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EDITORIAL

Independent Practice for Hygienists and Laboratory Technicians

Since World War II some dental laboratory technicians have wanted to be licensed to provide treatment to the public, including direct patient care for removable dentures. In addition we now have an increasing number of dental hygienists clamoring for independent practice. Numerous legislative bills have been introduced in an effort to allow hygienists and laboratory technicians to treat patients on their own, rather than as part of the health-care team.

I think it reasonable to assume that almost all dentists will state that they need these individuals as part of a team which, together, allows us to deliver a high quality of dental care. Almost universally, dentists will insist that these two groups not be permitted independent practice under any circumstances, with the exception of former-hygienists-turned-dentists. Many of that group would back independent practice for the hygienists.

We need to ask ourselves why. One reason, of course, is that it eliminates the "middleman," namely the dentist, and hygienists claim that the cost will be less if they are allowed independent practice.

Besides the economic factors, there is the fact that a large number of dentists have not fulfilled their doctor/patient relationship at a level required for quality care. Some hygienists are astounded by the type of care being delivered in many offices. They see patients with long-standing periodontal disease that the dentist has not diagnosed or treated. This is no small issue, as evidenced by the increasing numbers of malpractice suits and out-of-court settlements concerning the lack of periodontal diagnosis and treatment. Can we as members of the dental profession blame the hygienists for wanting independent practice, when they are well aware of so many dentists who are failing in their professional obligations?

The case for independent practice for laboratory technicians is yet another sad story. Many laboratory technicians tell me that they are continually sought out by dentists to answer questions about what they should be doing clinically for a patient or how to use the materials used in the clinical environment. Others tell of dentists sending the patient to them for procedures that could and should be done by the dentist. In a few isolated instances dentists have used laboratory technicians to make impressions, establish vertical dimension, and so on. If dentists want to rely on technicians for clinical expertise, then we should not be so alarmed about their desiring to go into practice for themselves.

I am certainly not supportive of independent practice for either hygienists or laboratory technicians. I feel they are an indispensable part of the dental-health-care team. However, their concerns are valid, and we must accept the responsibility for the problem and take steps to ensure that the profession corrects these deficiencies.

As a profession, we should see that all dentists are fully trained in the recognition and treatment of periodontal diseases and the proper use of the dental hygienist. Many dentists received little or no training in periodontal diseases before it became an established part of the dental-school-required curriculum. I hope the newer generation is being adequately trained. Organized dentistry should be responsible for spearheading this movement.

The laboratory technician problem is yet another one. Most dental schools do not teach students how to work with commercial laboratories, and those that do usually do not instruct the future dentist in what the limits of their use are. This should be incorporated as a requirement for dental school certification. As a profession, we have not adequately done our job in this area.

As a profession we need to be addressing the root cause of the movement for independent practice by hygienists and technicians. We need to place as much emphasis as possible on correcting the problem as we do on fighting their legislative efforts. It is time we "get our act together."

DAVID J BALES
Editor

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ORIGINAL ARTICLES

Placement and Replacement of Resin-based Composite Restorations in Italy

I A MJÖR • F TOFFENETTI

Summary

The use of resin-based composite restorations, the reasons for failure, and the longevity of these restorations have been surveyed in 62 Italian private practices. Almost two-thirds of the 1025 restorations inserted were class 3 and 5 restorations, while 18% were class 1 and 2 restorations. Secondary caries was the most common reason reported for replacement of resin-based composite restorations (44%), followed by discoloration (21%), and bulk and margin fracture (14%). The age of restorations needing replacement was reported for 53% of the sample. The median longevity in this sample was calculated to be 3.3 years.

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Introduction

Resin-based composite materials are the most commonly used tooth-colored restorative materials. They are used mainly in class 3, 4, or 5 restorations, but products intended for use in class 1 and 2 restorations have also been developed.

The drive toward "esthetic dentistry," including strong marketing efforts, has led to a limited use of resin-based materials for stress-bearing posterior restorations by some dentists, i e, in locations where amalgam has been the material of choice for decades. Such changes in treatment patterns are important to follow for a variety of reasons, including the effect on the cost of the restorative treatment, because of a relatively short longevity of resin-based composite restorations (Hendricks, 1985; Moffa, 1989; Qvist, Qvist & Mjör, 1990).

The aim of the present study was to record the restorative treatment pattern in Italy with respect to the use of resin-based composite materials, the reasons for failure, and the longevity of these restorations.

Materials and Methods

A survey form was distributed to 133 members of the Italian Academy of Operative Dentistry, asking them to record all restorations inserted in permanent teeth over a two-week period in practice. The response rate was 47%. Data for a total of 2960 restorations were recorded. Data on the amalgam restorations have been reported separately (Mjör & Toffenetti, 1992).

The clinicians were asked to differentiate between restorations placed in the treatment of primary caries and those inserted as replacements for failed restorations. The following alternative reasons for failures of resin-based composite materials were provided on the recording forms: secondary (recurrent) caries, discoloration (main bulk/body, margin), poor anatomical form, fracture of restorations (bulk, margin), fracture of tooth (cusp, enamel margin), pain/sensitivity, other reasons. The clinicians were also asked to note the type of restorations inserted and the age of the failed restorations, provided the time of insertion of these restorations was available from the patients' charts.

Results

A total of 1025 resin-based composite restorations were placed during this survey, 530 (52%) in the treatment of primary caries and the rest in order to replace failed restorations (Mjör & Toffenetti, 1992). The types of restorations inserted are outlined in Table 1. Approximately 18% of the restorations involved the occlusal area, while 67% were one-surface class 3 and 5 restorations.

Secondary caries constituted the main reason for failure of resin-based composite restorations, followed by discoloration and fracture of restorations (Table 2). Poor anatomical form, fracture of tooth, pain/sensitivity, and other reasons were rare causes for failure.

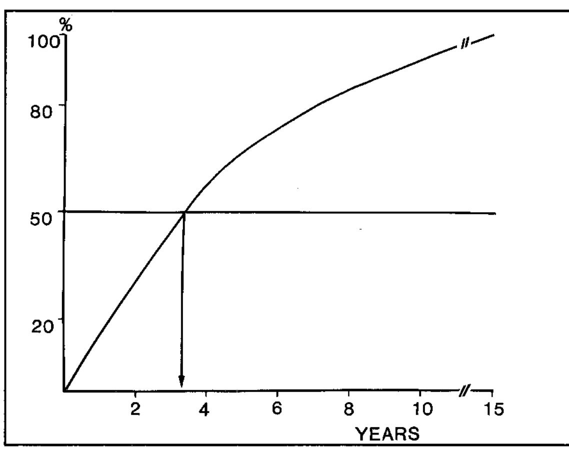
The age distribution of 262 (53%) of the 495 failed resin-based restorations that could be traced is shown in the figure. The median

Table 1. Distribution of Resin-based Composite Restorations in Italy Expressed as Percentages (n = 1025)

Types of Restoration	%
Class 1	6
Class 2	12
Class 3	46
Class 4	15
Class 5	2

Table 2. Reasons for Failure of Resin-based Composite Restorations in Italy Expressed as Percentage (n = 495)

Category of Failure	%	%
Secondary caries		44
Discoloration		21
body	12	
margin	9	
Poor anatomical form		8
Fracture of restoration		14
bulk	8	
margin	6	
Fracture of tooth		3
cusp	1	
enamel margin	2	
Pain/sensitivity		4
Other reasons		7



The accumulated percentage distribution of the age of failed resin-based composite restorations. The point where the horizontal 50% line crosses the curve represents the time on the abscissa when 50% of the failed restorations had been replaced, i e, the median longevity.

longevity of these restorations was 3.3 years. Less than 20% were seven years or older and about 8% exceeded 10 years in longevity. The oldest reported composite restorations replaced were 15 years, while one 30-year-old tooth-colored restoration was probably an unfilled resin material or a silicate restoration.

Discussion

Resin-based composite materials have been in common use as tooth-colored restorative materials for about 25 years. Marked improvements have occurred in the quality of the materials, and these have been reflected in other surveys of the type performed in the present study (Qvist & others, 1990). However, the use of resin-based composite materials in class 1 and 2 restorations is still limited as shown in the present survey. Less than 10% of the restorations involving the occlusal surface were fabricated using composites.

The main spectrum of diagnoses had apparently been covered by the alternatives provided for the study, and only 7% were listed as "other reasons." Surveys performed more than 10 years ago identified the loss of anatomical form as the major reason for replacement of class 3 and 5 restorations (Mjör, 1981), which are not directly subjected to masticatory forces. More recent studies indicated this mode of failure to be less important than previously (Qvist & others, 1990). The present data confirm this finding and also that discoloration is still a significant clinical problem with these materials. The relatively high proportion of margin discoloration in the present survey suggests inadequate acid-etching of the enamel prior to placing the resin-based composite restoration, and/or inadequate fabrication of the restorations in addition to the inherent problems associated with polymerization shrinkage.

The present survey supports secondary caries as the main cause of failure of resin-based composite restorations (Qvist & others, 1990). This information stresses the importance of complete sealing of the restorations to reduce the effect of the cariogenic plaque that collects at the tooth/filling interfaces (Svanberg, Mjör & Ørstavik, 1990). It also emphasizes the need for the optimal oral hygiene necessary from patients receiving resin-based composite restorations.

Fracture of restorations, including both bulk and margin fractures, constituted one of every seven failures. Previously reported surveys have included fractured restorations in the category "other reasons" (Mjör, 1981). The improvement in the overall quality of the products may have led to more brittle composites, which may explain the relatively high frequency of fractures. The low frequency of pain/sensitivity as a reason for replacement is comparable to that for amalgam restorations (Mjör & Toffenetti, 1992). This low frequency can be explained in part by the fact that the majority of the restorations inserted were small, one-surface fillings. Reports on pain are common for larger restorations (Qvist & Thylstrup, 1989).

The longevity of resin-based composite restorations is shorter than for amalgam restorations (Hendriks, 1985; Moffa, 1989; Qvist & others, 1990), independent of the class of restoration (Mjör, Jokstad & Qvist, 1990). The same observation was made in the present study. The relatively short longevity of the composite restorations reported calls for an improvement in both operative technique and in material quality, including handling characteristics. It is also noteworthy that the longevity of the restorations in the present study is more similar to that of adolescents than to that of adults in Denmark (Qvist & others, 1990). This observation may reflect differences in treatment patterns in the two countries due to different treatment experiences, e g, the availability of a school dental service for children and adolescents.

