methods (Crim, Swartz & Phillips, 1985). The amount of thermostressing in the present investigation was greater than in some other studies, and this could account for some of the reported differences. Crim and García-Godoy (1987) studied the effect of storage time and number of cycles on marginal leakage in class 5 preparations and found the number of cycles to be of little importance, but there was a difference with immediate and delayed thermocycling. The marginal leakage may be overestimated to some extent by the fact that the glass ionomer tends to absorb the isotope. It is possible that in some instances category 2 leakage was the result of absorption of the isotope by the cement liner. Generally the best adaptation was found in erosion lesion restorations when a thick cement liner was used. No significant difference was noted in the marginal leakage between the etched and unetched groups with both types of restorations. However, in three out of four groups, the etched specimens showed greater mean ridit values than the unetched specimens, indicating that etching may not be an advantage and possibly a detriment. Krejci, Lutz and Zwicky (1987), in their study of glass-ionomer-lined posterior composite restorations, found that the marginal leakage was greater when the liner was etched than when it was not. None of the unetched restorations was lost during finishing or thermocycling.

Scanning Electron Microscopy

SEM evaluation indicated that the first interface to fail during the stress of polymerization and/or thermocycling was that between the uncovered dentin and Scotchbond and composite resin. Hinoura, Moore, and Phillips (1986) determined the bond strength of Scotchbond and Silux to dentin after polycarboxylate pretreatment and found this to be 6 Kg/cm², while the bond strength between Silux and Scotchbond and the etched liner was in the order of 45 Kg/cm². That the gap developed at the deepest portion of the erosion lesion is not surprising, because this area is furthest away from the surface where the polymerization is initiated in a light-cured composite resin, hence the most vulnerable to polymerization shrinkage. The degree of marginal leakage did not always correlate

with the size of gap observed under SEM. Many of the specimens that had a large gap in the most axial portion of the restorations showed intact margins. Kemp-Scholte and Davidson (1988) have made similar observations. In the class 5 preparations the bulk of resin is towards the occlusal. As would be expected, the gaps in this type of preparation were primarily at the gingival margin or along the axial wall starting at the gingiva. Since the adhesion of the resin to enamel is superior to that of dentin, the material shrinks in an incisal direction, and the gap is formed at the gingival margin. As noted in earlier studies (Sneed & Cooper, 1985; García-Godoy & Malone, 1986), the cohesive strength of the cement is less than the adhesive strength between the liner and resin. The fracture in the cement creates a very ragged interface that can probably not be closed during water sorption. The fact that the gap was common in the etched as compared to the unetched specimens in thick lined class 5 restorations suggests a damaging effect of the acid on the cement, rendering it more susceptible to fracture.

CONCLUSIONS

Under the present experimental conditions the following conclusions can be drawn:

1. Scanning electron microscopy evaluation of the etched glass ionomers (Ketac Bond and G-C Liner) indicated that a 10-second etch is not satisfactory for a uniform etching pattern, and 60 seconds appear to be too destructive. The optimum time from a morphological point of view appeared to be between 15 to 30 seconds.
2. A minimal amount of glass-ionomer cement is lost during etching. The optimum times mentioned above would lead to a 4 μm loss of a G-C Liner cement surface, and the same figures for Ketac Bond are 12 to 18 μm.
3. A thick etched glass-ionomer liner appears to be significantly better in reducing marginal leakage, as compared to a thin etched liner in erosion lesions.
4. There is no significant difference seen in the marginal leakage between a restoration where the glass-ionomer liner is etched and one where it is not.
5. The marginal leakage of the glass-ionomer-lined composite resin restoration of erosion lesions and class 5 preparations in vitro is fairly substantial, with many specimens showing category 2 and 3 leakage and few category 4.
6. A gap is often formed between the glass-ionomer liner and the composite resin. Etching of the liner appears to aggravate this phenomenon. The gap in the erosion restorations is usually at the deepest point pulpally away from the margin. In the class 5 restorations the gap was along the axial wall of the liner.
7. In the class 5 restorations a marginal discrepancy was often observed at the gingival margin. This gap often started as a fracture in the liner and continued along the liner cavity interface.

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A Survey of the Accuracy of References in 10 Dental Journals

D B NUCKLES • N N POPE • J D ADAMS

SUMMARY

Several studies have evaluated the accuracy of bibliographic citations in the medical literature. The purpose of this study was to evaluate the accuracy of 300 reference citations in 10 dental journals. Thirty references were randomly selected from the January 1991 issue of 10 dental journals, for a total of 300 reference citations. Almost all of the citations were verified from the original source; a few were identified from other library sources. Only two references were unable to be identified, and they were both from foreign journals. This survey found 78% (n = 234) of the citations verified (n = 298) to be correct.

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INTRODUCTION

The accuracy of journal article references should be of significance to all authors, as well as to the numerous readers of the articles. One assumes that such references are correct; that is to say that one can always find the original article from each reference cited. The subject of journal reference accuracy has received little interest in the literature, as evidenced by the relatively short bibliography of this paper, which includes bibliographic citations in medical journals and one in a dental journal. Those who read the published word have the right to expect accuracy in what is published, just as those who publish have the responsibility to be accurate.

The question which led to this evaluation was a concern for the accuracy of references

in dental journals. Perhaps the first real question to be answered is, "Who should be responsible for the accuracy of the references?" The obvious answer, of course, is the author(s). But what about the editor? Should she/he be held responsible for checking each reference for accuracy?

A study of citations in major medical journals found that 29% were erroneous on direct check of the original source. This study of articles published in 1975 found 634 of 2195 references to be erroneous (Goodrich & Roland, 1977). In evaluating a single medical journal over a 13-month period, another study found a 54% rate of incorrect citations and 6% unverified citations from 1867 references (Key & Roland, 1977). Another study, involving two medical journals, showed one to have a 13.6% error rate for verified references, but also found that 23% of 487 citations could not even be traced (Boyce & Banning, 1979). Another study of six medical journals found a 24% error rate in citations, of which 8% were major errors (de Lacey, Record & Wade, 1985). A survey of three public health journals found an error rate of 31% out of 150 references. One out of 10 errors was a major error, such as not being able to locate the journal (Eichorn & Yankauer, 1987).

In a survey of five dental journals Doms (1989) reported that 42% of the 500 references he reviewed had inaccuracies. The citations were divided into correct and incorrect. The number of incorrect references was counted, then subdivided into major and minor errors. Errors were grouped by type: author, article title, citation (including errors in journal title, volume, issue, and page number, and Unable to Verify). There were 173 minor errors and 75 major errors. There were 86 title errors, 61 minor author errors, and 26 minor citation errors. Major errors included 32 incorrect journal citations, 25 Unable to Verify, and 10 incorrect authors, and 8 incorrect article titles.

Evans, Nadjari and Burchell (1990) evaluated the accuracy of references in three surgery journals in 1990. This study evaluated the accuracy of 50 randomly selected references in three surgery journals from a single monthly issue. Thirteen major and 41 minor citation errors were found in the three journals. Thirty-seven major quotation errors were identified.

The purpose of this article is to examine references from articles in 10 professional dental journals published in January 1991, checking for both major and minor errors in all aspects of the original journal citations.

METHODS AND MATERIALS

The purpose of this study was to assess the accuracy of bibliographic references in selected dental journals. Thirty references were selected at random in each of 10 dental journals to total 300 references. All of the references were verified from one of the following sources: the original source, the *Index to Dental Literature*, *Index Medicus*, and *Science Citation Index*.

The January 1991 issue of each of the following 10 dental journals was examined: *American Journal of Orthodontics* (AJO), *British Dental Journal* (BDJ), *Dental Materials* (DM), *Journal of the Canadian Dental Association* (CDAJ), *Journal of Clinical Pathology* (JCP), *Journal of Dental Research* (JDR), *Journal of Endodontics* (JE), *Journal of Prosthetic Dentistry* (JPD), *Operative Dentistry* (OD), and *Quintessence International* (QI).

The references were divided into two groups: correct (no citation errors) and incorrect. Correct references were identified as being identical to the source. Incorrect references were those that differed from the source document.

Errors within the incorrect reference group included the names and/or the initials of authors, article title, journal title, volume number, year of publication, page numbers, punctuation, spelling, and citations that were unable to be verified. The number of errors within the incorrect references group was counted and divided into two groups: minor errors and major errors.

Minor errors included minor omissions that did not prevent locating the article, such as paraphrased or incomplete article titles, incorrect author initials, or an error in the page numbers of an article.

Major errors were references that prevented locating the article cited immediately, such as incorrect journal titles, article titles, author, and citations including wrong volume, issue, year, and first page number. References that

could not be located by any of the sources used were marked "Unable to Verify" and placed in the major error group.