Conclusions

The great majority of composite restorations inserted were class 3 and class 5 restorations. The main reasons for failure of composite restorations were secondary caries and discoloration, followed by fracture of restorations. It is difficult to single out specific reasons for the low median age of the restorations replaced, but operative techniques and material quality and handling may play important roles.

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Stress Analysis of Five Prefabricated Endodontic Dowel Designs: A Photoelastic Study

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Summary

The stress generated by five prefabricated endodontic dowel designs was evaluated using a two-dimensional photoelastic model. Cemented posts caused the least stress. Of the threaded posts, Flexi-post and Radix Anker produced the least stress; Kurer Crown Anchor produced the most.

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Introduction

It is common in dentistry today to insert a dowel or post in severely broken-down endodontically treated teeth to reinforce the remaining tooth structure (Henry & Bower, 1977; Kantor & Pines, 1977; Trabert, Caputo & Abou-Rass, 1978; Sapone & Lorencki, 1981; Kern, von Fraunhofer & Mueninghoff, 1984) and to retain a core buildup on which an artificial crown can be fabricated (Baker, 1960; Hoag & Dwyer, 1982). The prefabricated post has achieved wide popularity because it is easy to place, the tooth can be prepared immediately for a crown, the cost is low, and retention is excellent (Colley, Hampson & Lehman, 1968; Johnson & Sakumura, 1978; Goerig & Mueninghoff, 1983). Of primary importance in retaining a core buildup is the retention of the dowel in the prepared root canal. Threaded posts that engage the dentin have been developed in the pursuit of maximum retention (Kurer, 1967). Many investigators have found the Flexi-post to be the most retentive (Kurer, Combe & Grant, 1977; Ruemping, Lund & Schnell, 1979; Newburg & Pameijer, 1976; Standlee, Caputo & Hanson,

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1978; Caputo & Hokama, 1984; Tjan & Miller, 1984; Deutsch & others, 1985; Brown & Mitchem, 1987).

In contrast to long-held beliefs, most authors now deny that posts strengthen teeth (Guzy & Nicholls, 1977; Sorensen & Martinoff, 1984; Trope, Maltz & Tronstad, 1985). Pulpless teeth become progressively more vulnerable in the course of treatment. The risk of compromising the tooth is increased by initial flaring of the canal during endodontic treatment, excessive force during lateral condensation of the gutta-percha, and preparation of the canal to receive the post (Gutmann, 1977; Littman, Silverstein & Silverstein, 1983; Meister, Lommel & Gerstein, 1980; Zmener, 1980; Leary, Aquilino & Svare, 1987; Gher & others, 1987). Fractures can be minimized by using conservative endodontic techniques and by reducing or eliminating stess during post placement. Any stress generated during cementation may remain and cause crazing that can lead to fractures when the additional dynamic forces of function occur (Chan & Svare, 1973). Screw-type posts can generate stress within a root canal system, resulting in dentinal crazing and possible fractures. Photoelastic models have customarily been used to measure the amount of stress generated by posts. The Flexi-post has not been compared in such a test with other commonly used self-threading posts.

The purpose of this study was to analyze the two-dimensional photoelastic stress generated by five commonly used prefabricated posts inserted and cemented into a birefringement photoelastic model.

Materials and Methods

This study examined five parallel-sided post systems (Table, Fig 1). Six samples of each post were made from PSM-5 photoelastic material (Measurements Group Inc, Raleigh, NC 27611) because its modulus of elasticity (450 000 lb/in^2) falls within the low range of human dentin but does not exceed it (Peyton, Mahler & Hershenov, 1952; Lehman, 1967). The samples were fabricated according to the criteria of Standlee and others (1972), who recommend "using machine oil to lubricate while drilling holes, slowly revolving drill bits, and backing the drill out every two turns to clean the flutes."

One pilot hole was drilled into each 45- x 35-mm sample to a depth of 14 mm,

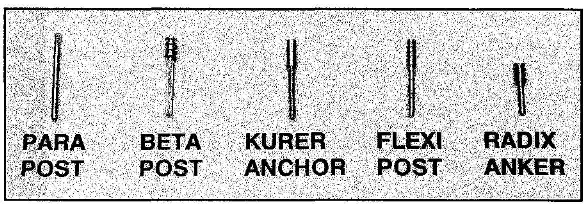

FIG 1. *The five post systems tested*

Post Systems Evaluated

Post	Manufacturer	Threads	Length (mm)	Diameter (mm)	Cement Vent	Engage Dentin
Para-post (black)	Whaledent International New York, NY 10001	transverse serrations	15	1.50	yes	no
Beta post #3	CTH, Inc West Babylon, NY 11702	axially oriented	13	1.55	yes	no
Kurer Crown Anchor #0	Teledyne Getz Elk Grove Village, IL 60007	spiral	11	1.60	no	fits into custom-made threads
Flexi-post #2	Essential Dental Systems, Inc New York, NY 10019	transverse threads	11	1.65	yes	self-threading
Radix Anker #2	Star Dental Mfg Co Inc Valley Forge, PA 19482	spiral	7	1.65	yes	self-threading

using a drill bit 0.8 mm in diameter. Pilot holes were prepared essentially stress-free. The holes were enlarged with sequential use of Peeso reamers (Unitek Corp, Monrovia, CA 91016) and a low-speed handpiece (Model 061, Measurements Group Inc), taking the same precautions that were used during pilot-hole preparation. Final instrumentation of the holes was completed with custom reamers and taps supplied by the manufacturers. Posts were cemented in the prepared canal, tightened, and seated according to manufacturers' instructions, using zinc phosphate cement (Fig 2). Contrary to manufacturers' instructions, one sample of each screw-type post, the sixth sample, was fully seated and backed-off one-half turn to reduce stress buildup during insertion (Standlee & others, 1972).

When photoelastic material is subjected to forces, optical properties change in direct proportion to the stresses developed. The material becomes "birefringent," and a colorful interference pattern is observed when polarized light passing through the stessed material splits into two beams. A fringe is defined as a line separating the red and green color bands. A fringe order will consist of a sequence of color bands, including one fringe line. The zero fringe order is black and indicates no stress. Stress can be quantified and localized by counting the number of fringes and the density (Mattison, 1982; Mahler & Peyton, 1955; Durelli & Riley, 1965; Measurements Group Inc, 1980). The closer the fringes, the steeper the stress gradient, indicating an area of stress concentration.

Each sample was photographed through a circular polariscope (Star Titan, Star Dental Mfg Co, Valley Forge, PA 19482) in dark field analysis with a telemicroscope (Model 241-50, Measurements Group Inc, magnification X15). Dark field analysis was used because it showed the magnitude of stress generated. Light field analysis indicated the direction of stress in a sample but not the magnitude. Slides of samples were projected onto a screen. The number of fringes in the apical one-third region were counted for each post. Theoretically, more valid comparisons can be made at the tip of the post, where light passes through the same amount of material for each post. Posts were classified as having produced minimal stress (less than two fringes) or moderate stress (two or more fringes). The amount of stress generated along the length of the post was observed.

Results

Stress patterns were consistent for all samples of each post. The locations of stress and number of fringes were similar among samples of like posts.

All Para-post and Beta post samples exhibited stress of one fringe or less. Para-posts exhibited multiple patterns, all of low magnitude (Fig 3). The Beta posts exhibited stress

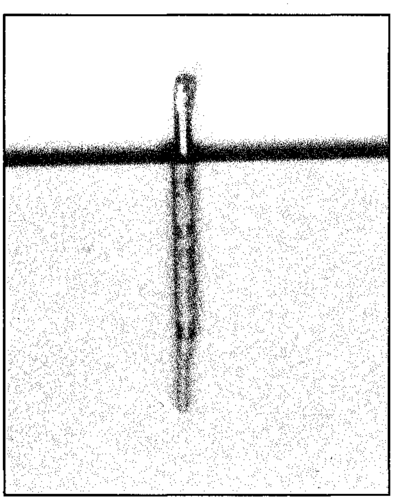

FIG 2. *Sample post cemented in PSM-5 photoelastic material*

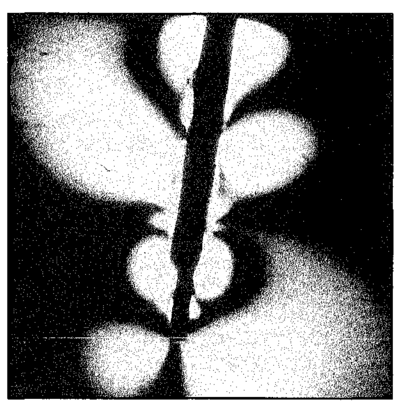

FIG 3. *Parapost cemented according to manufacturer's instructions (viewed in polariscope)*

concentrated at the junction where the post changed from parallel-sided to rounded tip (Fig 4).

The Kurer Crown Anchor exhibited the greatest amount of stress, with generally greater than three fringes in the apical region (Fig 5). In the sixth sample, which was backed-off one-half turn, stress was reduced from moderate to less than two fringes at the apex, with a concurrent reduction along the shaft (Fig 6).

The Radix Anker exhibited less than one fringe in the apical region in all six samples. Stress was concentrated around the threaded portion (Fig 7).

The Flexi-post showed some multiple patterns in its apical third, but still exhibited one fringe or less in all samples. As with the other screw-type posts, stress was evident around the threaded portion (Fig 8).