Each category, major or minor, was subdivided by type. Errors within an incorrect reference were counted by type of error: author, article title, citation, and Unable to Verify. A reference with a minor author error and a minor citation error counted as two minor errors; a reference with a major author and a minor article error counted as one major error and one minor error. Any reference that could not be verified counted as one major error. References with more than one error within a type of error counted as one error.

RESULTS

Of the 300 citations selected, 298 (99%) were verified, 289 (96%) in the original source and nine (3%) in other sources. Only two (1%) were not verified. Those verified reliably in the original source may be divided into 225 (75%) correct and 64 (21%) incorrect citations. There were nine (3%) citations that were verified as correct in other sources, including *Index Medicus* and *Science Citation Index*. These data are shown in Table 1. The total number of verified correct citations in this study was 234 (78%).

Table 2 shows the 64 (21%) incorrect or unverified citations ranging from two to 10 of the 30 references checked for each journal. Tables 3, 4, and 5 concentrate on the number and type of errors found in the incorrect or unverified citations. There were 31 minor errors, ranging from one to nine per journal, and 38 major errors, ranging from one to nine per journal. The total number of errors ranged from two to 12 per journal.

Sixteen errors of authors were found, ranging from zero to four per journal; these were almost half of all minor errors. There were six errors in article titles; four journals had these errors. The nine minor citation errors were found in four different journals.

No incorrect authors were found in verified citations. These may occur in the unverified references. Twenty-three of the 37 major errors were found in article titles, with one journal having as many as six. Eleven citations had minor inaccuracies, ranging up to three in each journal. Just two unverified references were shared by two journals.

DISCUSSION

The data support the hypothesis that authors do not check their references or may not even read them. The hypothesis may be expanded to maintain that reviewers do not check references.

Table 1. Frequency of Correct and Incorrect References Verified in the Original Source and Other Sources

	Original Source		Other Sources		Unable to Verify
	Correct	Incorrect	Correct	Incorrect	
	N	N	N	N	N
AJO	25	5	0	0	0
BDJ	21	8	1	0	0
CDAJ	23	6	1	0	0
DM	25	5	0	0	0
JCP	19	6	4	0	1
JDR	25	4	0	0	1
JE	21	8	1	0	0
JPD	18	10	2	0	0
OD	28	2	0	0	0
QI	20	10	0	0	0
Total	225	64	9	0	2

Based on 30 randomly selected references verified for each journal, January 1991

Table 2. Frequency of Incorrect and Unverifiable References of 10 National Dental Journals

	Incorrect References
	N
AJO	5
BDJ	8
CDAJ	6
DM	5
JCP	6
JDR	4
JE	8
JPD	10
OD	2
QI	10
Total	64

Based on 30 randomly selected references verified for each journal, January 1991

Table 3. Frequency of Minor and Major Errors in Incorrect References of 10 National Dental Journals

	Minor	Major	Total Errors
	N	N	N
AJO	4	1	5
BDJ	3	6	9
CDAJ	1	6	7
DM	2	3	5
JCP	2	4	6
JDR	3	1	4
JE	2	6	8
JPD	4	7	11
OD	1	1	2
QI	9	3	12
Total	31	38	69

Based on 30 randomly selected references verified for each journal, January 1991

Table 4. Frequency of Minor Errors among 10 National Dental Journals

	Minor Author Error	Minor Article Title Error	Minor Citation Error
	N	N	N
AJO	2	2	0
BDJ	3	0	0
CDAJ	1	0	0
DM	2	0	0
JCP	1	1	0
JDR	0	0	3
JE	1	1	0
JPD	2	2	0
OD	0	0	1
QI	4	0	5
Total	16	6	9

Based on 30 randomly selected references verified for each journal, January 1991

This study demonstrates a greater percentage of verified journal citations (99%) than any similar study found. The results of this study find a lower percentage of errors (21%) in the verification of dental journal citations as compared to other similar studies. There were fewer minor errors and fewer major errors using the same search methods. It is possible that

Table 5. Frequency of Major Errors among 10 National Dental Journals

	Incorrect Author	Incorrect Article Title	Incorrect Citation	Unable to Verify
	N	N	N	N
AJO	0	1	0	0
BDJ	0	6	0	0
CDAJ	0	5	1	0
DM	0	2	1	0
JCP	0	2	2	1
JDR	0	1	0	1
JE	0	2	4	0
JPD	0	4	3	0
OD	0	0	1	0
QI	0	2	1	0
Total	0	25	13	2

Based on 30 randomly selected references verified for each journal, January 1991

this reflects greater care on the part of both authors and editors in striving for accuracy in journal references.

The role of the editor in publishing professional journals is complex: receiving, reviewing, editing, and returning manuscripts, making decisions based on what reviewers think of submitted manuscripts, answering correspondence, and generally doing the myriad things necessary to publish the journal on a regular and timely basis. Some, though not all, editors, reviewers, and editorial boards are paid for their work. Authors should be responsible for accurate references, or should revise them, or should be refused publication. If authors cannot be depended upon, then the reviewers or the editor must be responsible. Creation and perpetuation of inaccurate citations makes the retrieval of information difficult if not impossible for the readers and/or librarians who assist them.

Coincidentally, shortly after the data for this paper were complete, the senior author was locating information for a subsequent project. In glancing over the references for a certain article he found his own name mispelled (Newman, 1991)!

CONCLUSIONS

Although there is a very high citation verification rate of 99% (n = 298) in this study, there was also a significantly high number of incorrect citations (n = 64; 21%) out of the 298 references that were verified. There was a high of 10 incorrect references in two different journals. This indicates that authors should devote greater effort to the verification of quoted references and should also be more careful in preparing bibliographies for submitted works. Editors of journals cannot be expected to verify all citations of submitted manuscripts. Authors must also assume the responsibility for checking references again in the galley proof.

Acknowledgment

The authors express their appreciation to Ms Diane Nuckles for her editorial assistance.

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The Effect of Cervical Grooves on the Contraction Gap in Class 2 Composites

P COLI • M BLIXT • M BRÄNNSTRÖM

Clinical Relevance
Properly placed cervical grooves may help class 2 composite restorations.

SUMMARY

The extent and the width of the cervical contraction gap in class 2 composite resin restorations were examined using a fluorescent resin-penetrating technique. In all restorations Scotchbond 2 bonding system and P-50 were used. The cervical wall was prepared either with no groove or with one or two grooves. The results indicated that the extent of the contraction gap was reduced when two retention grooves were prepared. The difference between no groove and two grooves was statistically significant. The width of the gap was also reduced, but not with statistical significance.

A statistical difference was also found when one retention groove was compared with no groove.

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INTRODUCTION

It has been suggested that retention grooves at the cervical wall of class 2 composite restorations may reduce the cervical gap and leakage (Ben-Amar & others, 1988). Such grooves may also reduce the risk of fracture of the filling and increase the cervical surface, minimizing the effect of stress (thermal and mechanical trauma) that may result in creep and flow. In addition, such grooves in combination with lateral grooves and etched, bevelled enamel may offer more acceptable retention of the composite. In this way the central bulk of dentin in premolars and molars may be preserved and the risk of

cusp fractures reduced.

The purpose of the present study was to compare the extent and width of the cervical gap in class 2 restorations in cavities with and without retention grooves using a fluorescent resin-impregnation technique.

METHODS AND MATERIALS

The material comprised intact premolar teeth stored frozen in which 60 class 2 cavities were prepared. The approximal box was about 4 mm wide and 1.5 - 2 mm deep. The cervical wall was located at the cemento-enamel junction. The cavity was prepared with a fissure bur at high speed under water coolant. A small round bur at low speed was used to cut retention grooves on the lateral walls. The teeth were then divided in three groups, with 20 cavities in each group: Group 1, with no retention grooves at the cervical wall; Group 2, with one retention groove made with a small round bur at low speed under water coolant; and Group 3, with two retention grooves (Figure 1) prepared with a special notched chisel (Dental Therapeutics AB, Nacka, Sweden). In all cavities the enamel on the lateral and occlusal walls was bevelled with a diamond point at low speed and etched for 15 seconds with an acid gel, followed by 10 seconds of water rinsing and then 10 seconds of air-jet drying. The light-cured resin-bonded ceramic P-50 (3M Dental Products, St Paul, MN 55144) in combination with the adhesive system Scotchbond 2 was used for all the groups. The whole cavity was filled with Scotchprep Primer for 60 seconds; this was then removed with a 15-second air blast.