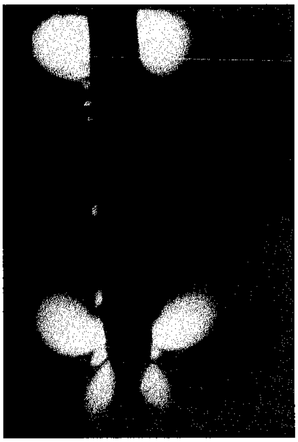

FIG 4. *Beta post*

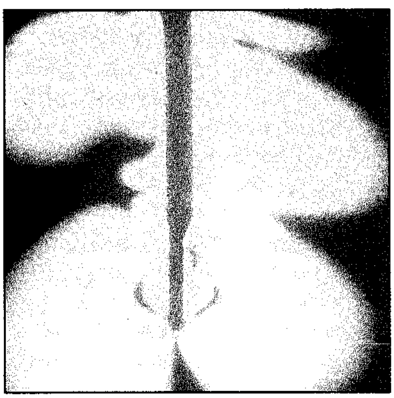

FIG 5. *Kurer Crown Anchor*

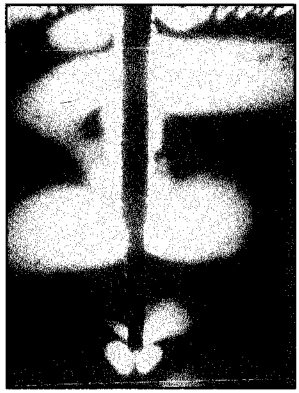

FIG 6. *Kurer Crown Anchor backed-off one-half turn*

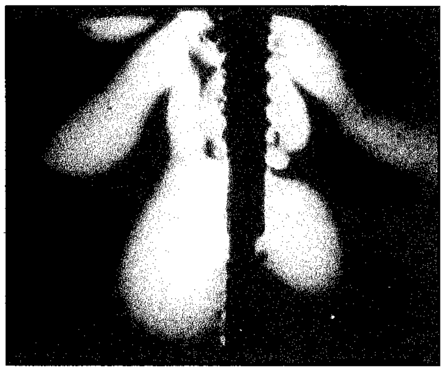

FIG 7. *Radix Anker*

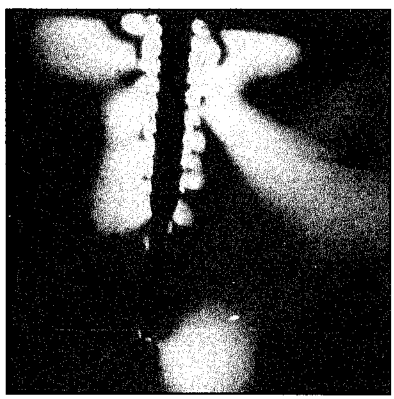

FIG 8. *Flexi-post*

The sixth sample of both the Radix Anker (Fig 9) and the Flexi-post (Fig 10) showed no difference in the apical region from previous samples, but there was a general reduction in stress in the more coronal threaded portions. Moderate stress was often centered around the threads of the screw posts.

Discussion

This study showed that the Flexi-post and the Radix Anker designs produced minimal stress in the apical region. The Flexi-post exhibited stress patterns in the apical region similar to the patterns for the cemented posts. This may be attributed to the slot design. The post apparently compresses and "gives" as it is inserted, as evidenced by a gradual lessening of stress around the threads from the unslotted coronal portion to the apical slotted tip. This is supported by the observations of Standlee, Caputo and Holcomb (1982), who noted "very mild, well-distributed stress levels of the order of two to three fringes when a Dentatus screw post was split along its long axis." The Radix Anker design, which did not contain any threads in the apical portion, consistently exhibited the least amount of stress of all the posts. However, there was stress concentrated about the threaded portion of both the Flexi-post and Radix Anker on the order of two fringes. This corroborates the findings of Burns and others (1990).

This study also reconfirmed that stress can be reduced in some posts by backing-off one-half turn after fully seating during cementation. When seated according to manufacturer's instructions, the Kurer Crown Anchor showed moderate stress. The sample that was backed-off one-half turn had minimal stress at the apical one-third and along the shaft.

When backed-off one-half turn, both the Radix Anker and Flexi-post exhibited a decrease in stress along the threaded portion; neither showed significant change in the apical region. Standlee and others (1972) and Ricker, Lautenschlager and Greener (1986) noted that high stress levels were generated when the dowel apex and threads of the Radix Anker engaged the model, but when the post was backed-off one-half turn, moderate stresses (one to two fringes) were observed.

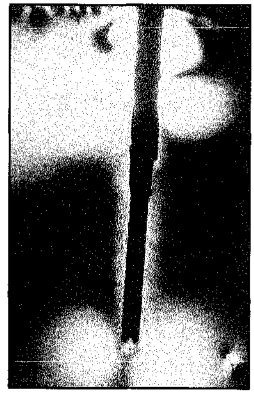

FIG 9. *Radix Anker backed-off one-half turn*

FIG 10. *Flexi-post backed-off one-half turn*

Backing-off a post may cause other effects not evaluated in this study. Before backing-off is recommended as a means of reducing stress, it should be studied for its ramifications on stability and the mode of failure.

Photoelastic study does not mimic all the effects of posts in vivo. However, photoelastic study is a simple and reasonably accurate way to compare stresses caused by various post designs without the variables of a biologic model.

Ricker and others (1986) performed tensile-strength and compression-fatigue tests on extracted teeth and found that the Kurer Crown Anchor #0 and Radix Anker #2 "provided superior strength properties with regard to the clinical factors of retention and stress root fracture." Scanning electron microscope examination of elastomeric impressions of these post-tapped canals revealed that neither post produced any crazing or microcracks. Based on the photoelastic comparison to the Radix Anker and Kurer Crown Anchor, the Flexi-post should behave similarly in extracted teeth.

Conclusions

Previous retention studies have ranked the Flexi-post and the Kurer Crown Anchor as the most retentive, the Radix Anker one-half as retentive, and the cement-retained Beta post and Para-post as the least retentive. Of the two posts previously reported, the most retentive, the Flexi-post, produced less stress than the Kurer Crown Anchor. Of the screw-type posts, the Flexi-post and Radix Anker produced a similar amount of minimal stress, but the Radix Anker was only half as retentive as the Flexi-post and Kurer Crown Anchor. The cement-retained Beta posts and Para-posts were the least stressful of all posts tested, but they were also the least retentive, according to previous studies. The Radix Anker and Flexi-post designs provided the best combination of high retention and low stress.

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Regional Variation in Permeability of Young Dentin

S MAROLI • S C KHERA • K V KRELL

Summary

Variation in the permeability of dentin in people 19 years and less in age was evaluated. The regions compared were the occlusal third versus the middle third versus the cervical third of approximal surfaces. Also compared were the mesial approximal surface versus the distal. The comparison was done by obtaining 1 mm-thick dentin discs from the area of dentin close to the dentinoenamel junction. It was seen that the cervical area was significantly more permeable than the occlusal area. The middle third, though not statistically significant, had mean values almost twice those in the occlusal third and almost half of the values in the cervical third. No difference was seen in permeability between the mesial and distal surfaces. The reasons for these regional variations and their clinical implications are presented.

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INTRODUCTION

The dentinopulpal organ is a highly specialized living tissue. The odontoblasts found at the dentinopulpal junction have odontoblastic processes extending into the dentinal tubules and are shielded by the hydroxyapatite-rich peritubular dentin (Bhaskar, 1980; Brännström, 1981). The presence of dentinal fluid in these tubules illustrates that dentin is permeable (Bhaskar, 1980; Brännström, 1981).

Normally, there is positive outward flow of this fluid due to normal intrapulpal pressure. If enamel is removed and the dentin is exposed, this outward fluid flow may affect the materials placed on the raw dentin. This fluid flow could affect the bonding of composite resin and/or glass-ionomer-type restorative materials to dentin and thereby influence both the microleakage at margins of restorations and the degree of dentin sensitivity (Tao & Pashley, 1989; Qvist & Thylstrup, 1989).

Permeability, in general, is affected by a number of factors, such as the porosity of the medium, surface tension, capillary forces, electrical charges, osmotic pressure, adsorption, protein constituents, and molecular size (Pashley, Livingston & Outhwaite, 1977; Rowe, 1982). Dentin permeability is also affected by other important factors, such as a break in the continuity of the tubules. Such a break may occur when the tubules terminate blindly or when their continuity is blocked by bacteria or restorative debris, i e, the smear layer. Any such deviation may reduce dentin permeability, thereby reducing the ingress of fluids and substances, including bacteria and bacterial products, into the pulp (Rowe, 1982).

Any changes in the normal histological morphology and quantity of dentinal tubules may directly affect the permeability of dentin. Variation in the number and potency of dentinal tubules in the different regions of the occlusal surface of the crowns of third molars has been demonstrated (Pashley & others, 1987). One study compared the permeability of dentin in the radicular area with that of the coronal dentin (on the occlusal surface) and found that the coronal (occlusal) dentin was more permeable (Fogel, Marshall & Pashley, 1988). Regional variation in dentin permeability may have an effect on the overlying enamel in the different areas of the tooth. Areas with low permeability may have less moisture in the dentin closer to the dentinoenamel junction from the pulp through dentinal tubules. In these areas, the biologic bond between enamel and dentin may not be as strong and thus may be more prone to fracture or chipping due to stresses produced by mastication. Chipping of enamel may be partly responsible for increased carious activity in the cervical area of the teeth in elderly patients, where fluid flow through the dentinal tubules from the pulp may have decreased due to aging (Brännström, 1981; Ketterl, 1983). Many other studies suggest that the bond strength of composite resins is influenced by the depth of the cavity preparation. "Superficial dentin" exhibited greater bond strength, whereas "deep dentin" had the lowest bond strength (Nakamichi, Iwaku & Fusayama, 1983; Causton, 1984; Mitchem & Gronas, 1986; Suzuki & Finger, 1988). This has been, in part, attributed to the regional variation in wetness caused by dentin permeability. Tao and Pashley (1989) reported that there is an inverse correlation between dentin permeability and the shear bond strength of Scotchbond to dentin after smear layer removal.

The number, size, and tubular orientation in the different regions of a tooth suggest variation in the permeability of dentin (Trowbridge, 1987). Regional variation in the permeability of coronal dentin along these surfaces parallel to the dentinoenamel junction has not been investigated or reported to date. Knowledge of the permeability patterns along the approximal surfaces may be a critical factor when considering bonding of restorative materials, microleakage, and dentin hypersensitivity.

The purpose of this study was to examine the regional variation of coronal dentin permeability in the occlusal, middle and cervical third of approximal surfaces of human teeth. Specific differences in dentin permeability between mesial and distal approximal surfaces were also examined.

MATERIALS AND METHODS

Five freshly extracted third molars from individuals 19 years of age and younger were placed in normal saline, cleaned, and then stored in 0.04% sodium azide and refrigerated. Only sound teeth with no caries, restorations, fractures, cracks or crazing in enamel were used in this study.