To facilitate the removal of excess composite, a polystyrene liner (Tubulitec, Dental Therapeutics AB) was applied to the surface outside the cavity. Scotchbond 2 was applied in a thin layer and light cured for 20 seconds. A plastic matrix strip was used on the approximal surface. P-50 was applied in bulk and light cured from the cervical region for 40 seconds and then from the occlusal wall for 80 seconds. Excess composite was removed with a hand instrument. In order to disclose possible lack of bonding (the presence and location as well as the width and extent of a contraction gap), the following method was used as described previously (Brännström, Torstenson & Nordenvall, 1984; Torstenson & Brännström, 1988a & b): three minutes after the beginning of light curing, a drop of Enamel Bond Resin (3M Dental Products) containing a fluorescent dye (hereafter called FEB) was applied at the cervical margin. This allowed aspiration of the resin by capillary action into any air-filled contraction gap.

The teeth were ground longitudinally from lingual to buccal, perpendicular to the restorations. The surface was polished under water cooling.

Each tooth was examined and microphotographed at two or three levels with reflected UV light at a magnification up to X210. The gap width of each group was determined by calculating the mean of the smallest and the greatest width measured.

The extent of each gap was scored from 0 to 3: 0 for no gap, 1 for penetration to the middle of the cervical wall, 2 for penetration to the angle between the cervical and axial

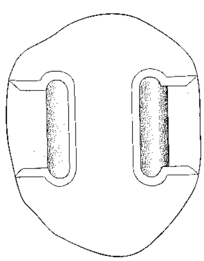

Figure 1a. *Occlusal view of the grooves on the lateral walls*

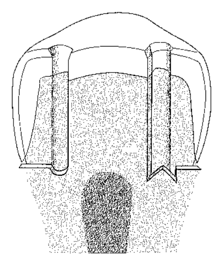

Figure 1b. *Cavity with one and two retention grooves at the cervical wall*

wall, and 3 for penetration not only along the cervical wall but also in the axial wall (table).

RESULTS

One restoration in Group 1 and two restorations in Groups 2 and 3 were excluded because excess composite prevented the penetration of FEB.

Group 1: No Retention Grooves, 19 Restorations

In 11 out of 19 restorations FEB had penetrated to the axial wall (Figure 2), in three it had penetrated to the inner angle (score 2), and in three it had penetrated to the middle of the cervical wall. No penetration could be observed in two restorations in this group (table). The width of the gap varied from 0 to 14 microns, mean 7.3.

Group 2: One Retention Groove, 18 Restorations

In three out of 18 restorations FEB was present at the axial wall, in nine it had penetrated to the inner corner, in five it had penetrated to the middle part of the cervical wall; only one restoration was gap-free (table). The width of the gap varied from 0 to 14 microns, mean 8.4.

Group 3: Two Retention Grooves, 18 Restorations

In two out of 18 restorations FEB was present at the axial wall, in three it had

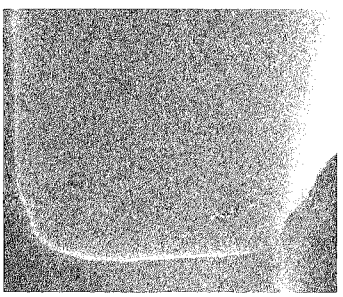

Figure 2a. *Along the cervical and axial walls*

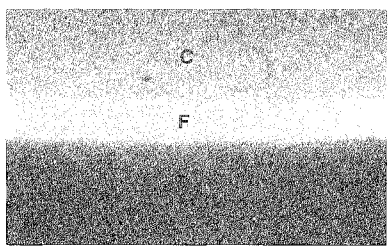

Figure 2b. *Detail: the width of the gap is 12 microns.*

Figure 2. *Restoration from Group 1; penetration of FEB. C = composite; D = dentin; F = Fluorescent Enamel Bond.*

Gap Extension

	SCORE					
Group	**0**	**1**	**2**	**3**	**Total**	**Excluded**
No retention groove	2	3	3	11	19	1
%	10.5	15.8	15.8	57.9		
One retention groove	1	5	9	3	18	2
%	5.6	27.8	50.0	16.7		
Two retention grooves	4	9	3	2	18	2
%	22.2	50.0	16.7	11.1		

Score 0 = No penetration.
Score 1 = Penetration to the middle of the cervical wall.
Score 2 = Penetration to the angle between the cervical and the axial wall.
Score 3 = Penetration along the axial wall.

penetrated to the inner corner, in nine it had penetrated to the middle part of the cervical wall (Figure 3), and four restorations were gap-free (table). The width of the gap varied from 0 to 18 microns, mean 5.8.