Radiographs were taken to allow measurement of the thickness of enamel and dentin in the mesial and the distal aspects of the tooth, as well as to approximate the dentinoenamel junction contour in these areas as closely as possible. The cementoenamel junction was delineated using an indelible marker. Using the Silverstone-Taylor hard tissue microtome (SCIFAB, Scientific Fabrication, Littleton, CO 80123), the teeth were sectioned occlusogingivally. Two parallel cuts were made on the mesial and distal aspect of each tooth, one approximately at the dentinoenamel junction and the other approximately at the beginning of the pulp chamber (Fig 1). Tooth structure between these two sections provided a total of 10 dentin discs along with buccal, occlusal, and lingual enamel (Fig 2). This procedure yielded five discs from the mesial and five from the distal aspect of the teeth. These sections were ground on wet sandpaper to obtain a thickness of 1.00 mm ± 0.05 mm. To remain consistent in the treatment, all sections were reduced only on the pulpal side of the sections to avoid affecting the dentinal tubules closest to the dentinoenamel junction. The enamel side of the sections was reduced only if any enamel was present in the sections and to remove completely any enamel present. The thickness of the dentin discs was measured using a laboratory digital micrometer. Prior to permeability measurements, the smear layer produced by the sectioning and grinding process was removed using 6% citric acid and rubbing it for two minutes on each side, followed by a 20-second water rinse for each side.

Each of these sections was then identified with a number, and this identification was placed on enamel only, so as not to compromise the dentin portion of the disc in any way (Fig 2).

Each disc was then placed in a split chamber device (Fig 3). Plastic spacers with appropriate rubber 'O' rings were used to seal each half of the chamber to the disc. This limited the exposed surface area on the pulpal side of dentin to 0.01981 cm^2 or 0.07917 cm^2, depending on the size of the 'O' ring used. A large 'O' ring exposing a surface area of 1.1314 cm^2 of dentin was placed on the outer surface of the dentin (towards the dentinoenamel junction).

Phosphate-buffered saline was filtered through the dentin disc in the split chamber device by attaching a nitrogen gas source to a pressure cooker attached by polyethylene

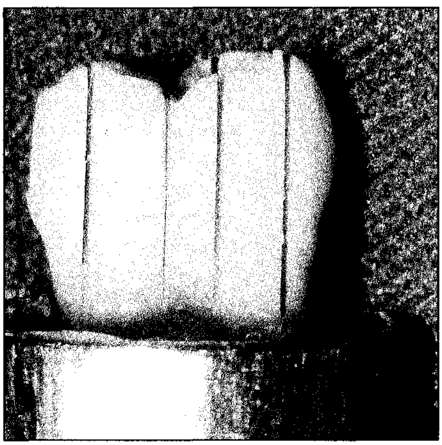

FIG 1. *Occlusogingivally and buccolingually sectioned sample*

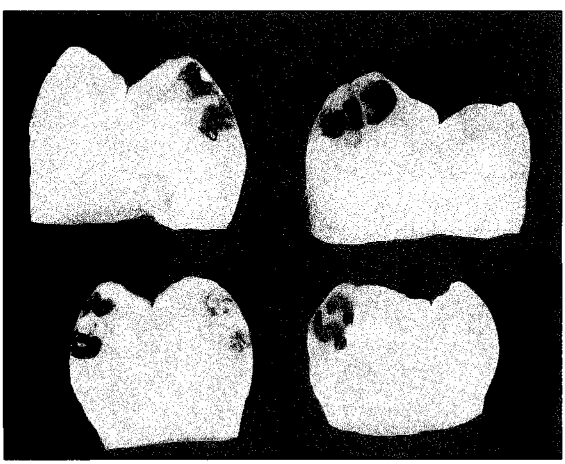

FIG 2. *Samples obtained and marked (in enamel only) after sectioning*

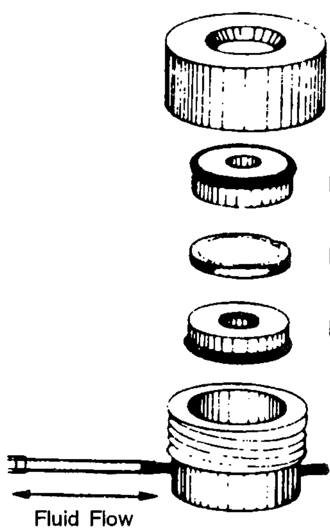

FIG 3. *Illustration showing the placement of the dentin discs in the split chamber device*

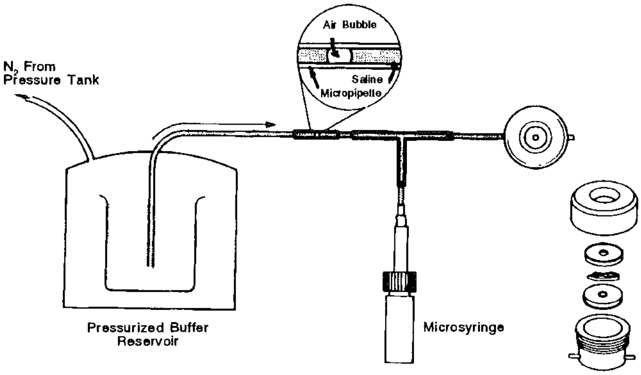

FIG 4. *Diagrammatic representation of the equipment setup, with the air bubble in the micropipette and dentin displaced between the rubber 'O' rings*

tubing to a pressure regulator (Fig 4). The fluid movement was always from the pulpal side to the enamel side of the section and was under a constant hydrostatic pressure of 703.1 cm of H_2O for all specimens.

Hydraulic Conductance Measurement (Lp)

A micropipette was connected between the fluid reservoir and the split chamber device. By introducing a small air bubble into the micropipette and monitoring its progress in this micropipette of known length and radius, the fluid movement could be calculated as described below.

The hydraulic conductance (Lp) was expressed as a function of

Lp = Jv/A^Pt, where

Jv = fluid flow in microliters;

A = surface area through which fluid permeates;

^P = hydrostatic pressure gradient in cms of H_2O;

t = time in minutes; and

Lp = hydraulic conductance, in microliters, cm^{-2}, $minutes^{-1}$, cm H_2O^{-1}.

Eight hydraulic conductance measurements at two-minute intervals were obtained for each area, i e, the occlusal third, middle third, and cervical third in each specimen. The mean of these eight measurements was used as a representative of hydraulic conductance for each area for statistical analysis using the Analysis of Variance and Scheffé F-test.

Scanning Electron Microscopic Examination

Selected specimens of discs used for hydraulic conductance were further examined using scanning electron microscopy (SEM). The specimens being analyzed by SEM were thoroughly rinsed with water and then dehydrated using alcohol. Scanning electron microscopy of representative samples was used to help determine the number of tubules in the three areas, the occlusal, middle, and cervical thirds. The micrographs were taken from the pulpal side of the discs at approximately the region where the small 'O' rings were placed on the specimens. When the hydraulic conductance measurements were being taken, a diagram of each specimen was drawn and the positions of the 'O' rings were recorded in this diagram for reference purposes during SEM examination. These sections were then coated with a gold/palladium coating and examined using an AMRAY (1820) Lab SEM (Amray, Inc, Electron Optics, Bedford, MA 01730). The discs were viewed at 50k - X10 000 magnification from the pulpal aspect.

RESULTS

Regional variation in the permeability of dentin was found for all specimens (Tables 1-3).

Hydraulic Conductance (Lp)

Table 1 shows the mean and standard deviations for the three regions: occlusal third, middle third, and the cervical third, for all specimens. The mean Lp for the occlusal third was 0.026 $\mu l/cm^2$ min cm H_2O. In the middle third, this value was 0.053 $\mu l/cm^2$ min cm H_2O, and in the cervical third, Lp value was 0.094 $\mu l/cm^2$ min cm H_2O. This essentially demonstrates that there is regional variation in the permeability of dentin occlusogingivally.

Table 2 shows a two-way analysis of variance comparing Lps of the occlusal, middle, and cervical thirds, and the mesial and distal surfaces. This analysis resulted in an 'f' score of 4.12 ($P < 0.05$) for position (occluso-gingival), indicating significant differences in

Table 1. One-Factor ANOVA Showing Permeability of Dentin in the Positions: Occlusal Third, Middle Third, and Cervical Third

Group	Mean Lp (µl/cm mins cm H_2O)	Std Dev	Std Error
Occlusal third	0.026	0.028	0.007
Middle third	0.053	0.000	0.012
Cervical third	0.094	0.098	0.026

Table 2. ANOVA Table for Two-Factor Analysis of Variance on Y_1: Lp Mean Showing Interaction between Occlusocervical Positions (A) and Approximal Surfaces (B)

Source	df	Sum of Squares	Mean Square	F-test	*P* Value
Position (A)	2	0.032	0.016	4.12	0.0240
Tooth Surface (B)	1	0.010	0.010	2.50	0.1218
AB	2	0.003	0.002	0.39	0.6807
Error	38	0.152	0.003	—	—

Table 3. One-Factor ANOVA Comparing the Three Occlusocervical Positions for Permeability of Dentin

Comparison	Mean Difference	Scheffé F-test
Occlusal third versus middle third	-0.027	0.684
Occlusal third versus cervical third	-0.068	4.248*
Middle third versus cervical third	-0.040	1.428

*Significant at 95%

the permeability. Examining tooth surfaces (mesial versus distal), this table also shows that the 'f' score was 2.5 ($P > 0.05$), demonstrating that the mesial and distal surfaces did not have significant differences in permeability.

A Scheffé F-test was performed. A significant difference was found in the permeability values between the occlusal and cervical thirds only. No other comparison was significant (Table 3).

In the statistical analysis, Scheffé's test was used as it allows testing of all possible pairwise and nonpairwise contrasts, while ensuring that the level of significance for all of these combined does not exceed that used in the overall F-test.

Scanning Electron Microscopy

In the scanning electron micrographs, the dentinal tubular openings appeared to be greater in number and smaller in diameter in the cervical third than tubules in the occlusal and middle thirds. In the occlusal and middle thirds, the number and diameter of the dentinal tubular openings appeared to be smaller (Fig 5). Because the tubules were not sectioned at an

FIG 5. *Scanning electron microradiographs showing the number and diameter in: occlusal third (top); middle third (middle), and cervical third (bottom); original magnification X500*

angle perpendicular to their opening, it was not possible to measure the exact diameter of the tubules in the middle and occlusal thirds. Detailed qualitative and quantitative analysis regarding the regional variation and number of the size of dentinal tubules was therefore not possible since the data obtained from these sections would not be reliable.