A one-way analysis of variance of the gap width showed that the difference between the groups was not statistically significant ($F = 2.65$; $P = 0.0805$).

Regarding the contraction gap extension, the chi-square test indicated a statistical difference between Groups 2 and 3 compared to Group 1 for scores 0, 1, and 2 versus score 3 (chi-square = 11.67; $P = 0.004$) and a statistical difference between Group 3 and Group 2 for score 0 - 1 versus score 2 (chi-square = 6.7; $P = 0.004$).

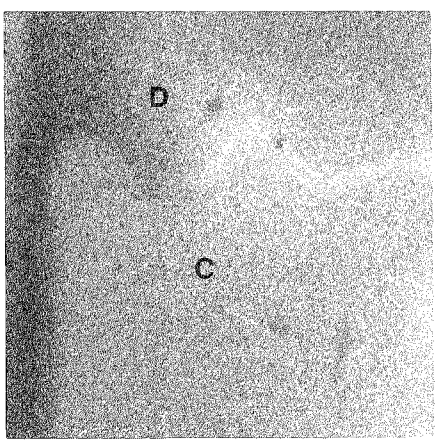

Figure 3a. *FEB penetration to the middle of the cervical wall*

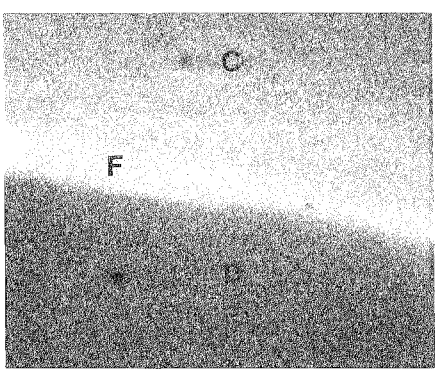

Figure 3b. *Detail: the width of the gap varies from 6 to 10 microns.*

Figure 3. *Restoration from Group 3. C = composite; D = dentin; F = Fluorescent Enamel Bond.*

CONCLUSIONS

The results of this in vitro study indicate that the presence of two retention grooves at the cervical wall, made by a notched chisel, may reduce the extent of a contraction gap for resins such as P-50.

Some reduction in gap width may also occur. The reduction of the extension of the gap may be due to counteraction of polymerization shrinkage when the composite is locked at the retention grooves, where initial light curing occurs.

Thus, the composite may not be as readily detached from the axial wall. The use of one retention groove also reduced the length of the contraction gap, but not as much as two retention grooves did. The risk of pulpal exposure during preparation of retention grooves was minimal when a notched chisel was used; use of the bur occasionally resulted in a pulpal exposure. Further laboratory and in vivo experiments are necessary to determine whether the presence of retention grooves reduces the effect of mechanical and thermal stress and the development of creep and flow.

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Effect of Rinse Time on Microleakage between Composite and Etched Enamel

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F B DUTTON • J O BURGESS

Clinical Relevance
Reduced rinsing times are effective.

SUMMARY

This study compared microleakage of composite bonded to etched flattened enamel in seven groups of five extracted maxillary molars. The facial enamel of the molars was ground flat and etched for 20 seconds with 37% phosphoric acid gel. In one group, etching gel was not rinsed but dried only. In four groups, gel was rinsed with an air/water spray for varying amounts of time. In the other two groups, gel was rinsed with water only for two different amounts of time. Etched surfaces were dried, and a liquid resin was applied and polymerized; a button of composite resin was polymerized to the flattened surface. Specimens were thermocycled, stained, then sectioned longitudinally. Microleakage was measured at the occlusal and gingival enamel margins and expressed as a percentage of the total length of interface. A mean (SD) percentage microleakage was determined at the occlusal and at the gingival margins for each group as follows: no rinse—89.60 (14.34); one second—water 0 (0), air/water 0 (0); three seconds—water 0.98 (1.34), air/water 0 (0); five seconds—air/water 0 (0); 20 seconds—air/water 0 (0). Because of abnormal distribution, data were analyzed using Wilcoxon two-sample tests. The no-rinse group had significantly more microleakage than any of the other groups ($P = 0.0067$),which were not significantly different from each other ($P = 0.18$). A one-second rinse with either water or air/water spray was as effective as a 20-second rinse with air/water spray in preventing microleakage at the resin-enamel interface.