DISCUSSION AND CLINICAL IMPLICATIONS

The permeability of dentin in the occlusal, middle, and cervical thirds was compared to each other in each specimen. This investigation also compared the permeability of dentin between the mesial and distal surfaces. This made each specimen its own control and also allows one to correlate the results to in vivo situations, as any factors affecting the permeability would affect all regions or surfaces equally. The measurements for hydraulic conductance obtained in this study can be regarded as the maximum that could be obtained. This is because the tubules were devoid of odontoblastic processes, as the sections were obtained close to the dentinoenamel junction. Moreover, any cell remnants, if present, would have been degenerated (Pashley, Livingston & Greenhill, 1978). Additionally, the sections were acid-etched for two minutes to completely remove the smear layer.

Under the conditions of this study, the cervical third of the dentin was found to have the highest hydraulic conductance values. These findings may be extrapolated to an in vivo situation when considering dentin permeability in any vertical plane. The number of tubular openings in the approximal surface of the tooth at the dentinoenamel junction may be fewer in the middle and occlusal thirds. This may be due to the fact that the tubules run occlusally, and many of them may actually open on to the occlusal surface of the dentinoenamel junction itself. Additionally, tubules near the pulp have diameters of about 2.5 μm, while those closer to the dentinoenamel junction have diameters of about 0.8 μm (Garberoglio & Brännström, 1976). The combination of fewer dentinal tubules present along the axial surface of the occlusal and middle thirds and their reduced diameter could be directly affecting the permeability of dentin in these areas.

The high permeability patterns seen in the cervical third may also be partially accounted for by cervical pulp horns that have been found to be present in multiple locations in up to 96% of molar teeth (Pashley, 1985; Sproles, 1974). The presence of cervical pulp horns would result in tubules with wider diameters in the cervical region (Moss-Salentijn & Hendricks-Klyvert, 1985).

The scanning electron micrographs showed the number of tubular openings to be greater in the cervical region than in the occlusal or the middle third regions, and this obviously will have the greatest influence on the permeability in this region. This is in agreement with Trowbridge (1987), who also reported that the number of dentinal tubules is greater in the dentin closer to the pulp than in dentin closer to the dentinoenamel junction in the occlusal area. Cervical dentin is closer to the pulp than the occlusal, with a greater number of dentinal tubules, and thus demonstated greatest permeability.

The tubular openings in the middle and occlusal thirds appear to be oval as compared to round in the cervical third. This may be due to the fact that the tubules are cross-cut in the cervical region, whereas in the occlusal and middle third regions they are more or less parallel to the angle of sectioning. The SEM findings subjectively support the results obtained by hydraulic conductance measurements.

Many clinical problems of dentin hypersensitivity, microleakage associated with the restorations, and recurrent caries are related to dentin permeability. Clinical observations seem to suggest that lesions of similar depth in the cervical area, either carious or abrasion, may be more sensitive than those in occlusal or approximal areas. This greater sensitivity may be due to the changes in the dentinal tubules' diameter and density in this area. With increased potential for outward dentin permeability, the potential for the inward diffusion of microbial products or by-products through the tubules to the pulp is also increased. The amount of microbial products diffusing into the pulp is dependent upon several important variables, such as thickness of the remaining dentin (the thicker the dentin, the lower the concentration of microbial products) (Nakamichi & others, 1983) and the surface area (Outhwaite, Livingston, & Pashley, 1976) of the exposed cervical dentin.

With increasing age, there can be "sclerosis" of dentin and secondary dentin formation, and this reduces the pulp volume (Brännström, 1981; Ketterl, 1983). This may result in decreased dentin permeability, thereby reducing dentinal sensitivity. This may explain why elderly patients do not experience much pain during operative procedures in the cervical region, even though this region is normally very permeable.

The increased permeability in the cervical region of dentin could also possibly adversely affect the adaptability of restorative materials. Acid-etching of dentin for better bonding of composite resin or other restorative materials would remove smear layers and open the tubules, thereby increasing permeability. Greater fluid flow may occur from the pulp, and this pulpal fluid, when it reaches the cut surface of the dentin, could compromise the adaptability of the restorative material since it may be adapting to a wet surface of dentin. This could be especially detrimental in deeper preparations where the tubular diameter is much greater. This may result in greater microleakage between the restoration and the dentin in this area with possible resultant pulpal irritation. The inverse correlation between bond strength of composite resin to superficial dentin (similar to that in the occlusal third) and deep dentin (similar to that in the cervical third) after the removal of the smear layer has been repeatedly demonstrated (Nakamichi & others, 1983; Causton, 1984; Mitchem & Gronas, 1986; Tao & Pashley, 1989; Tagami, Tao & Pashley, 1990).

The regions with lower permeability, such as the occlusal and middle thirds of the approximal surface, may have a higher mineral content and more intertubular dentin matrix as they reach the dentinoenamel junction since they follow a more tortuous course and hence are longer. This makes these areas behave as superficial dentin, while the dentin in the cervical region of the approximal surface behaves as deep dentin, due to the greater number of tubules as well as these tubules taking a straight course and hence being comparatively shorter. Bond strength of composite resins to superficial dentin has been shown to be greater than to deep dentin (Causton, 1984; Nakamichi & others, 1983; Stanford, Sabri & Jose, 1985). The reduced bond strength in the 'deep' dentin may be because of the greater number of tubules present in this area, similar to the number in the cervical third. Clinically, it may also be related to increased permeability of dentin, which allows faster or greater moisturization of the cut dentin surface by pulpal fluid just prior to placement of the material. Brännström (1981) suggests that it may only take as short as one second to remoisturize the dentin with pulpal fluid after it has been dried with air. These two factors together may affect the bond strength in the 'deep' or cervical dentin and this may, in turn, cause or contribute to the development of a greater degree of sensitivity, microleakage, and recurrent decay. Hence, it is an important issue to consider when testing restorative materials for bond strength as well as manipulating restorative materials for restorative procedures. Further tests to determine the effect of aging and other factors on the regional variation in the permeability of dentin are currently in progress, and those results will be reported later.

CONCLUSIONS

On the basis of the conditions and results of this study, the following conclusions can be made:

1. The permeability of young dentin along the approximal surfaces gradually increases occlusogingivally. The cervical third is the most permeable, and the occlusal third is the least permeable. The middle and the occlusal thirds did not demonstrate a statistically significant difference in permeability when compared to each other, but the middle third was twice as permeable as the occlusal third. The cervical third, however, demonstrated a statistically significant difference from the occlusal third.

2. There was no statistically significant difference seen in the permeability on the mesial and distal surfaces of the same teeth.

3. In the scanning electron micrographs, it appears that there are more tubular openings in the cervical third of approximal sections as compared to the occlusal and the middle thirds.

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Enhanced Prosthetics Using the Gingival Mask

CRAIG PASSON

Summary

The removal and trimming of working model dies destroys important soft tissue information. Features such as the gingival sulcus, interdental papilla, and ridge form are often destroyed. The loss of these features makes the fabrication of correct restoration contours difficult. Using the gingival mask will restore vital soft tissue as well as hard tissue information. This paper discusses the gingival mask, its advantages and disadvantages, and describes the direct and indirect methods of fabrication. Whatever method is employed, the gingival mask will prove to be a valuable adjunct for improving the quality and esthetic values of the fixed prosthesis.

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INTRODUCTION

The fabrication of cast gold restorations can be performed either directly (on the prepared tooth) or indirectly (on a model cast from a replica of the prepared tooth). Many restorative dental textbooks (Charbeneau, 1988; Gilmore, 1967; Schillingburg, Hobo & Whitsett, 1981; Sturdevant, Barton & Brauer, 1968) have discussed the technique for the direct fabrication of cast gold restorations. One advantage of this technique is that the operator is able to use the surrounding soft and hard tissues as a guide for the development of biocompatible contours in the wax pattern. The casting that results will require little if any contour adjustment. However, the direct technique is generally limited to simple one-, two-, or three-surface restorations. More complex single-unit (crown) or multiple-unit (fixed partial denture) restorations are more easily fabricated using the indirect approach.

The indirect approach requires the fabrication of removable dies and models cast from a replication of the prepared tooth. There is a plethora of removable die fabrication systems, each having advantages. One significant disadvantage of any removable die system is that critical soft and hard tissue information is removed during the process of die preparation. Sawing of the model for the separation of dies and trimming of the gingival area of the die to reveal preparation margins usually removes critical anatomy, which would help guide the creation of optimal restoration contours. This anatomy includes interdental papillae, free gingival margins, residual ridge form, and underlying bone architecture (Figs 1 & 2). However, this lost anatomy can be reproduced on the model by fabricating and using a "gingival mask." This paper discusses the gingival mask, its advantages and disadvantages, and presents two methods of fabrication.

GINGIVAL MASK BACKGROUND

The term "artificial resin gum mask" was used by Schweitzer (1960) to describe the fabrication of a gingival-colored rigid acrylic prosthetic device, which is to be worn by a patient to mask defects caused by periodontal disease and therapy. A similar type of cosmetic appliance intended to serve the same purpose as the gingival mask has also been described by Ela and others (1990), who called their appliance a gingival stent. However, the term "gingival mask" as used in this paper refers to the placement of an elastomeric material on the working casts of prosthetic cases. This enhanced cast can serve as an esthetic and functional model of periodontal tissues to aid in the correct fabrication of crowns and fixed partial dentures by providing soft tissue contours.

Using the gingival mask has several advantages, which include: prevention of the axial over-contouring of restorations, prevention of encroachment of the restoration on the interdental papilla, facilitation of the development of proper solder joint and pontic form, guidance of the placement of precision and semi-precision attachments, and facilitation of establishing overall esthetic harmony.

Using the gingival mask is not without disadvantages, however. These include: necessity of additional laboratory procedures, some additional time required, additional expense, possibility of interfering with convenient die removal, and the inaccurate reproduction of soft tissue form is possible if an improper technique is used.

There are two methods for fabricating a gingival mask: direct and indirect. One method of indirect fabrication of a gingival mask was described by Martin (1982), who called his system a "soft tissue master cast." In his technique, Martin describes the use of a pink soft denture relining material to reproduce the gingival tissue on the master cast.

Two commercial products recently have been developed specifically for the indirect fabrication of a gingival mask: Gi-Mask (Coltene, Inc/West, Carlsbad, CA 92008) and Vestogum (ESPE-Premier Sales Corp, Norristown, PA 19401). Each of these products uses an elastomeric impression material that is applied to the master cast after the dies have been trimmed. The technique for the use of Gi-Mask has been presented by *Dental Products Report* (1989) in addition to the manufacturer's instructions. The technique for using Vestogum generally follows that recommended by the manufacturers of Gi-Mask. The direct method of gingival mask fabrication was developed by the author and is described in this paper.

DIRECT TECHNIQUE OF FABRICATION

The direct method of gingival mask fabrication is defined as the application of the elastomeric material used to form the gingival mask

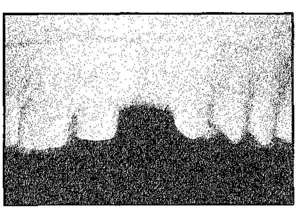

FIG 1. *Stone preparation model before die separation and trimming*

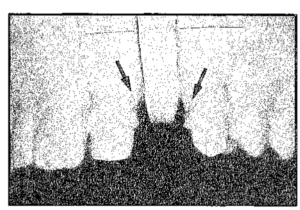

FIG 2. *Stone preparation model after die separation and trimming. Note loss of critical soft and hard tissue anatomy (arrows).*

FIG 3. *Verified cast substructure ready for pick-up impression*

FIG 4. *Full-arch pick-up impression. Note substructure in impression (arrows).*

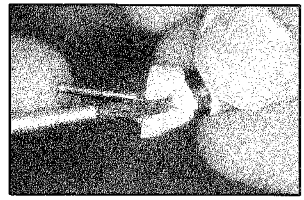

FIG 5. *Lubricate die and impression surfaces with liquid silicone.*

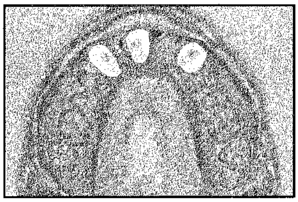

FIG 6. *Lubricated dies properly replaced in the cast substructure*

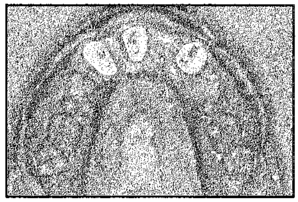

FIG 7. *Mask material injected around the dies and surrounding areas*

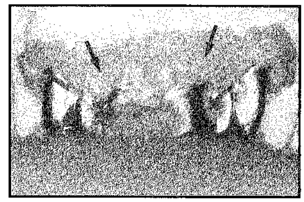

FIG 8. *Cast substructure on the dies of the new master model. The gingival mask is indicated by the arrows.*

directly into the master or "pick-up" impression, which includes the already trimmed and repositioned dies. The direct method requires intervening steps in the restorative procedure. These steps require that transfer copings (acrylic or similar) made on accurate dies can be picked up as part of the master impression. This can also apply to making an impression over cast metal substructures prior to porcelain application, thus using the substructures as transfer copings. This method of fabrication is described with the following clinical case and presents but one example of the use of this technique.

Clinical Case

After verifying the quality of fit of the cast substructure and, if needed, establishing soldering relations (Fig 3), the substructure is picked up by using a heavy-bodied impression material in a full-arch impression tray (Fig 4). To facilitate accurate recording of the gingival tissue, it is helpful to inject a light-bodied impression material around the cast substructure before the heavy-bodied pick-up impression is placed. The nonpreparation surfaces of the dies, along with the surface of the impression immediately adjacent to the cast substructure, are lubricated with liquid silicone (Fig 5). The lubricated dies are properly replaced in the cast substructure (Fig 6). In this case, a polysulfide impression material was used, although other materials are also available. The mask material selected is mixed as directed. It is then loaded into an impression syringe and injected around the dies and surrounding areas (Fig 7). Small pieces of bent wire may be placed in the unset mask material to help anchor it to the base stone.

After the mask material has set, excess material that may have spilled over into adjacent areas can be removed by trimming with a scalpel blade or similar instrument. It is important to note that if the mask is to be removable from the rest of the model, the retaining wires should not be placed; and the surface of the set mask material should be lubricated with silicone before pouring the model base. The next step is to mix and pour dental stone into the impression, taking care to fill all dental areas, cover the gingival mask and dies, and form the model base. The gingival mask will remain on the model. The mask should require little or no trimming or modification. The cast substructure is then placed on the dies of this new model (Fig 8), and the lab technician should be instructed to use the mask to help

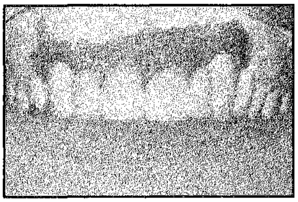

FIG 9. *Completed fixed partial denture on the master model*

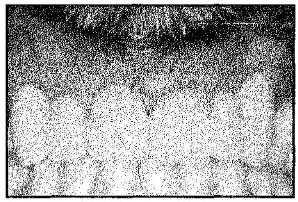

FIG 10. *Completed fixed partial denture ready for cementation. Compare the patient's soft tissue contours to those of the gingival mask (Fig 9).*

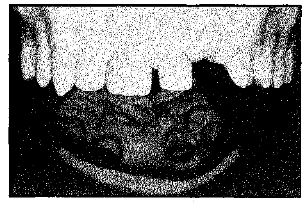

FIG 11. *Polyvinyl putty impression of the prepared teeth and surrounding areas made before the stone dies are cut from the model and trimmed*

FIG 12. *Mask material is injected on the model in all trimmed areas.*

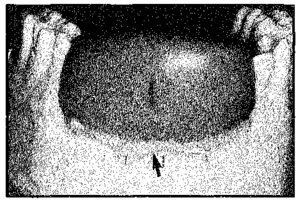

FIG 13. *Polyvinyl putty impression reseated on the model. Note the excess mask material (arrow).*

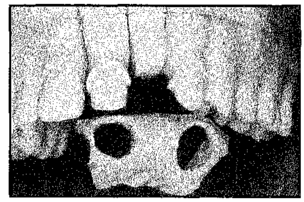

FIG 14. *Gingival mask trimmed and ready for replacement over the dies and model*

develop more accurate restoration contours (Fig 9). The completed case should require only very minor adjustments of contours when placed on the patient's teeth (Fig 10).

INDIRECT TECHNIQUE OF FABRICATION

The indirect method of fabrication of a gingival mask assumes that the restorations will be completely fabricated on the master model with no intervening clinical steps. This method involves the use of an elastomeric impression material to form the gingival mask, thus adding to the appropriate soft tissue areas of the completed working model. As stated previously, there are two commerical products available for this purpose, and the manufacturer's instructions must be followed for each product. The description of the indirect technique in this paper is general and is included to permit comparison to the direct technique.

The impression of the prepared teeth is poured with dental stone to produce a solid working model. Before the stone dies are cut from the model and trimmed, a polyvinyl putty impression is made of the prepared teeth and surrounding areas. This procedure will record the gingival tissue contours present at the time of the impression (Fig 11). The dies of the working model are then cut and trimmed. It is helpful to trim the dies and edentulous areas a little more than usual to provide bulk for the mask material. The surface of the model and the internal surface of the putty impression that will receive the mask should be lubricated with silicone spray or liquid. The mask material should be mixed following the instructions of the manufacturer and the mixed material loaded into an impression syringe. The mask material on the model is injected in the areas where soft tissue restoration is desired (this is usually all trimmed areas) (Fig 12). The polyvinyl putty impression should be immediately reseated accurately and forcefully on the working model. Excess mask material will flow from under the polyvinyl putty impression (Fig 13).

This putty impression serves as the mold, which shapes the mask material to form the soft tissue. After the mask material is set, the putty impression is removed. The gingival mask should remain on the model. The gingival mask is then carefully removed from the model. It may be necessary to remove the dies and the mask at the same time. Once removed from the model, excess material and flash is removed from the gingival mask using sharp surgical scissors (Fig 14). The trimmed gingival mask can now be replaced over the

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Permeability of Root Dentin to Epinephrine Released from Gingival Retraction Cord

A E CIARLONE • D H PASHLEY

Summary

The permeation of racemic epinephrine across roots of human molar crown segments was studied in vitro. Permeation was measured in the presence of cementum, with cementum removed (dentin exposed), and with and without dentin smear layers. Epinephrine was initially detected at 10 minutes and reached a steady state in 70 minutes. Epinephrine flux (the product of concentration and the flow rate per unit of dentin surface area) significantly increased when both the cementum and dentin smear layers were removed. The $T^{1}/_{2}$ (half-time in minutes necessary to reach steady-state diffusion) was zero with intact cementum and increased to approximately 40 minutes in dentin with and without smear layers. This study suggests that the permeation of epinephrine across root surfaces is prevented by the presence of cementum and retarded by the presence of dentin smear layers. Also, the data suggest that root dentin is another source of absorption when epinephrine-impregnated retraction cord is applied to the gingival sulcus.

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Introduction

The systemic absorption of epinephrine from the gingival crevice is controversial. Phatak and Lang (1966) and Houston and others (1970) showed that normal patients did not produce consistent changes in blood pressure or heart rate when epinephrine-impregnated cords were used. However, Forsyth and others (1969) described both increased blood pressure and heart rate in rhesus monkeys

FIG 15. *Gingival mask replaced and ready for the fabrication of the fixed partial denture*

FIG 16. *Clinical case showing the completed fixed partial denture on the master model. The gingival mask is indicated by the arrows.*

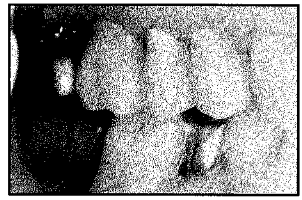

FIG 17. *Clinical case showing the completed fixed partial denture ready for cementation. Compare the patient's soft tissue contours to those of the gingival mask (Fig 16).*

seated dies (Fig 15).

The gingival mask can be removed and replaced as needed by the technician during the fabrication of the restorations. In this clinical case the restorations were fabricated using the gingival mask as a guide (Fig 16). One of the advantages of the gingival mask is that over-contoured restorations will be difficult to seat on the model due to the restrictive nature of the gingival mask. The technician will then make adjustments as needed to allow for complete seating and to perfect the adaptation. The completed restorations should accurately adapt to the gingival contours of the patient with little, if any, adjustment needed (Fig 17).

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and Todd and others (1988) reported similar responses in dogs with the use of epinephrine-containing cords. Although most of the systemic absorption of epinephrine was probably via gingival tissues, some of the epinephrine may have permeated across the cementum and dentin of the roots of the involved teeth, followed by uptake by pulpal blood vessels.