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INTRODUCTION

Two recent studies (Mixson & others, 1989; Summitt & others, 1992) evaluated the effect of reduced rinse time on the shear bond strength of composite resin bonded to etched enamel. These studies reported a greatly decreased shear bond strength when a phosphoric acid etching gel was not rinsed from etched enamel, compared to the bond strength of etched enamel that had been rinsed, even very briefly. Mixson and others (1989) concluded that a two- to five-second rinse per tooth surface should sufficiently cleanse gel-etched enamel. Summitt and others (1992) found a one-second water or air/water rinse was as effective as a 20-second water or air/water rinse in producing an enamel surface that would bond to resin with a high shear bond strength.

Although the effect of reduced rinse time on shear bond strength has been investigated, and very short rinse times produce optimum bond strengths, the microleakage obtained with a reduced rinse time has not previously been investigated.The purpose of this study was to determine the minimum effective rinse time, with water or air/water spray, for minimum microleakage at the resin-to-enamel interface when composite resin is bonded to etched enamel.

METHODS AND MATERIALS

Thirty-five extracted maxillary molar teeth were collected and were divided into seven groups of five teeth each. The facial enamel of each molar was flattened and polished with 320-grit disks on a polisher/grinder (Polimet Polisher, Buehler, Ltd, Evanston, IL 60204). Enamel was etched for 20 seconds using a 37% phosphoric acid gel (Tooth Conditioner Gel, L D Caulk, Milford, DE 19963-0359). Water or air/water rinsing was accomplished with a three-way syringe (A-dec, Inc, Newberg, OR 97132) as shown in Table 1. Water and air pressures were monitored using A-dec pressure gauges. After thorough drying of each specimen with air, a liquid resin (Universal Bond 3 Adhesive, L D Caulk) was painted onto the etched enamel surface and polymerized for 10 seconds with a visible light source (Optilux 400, Demetron Research Corp, Danbury, CT 06810). Performance of the visible light unit was monitored with a radiometer (Curing Radiometer, Demetron Research Corp). A round button of composite resin (Prisma APH, Universal Shade, L D Caulk) approximately 3 mm in diameter and 1-2 mm high, was applied to each specimen and polymerized for 30 seconds using the same visible light source (Figure 1). Polymerized resin adhesive on the

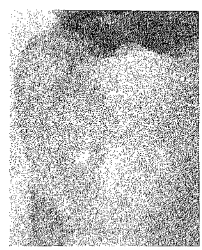

Figure 1. *Button of composite resin bonded to flattened and etched enamel on the facial surface of a maxillary molar*

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

Group	Rinse Duration	Mean (SD) Air Pressure (psi)	Mean (SD) Water Pressure (psi)	Mean (SD) Water Volume (ml)
1	No rinse	59.2 (0.8)	NA	NA
2a	1 second, water	NA	21.6 (0.6)	1.1 (0.2)
2b	1 second, air/water	58.2 (1.8)	24.8 (1.8)	1.0 (0)
3a	3 seconds, water	NA	24.0 (0)	4.4 (0.2)
3b	3 seconds, air/water	56.6 (0.6)	23.0 (1.0)	4.1 (0.2)
4	5 seconds, air/water	58.0 (3.7)	22.4 (2.2)	7.0 (0.4)
5	20 seconds, air/water	56.6 (1.3)	22.4 (0.5)	27.9 (1.1)

enamel peripheral to the composite resin button was polished away using Sof-Lex disks (3M Dental Products, St Paul, MN 55144-1000). The apical foramina of the molars were filled with wax, and each molar was painted with two coats of fingernail polish to the periphery of the flattened enamel. Throughout the study, specimens were stored in tap water at room temperature when not being prepared, thermocycled, or examined.

Specimens were thermocycled from 6 to 60 °C for 500 cycles with a 30-second dwell time. They were then stained according to the technique of Wu and Cobb (1981) and Wu and others (1983) by immersion in 50% silver nitrate aqueous solution for two hours in darkness, then rinsing for one minute to remove excess silver nitrate. The specimens were then immersed in photodeveloping solution (Kodak Microdol-X-developer, Eastman Kodak Co, Rochester, NY 14650) for six hours while exposed to fluorescent light.

Each specimen was sectioned once longitudinally with a microtome (Scientific Fabrication, Littleton, CO 80123) through the center of the resin button and its underlying enamel. Sections were examined with a measuring microscope (Gaertner Scientific Corp, Chicago, IL 60611) at a magnification of X30 by two examiners. Microleakage at the occlusal and gingival margins was measured to the nearest micron and expressed as a percentage of the total length of the interface (Figure 2). Interevaluator coefficient of correlation was 0.998.