There are only a few reports on the quantitative diffusion of drugs across dentin. Both Pashley, Livingston and Outhwaite (1978) and Hastings and others (1986) studied the permeability of lidocaine to coronal dentin. The diffusion of triamcinolone and tetracycline was reported across both coronal and radicular dentin (Abbott, Heithersay & Hume, 1988; Abbott, Hume & Heithersay, 1989a, 1989b, 1989c), whereas Csukas and others (1987) studied the permeability of metronidazole to radicular dentin. Ciarlone and others (1988) and Ciarlone, Johnson and Pashley (1989) reported both the diffusion and filtration of tetracycline across crown segments. Recently, both Ciarlone and others (1991) and Grower, Abueme and Seng (1990) used discs to study the permeability of epinephrine and indomethacin respectively across dentin.

The first four studies of epinephrine absorption already cited assumed absorption of the drug was limited to the gingival crevicular epithelium lining the gingival sulcus. Ciarlone and others (1991) measured the quantitative diffusion of epinephrine across coronal dentin. The purpose of this study was to examine the influence of the presence of cementum, and the presence and absence of dentin smear layers on the permeation of radicular dentin to epinephrine released from gingival retraction cord.

Materials and Methods

Fully erupted human molars extracted for periodontal reasons were used. The teeth had minimal or no occlusal caries and there were no carious lesions on the approximal surfaces of enamel or cementum. They were stored in isotonic saline containing 0.2% (wt/vol) sodium azide at 4 °C until used; sodium azide was added to inhibit the growth of microorganisms. The teeth were cut perpendicular to the long axis of the tooth with a low-speed diamond saw (Isomet, Buehler Ltd, Evanston, IL 60204) so that there was at least 2 mm of root surface remaining below the cementoenamel junction. These crown segments were cemented to a 2 x 2 x 0.7 cm piece of Plexiglas using cyanoacrylate (Fig 1). The Plexiglas was penetrated by a 20-gauge needle to permit perfusion of the pulp chamber. A wax replica of periodontal tissue and gingiva was constructed peripheral to a spacer that was placed circumferentially around the tooth. The plastic spacer was then removed to create a circumferential space around the root surface that simulated a gingival crevice/pocket, depending on its depth (Fig 1).

A thin polyethylene tube (PE10) was then passed up a 20-gauge needle to reach the top of a pulp horn. This inlet was attached to a syringe pump set to deliver 0.1 ml/min of 0.005 N hydrochloric acid. This acid solution was insufficient to remove any smear layers but adequate to prevent breakdown of epinephrine. The larger outlet polyethylene tube (PE90) carried the effluent into test tubes that were placed in a fraction collector (ISCO Foxy, ISCO, Lincoln, NE 68505) such that 1 ml of solution was collected every 10 minutes (Fig 1).

Experimental drug diffusion studies began when the crevice was dry and then filled with study drug. The "crevicular fluid" was sampled with 1 μl pipets from a capped sampling port every 10 minutes for a total time of 120 minutes in each experiment. Evaporation from the gingival crevice was prevented by covering the opening with boxing wax that contained a pin hole.

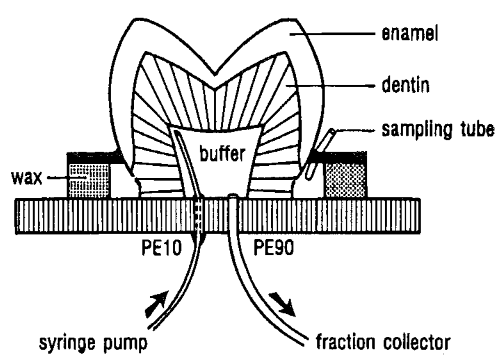

FIG 1. *Cross section of schematic that demonstrates an in vitro gingival crevice/pocket model*

The drug that was used for the diffusion studies was epinephrine contained in gingival retraction cord (Gingi-Pak Cord #2, racemic epinephrine HCl, Henry Schein, Inc, Port Washington, NY 11050). This cord was labeled to contain 0.5 mg of racemic epinephrine HCl per inch of cord, or 0.42 mg of racemic epinephrine per inch.

For each experiment, one inch of cord was placed circumferentially in the gingival crevice followed by addition of 200 µl of 0.005 N hydrochloric acid. The released epinephrine was allowed to diffuse across the intact root cementum for two hours, then the gingival crevice was emptied of both the cord and diluent, dried, refilled with 0.005 N HCl, and the diffusion resumed for an additional 30 minutes in order to empty all dentinal tubules that might contain epinephrine. This sequence was repeated with the cementum removed (dentin exposed) and again without the dentin smear layer. Smear layers were removed with 0.5 M EDTA at pH of 7.4, and the root was rinsed with distilled water after a two-minute exposure.

Cementum was removed with a diamond depth cutter (834-016, Brasseler USA, Savannah, GA 31419). The diamond depth cutter was applied to the root surface such that the shank portion of the cutter always contacted the root surface, allowing the diamond cutter to produce essentially the same depth (0.3 mm) around the root. Then a #557 carbide crosscut fissure bur (Henry Schein, Inc) was used to create the same depth as the diamond cutter on the remaining cementum-covered root surface, apical to the original groove. Finally a #4 carbide round bur (Henry Schein, Inc) was used to remove the remaining cementum, occlusal to the initial groove, up to the cementoenamel junction.

Diffusional surface area was calculated from rubber-base impressions of the prepared radicular dentin. The impressions were slit in such a manner that a glass slide could spread the area flat to permit a photograph to be taken. The surface areas were integrated from photo enlargements using a computer-driven digitizing tablet (Summa Sketch, Sigma-Scan, Jandel Scientific, Sausalito, CA 94925). Dentin thickness was measured with an electronic digital caliper (Stoelting Co, Chicago, IL 60623).

All effluent samples and epinephrine standards were analyzed fluorometrically on an Aminco-Bowman spectrophotofluorometer (SLM Instruments, Inc, Urbana, IL 61801), by the same method described for norepinephrine (Ciarlone, 1976). The excitation and emission settings were 420 and 500 nm respectively (uncorrected). Preliminary experiments (data not shown) demonstrated that neither the analysis of epinephrine nor the use of the spectrophotofluorometer resulted in any quantitative difference between the fluorometric measurement of racemic epinephrine or l-epinephrine, although the standards used were racemic epinephrine HCl (Sigma Chemical Co, St Louis, MO 63178).

Statistical analyses of the data were done using Student's *t*-test and paired *t*-tests. Epinephrine permeation across dentin was expressed both as a measure of concentration in the collected fractions and as a flux. The latter was calculated as the product of diffused epinephrine concentration and the flow rate per unit dentin surface area.

Results

Figure 2 summarizes the results of epinephrine diffusion across dentin as a function of time. There was no diffusion of epinephrine across crown segments with intact cementum over the two-hour test period. The crown segments studied after removal of the cementum but with intact smear layers (Fig 2)

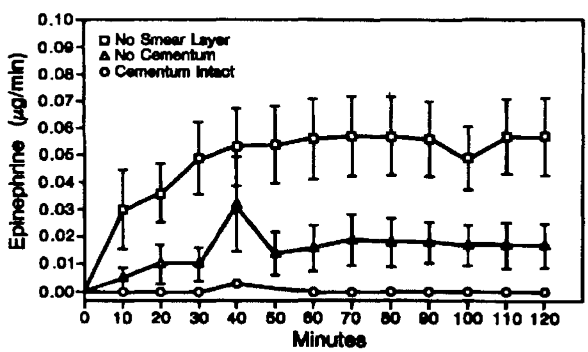

FIG 2. *The pulpal appearance of racemic epinephrine in µg/min (X ± SEM) that diffused across dentin (0-120 min). One inch of gingival retraction cord (0.39 mg) and 200 µl of 0.005 N HCl were applied to the root surface crown segments at zero time (N = 6).*

showed an initial average flux (± standard error of the mean) of racemic epinephrine at 10 minutes of 5 ± 4 ng/min and appeared to peak at 70 minutes (19 ± 11 ng/min). When these same crown segments had their smear layers removed, the initial value was 30 ± 17 ng/min, and the peak occurred at 70 minutes (57 ± 18 ng/min). Removal of the smear layer increased the magnitude of the epinephrine flux but not the time required to reach a peak value. With the exception of the zero- and 40-minute data, all the other data points at every time period were significantly different, comparing crown segments with and without smear layers ($P < 0.05$). All the average values from 10-120 minutes were significantly different, comparing crown segments with and without cementum ($P < 0.05$).

In the table, epinephrine peak flux (the concentration multiplied by the volume of the effluent per minute) increased from zero with intact cementum, to 19.65 ± 0.01 ng min^{-1} cm^{-2} when cementum was removed and with a smear layer present ($P < 0.002$). Similarly, the flux increased from 19.65 ± 0.01 ng min^{-1} cm^{-2} with intact smear layers to 69.72 ± 0.03 ng min^{-1} cm^{-2} when the smear layers were removed ($P < 0.001$). Lastly the flux increased from zero with intact cementum to 69.72 ± 0.03 ng min^{-1} cm^{-2} when both cementum and smear layers were removed ($P < 0.001$).

The $T^1/_2$ (half-time in minutes necessary to reach steady-state diffusion of epinephrine) was not significantly different when comparing dentin with and without smear layers. It ranged between 36-40 minutes.

Each time one inch of epinephrine cord was cut and used, it was also weighed so that we would have a more accurate accounting of drug use and content. This resulted in a mean (± standard error of the mean) weight of cord used of 7.16 mg ± 0.05. Based on preliminary experiments (data not shown) we have determined that one inch of cord (7.16 mg) contained 0.39 mg of racemic epinephrine in a releasable or soluble form. That amounted to 93% release of the theoretical amount of epinephrine that the manufacturer claimed was in the cord.

Racemic epinephrine is a mixture thought to contain equal parts of d- and l-epinephrine. It is well known that l-epinephrine is the active form, whereas d-epinephrine is often thought to be inactive. However, Weiner (1985) suggested that l-epinephrine was 10 or more times as potent as the d-isomer, and Bowman and Rand (1980) reported that the l-isomer was 15 times more potent. If we assume that the l-isomer is 12 times as potent as d-epinephrine, then one inch of racemic epinephrine has about 0.21 mg of the pharmacologic activity of l-epinephrine (instead of one-half of 0.39 mg or 0.195).

The average dentin surface area (± standard error of the mean) of the roots of six crown segments used in these experiments was 0.93 cm^2 ± 0.08, whereas the average thickness (± standard error of the mean) of radicular dentin remaining on all teeth at the end of this study was 1.74 mm ± 0.06 (N = 6).