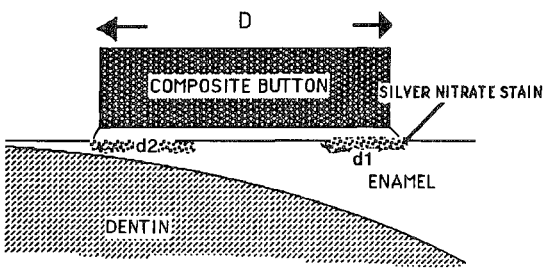

Figure 2. *Diagram of composite resin button bonded to enamel after staining and of method of calculating percentage penetration (microleakage). D = diameter of button; d1 = penetration of silver nitrate stain under resin at occlusal aspect of button; d2 = penetration under resin at gingival aspect of button.*

RESULTS

Because of abnormal distribution, data were analyzed using Wilcoxon two-sample tests. Results are summarized in Table 2. The group that was etched with the gel etchant simply dried on the enamel showed significantly more microleakage than the groups that were etched, rinsed, and dried prior to application of the composite resin. Microleakage in the groups that had been rinsed and dried were either zero or insignificant, and there was no difference in the microleakage between groups that were rinsed for one second, three seconds, five seconds, or 20 seconds. There was also no significant difference in microleakage between groups that were rinsed with air/water spray and those rinsed with water only.

DISCUSSION

An effective composite resin to etched enamel bond strength has been demonstrated with a short rinse of the gel etchant from an etched enamel surface (Mixson & others, 1989; Summitt & others, 1992). Microleakage and bond strength do not correlate; a material providing high bond strength may leak significantly. To determine the effect of a reduced rinse time on microleakage, this study was undertaken.

Although the results of this study and the two studies that dealt with bond strength do

Table 2. Mean Percentage of Microleakage for Each Group

Group	Rinse Duration	Mean (SD) Microleakage (%)
1	No rinse	89.6 (14.3)*
2a	1 second, water	0 (0)
2b	1 second, air/water	0 (0)
3a	3 seconds, water	0.98 (1.3)
3b	3 seconds, air/water	0 (0)
4	5 seconds, air/water	0 (0)
5	20 seconds, air/water	0 (0)

*Group 1 had significantly more microleakage (P = 0.0067) than the other groups. The other groups were not significantly different from each other.

not show conclusively that every type of phosphoric gel etchant or every concentration of etchant will be adequately removed with a short rinse, three different etching gels by three different manufacturers were used in the three studies; each study indicated that a very short rinse time (two to five seconds or one second) for an etched surface was adequate.

Although the briefest rinsing period of one second was effective in this study, it must be pointed out that only one surface was rinsed, and it was rinsed with a stream of water or air/water spray that was directed at approximately a 90° angle to the surface being rinsed. It might be wise to allow slightly more time in cavity preparations that have several walls that cannot be rinsed with a 90° stream of water.

CONCLUSIONS

1. Rinsing the gel etchant from a smooth, flat enamel surface for one second with a direct stream of water produced a resin-to-enamel seal that exhibited essentially no microleakage and was not significantly different from the seal produced by longer rinse times or by rinsing with an air/water spray.

2. One-second rinse times per tooth surface with either a stream of water or an air/water spray should adequately remove the etching gel from the etched enamel surface to provide adequate seal of resin to etched enamel.

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INDIANA DIRECT GOLD COURSE

The continuing education course in Direct Gold Technique is again being offered at Indiana University School of Dentistry in 1993. This course was originally designed to offer assistance in technique and materials involving gold foil and other direct golds as a restorative service. It was co-sponsored by the American Academy of Gold Foil Operators and the Academy of Operative Dentistry. Response last year was very positive, so the course will be held again on 1-4 June 1993. As in the past, there will be a Basic and an Advanced course. The Basic course is designed for those who wish to acquire a basic level of information, or as a refresher course, and the cost will again be $100, including everything except room and board. Patients and equipment are provided, as well as all materials. The Advanced course is primarily for those who have either taken the Basic course, or who feel comfortable with general technique and wish to improve their skills. The cost for the advanced course is $150.00. Anyone interested in enrolling should contact:

Dr Ronald K Harris
1121 W Michigan St
Indianapolis, IN 46202

Applications should be received by 15 March 1993. Space is limited, and applications will be considered in the order received.

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