The Peak Flux and $T^1/_2$** of Racemic Epinephrine (N = 6)*

Surface Condition	Epinephrine Flux (X ± SEM)	$T^1/_2$ (X ± SEM)
cementum intact	0	0
dentin + smear layer	20 ± 0.01	40.0 ± 10.0
dentin - smear layer	69 ± 0.03	35.8 ± 7.5

Groups not joined by a vertical line in the same plane are statistically different at $P < 0.05$.

*Absolute flux in ng min^{-1} cm^{-2}
**Half-time in minutes of steady-state diffusion of epinephrine

Discussion

Very little detailed information is known about the diffusion of drugs across dentin. For water-soluble drugs, diffusion is presumably limited to the area or volume offered by the fluid-filled dentinal tubules. This area increases as dentin is made thinner (Outhwaite, Livingston & Pashley, 1976) and when smear layers are removed (Pashley, Michelich & Kehl, 1981b).

Once enamel or cementum is removed from a tooth in situ, there is a natural movement of dentinal fluid from the pulpal side of dentin to the external surface, which tends to oppose diffusion and is driven by pulpal pressure

(Vongsavan & Matthews, 1991). However, Pashley and others (1981a) reported that dog dentin permeability to ^{131}I is similar both in vivo and in vitro. Moreover, the in vivo application of 1 mg/ml epinephrine topically to dentin of dog molars caused a 90% reduction in pulpal blood flow within eight minutes, as measured with a Laser Doppler flowmeter (Perimed Inc, Piscataway, NJ 08855) (unpublished observations). Therefore, despite the fact that pulpal pressure tends to oppose diffusion of substances, epinephrine does diffuse across dentin in vivo.

Epinephrine released from gingival retraction cord and absorbed has been shown to produce systemic effects (Forsyth & others, 1969; Todd & others, 1988), but no one has quantified the diffusion of epinephrine across radicular dentin. Certainly such diffusion is possible if the cord is in close apposition to dentin, whether it be axial wall dentin associated with the crown, or radicular dentin. Regarding the latter, even if the restorative preparation does not extend to include the root surface, patients still present on occasion with teeth whose cementum has been removed, for whatever reason or cause. Such exposed dentin will contain tubules available for diffusion of epinephrine. One would expect the gingival absorption of epinephrine to occur within minutes. The half-time of epinephrine diffusion across radicular dentin was nearly 40 minutes. Thus radicular dentin, because it slows diffusion, may serve as a depot of epinephrine that would be released over a longer time than would be seen in gingival absorption.

Although the amount of epinephrine permeable to radicular dentin without a smear layer was significantly less (36%) than we reported for 1.0 mm thick coronal dentin discs at steady-state (Ciarlone & others, 1991), the actual amount (57 ng/min at 70 minutes) is a large dose of either racemic epinephrine or l-epinephrine for a single pulp. (Converting 57 ng/min to l-epinephrine activity = 31 ng/min). Also, the average thickness of radicular dentin used in this study was 1.74 mm, and so a lesser amount was to be expected since there is an inverse relationship between concentration of drug and dentin thickness. In addition, we were not surprised to note a lesser amount of epinephrine diffusion across radicular dentin since Fogel, Marshall and Pashley (1988) reported that radicular dentin is 10-20 times less permeable than coronal dentin. Moreover, this dose of epinephrine might result in pulpal ischemia and perhaps be deleterious to the pulp. This is because a small dose of epinephrine diffusing across dentin may increase the pulpal concentration of the drug by constricting resistance vessels, producing a positive feedback. This would result in higher pulpal epinephrine concentrations, which would produce more vasoconstriction. Therefore, even a small dose of epinephrine could be potentially damaging to the pulp. Few investigators have considered the potential pulpal effects of the use of epinephrine-containing gingival retraction cord. The in vitro model described in this report should be useful in studying the kinetics of any therapeutic substance placed in the gingival crevice.

Conclusions

The diffusion of racemic epinephrine across radicular dentin was prevented by the presence of cementum and was retarded by the presence of a dentin smear layer. The application of one inch of racemic epinephrine-containing retraction cord (0.39 mg) produced relatively high concentrations of the drug on the pulpal side of crown segments, and this concentration could have a significant effect on pulpal microcirculation.

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In Vitro Evaluation of the Use of Resin Liners to Reduce Microleakage and Improve Retention of Amalgam Restorations

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Summary

This in vitro study evaluated the ability of three commercially available adhesive resins to reduce microleakage and provide retention between amalgam restorations and tooth structure. Results indicated that Amalgambond reduced leakage significantly more than Panavia EX, Prisma Universal Bond 2, and Copalite. In addition Amalgambond and Panavia EX exhibited the ability to bond amalgam to tooth structure. These results suggest that Amalgambond has the potential for serving successfully as a cavity liner with amalgam.

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INTRODUCTION

Amalgam has served effectively as a dental restorative material since its introduction to the United States in 1833 (Craig, 1985). Amalgam has many advantages including ease of manipulation, long clinical service life, and low cost. Because it is one of the least technique-sensitive direct restorative materials, it accepts a great deal of misuse without failure (Jordan, Suzuki & Boksman, 1985). As with most other materials, however, amalgam has its own distinct set of disadvantages. In particular, microleakage and a lack of adhesion to the structure are shortcomings that have limited its effective use in certain clinical situations.

Recently, adhesive resins have been used as cavity liners in an attempt to reduce leakage and provide retention of amalgam restorations. In particular, resins based on the bisphenyl-A glycidyl methacrylate (BIS-GMA) monomer or the methacryloxyethyl trimellitic anhydride (4-META) monomer have been studied in some depth. Research has indicated that these adhesive resins may be capable of reducing the degree of leakage at the tooth/amalgam interface and increasing retention of amalgam restorations (Shimizu, Ui & Kawakami, 1987; Torii & others, 1988; Staninec & Holt, 1988; Shimizu, Ui & Kawakami, 1986).

The purpose of this study was to evaluate the efficacy of three commercially available adhesive resin materials in reducing microleakage and providing an adhesive bond between amalgam and tooth structure.

MATERIALS AND METHODS

Retention Test

A total of 100 extracted, intact human molars were used for the retention test. The crowns were separated from their roots at the level of the cementoenamel junction using a sectioning machine with a diamond disc under a constant stream of water. The crowns were mounted in autopolymerizing acrylic resin cylinders to expose a flat facial, lingual, or approximal enamel surface. Each specimen was mounted in the chuck of a three-inch lathe, and a cavity 3.5 mm deep and 3 mm in diameter was prepared using a #557 carbide bur in a high-speed handpiece with water spray coolant. Each bur was used to prepare only 15 cavities. The preparations were machined to produce slightly divergent lateral walls, which ensured that the cavities were not undercut. Immediately prior to treatment, each preparation was cleansed with 3% hydrogen peroxide for 10 seconds, rinsed, and dried. The prepared teeth were randomly divided into five test groups, each consisting of 20 specimens, to test three commercially available adhesive resin systems. The test groups were treated in the following ways: Group 1, no varnish or liner; Group 2, Copalite varnish (Harry J Bosworth Co, Skokie, IL 60076); Group 3, Prisma Universal Bond 2 (L D Caulk Co, Division of Dentsply, Milford, DE 19963); Group 4, Panavia EX (J Morita, Tustin, CA 92680); Group 5, Amalgambond (Parkell Products, Farmingdale, NY 11735). The adhesive resins were prepared and applied to the cavity walls according to their manufacturers' instructions. Following treatment of the preparation a 3/4-inch by 18-gauge flat-headed wire nail was placed into the cavity with the head resting on the pulpal floor. Before the nail was placed into the preparation, a thin layer of Copalite was applied to the nail head to prevent it from bonding to resin adhesives. Tytin (Sybron/Kerr, Romulus, MI 48174) was triturated for five seconds at the M2 setting of a mechanical amalgamator (Vari-Mix II, L D Caulk Co) and immediately condensed into the preparation using a small-diameter condenser. An interproximal instrument was used to carve the restoration flush with the external surface of the tooth (Fig 1). In Group 4 (Panavia EX), immediately after carving, the margins of the restorations were coated with Oxyguard as recommended by the manufacturer.

Following preparation, the specimens were stored for 24 hours in distilled water at 37 °C. The specimens were thermally stressed by subjecting them to 2500 thermocycles between a 5 °C bath and a 45 °C bath. After thermocycling, the specimens were stored in distilled water at 37 °C.

Retention testing was performed five days after specimen preparation. Each specimen was attached to an Instron Universal Testing Machine (Instron Corp, Canton, MA 02021) by

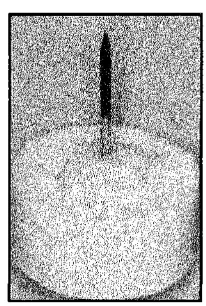

FIG 1. *A specimen prepared for retention testing: the head of the nail rests on the pulpal floor of the preparation.*

suspending the acrylic resin base of the specimen from a wire basket attached to the upper grip of the Instron. The nail projecting from the specimen was fastened into a pin vise inserted into the lower grip (Fig 2). The specimens were loaded to failure in tension at a crosshead speed of 2 mm/min, and the load required for failure was recorded. The modes of failure of the specimens were grossly observed and recorded as adhesive, cohesive, or mixed. Adhesive failures were those in which the nail and amalgam were removed from the preparation intact without causing fracture of the tooth structure. Cohesive failures were those entirely within the tooth structure, and mixed failures occurred within both tooth structure and between the amalgam and tooth structure.

After performing a Hartley test to determine that the variances were homogeneous, the data were analyzed by one-way analysis of variance to test for significant differences between the five treatment groups. Multiple comparisons were made between group means by employing Fisher's Least Significant Differences method.

Microleakage Test

A total of 100 extracted, intact human canines and premolars were used for the microleakage test. In each of the teeth a 3 mm

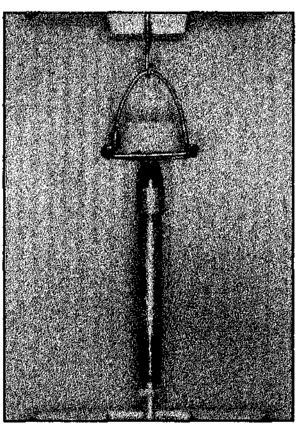

FIG 2. *Apparatus for retention testing mounted in the Instron machine*

mesiodistal by 2 mm occlusogingival by 2 mm deep class 5 cavity was prepared in the middle third of the facial surface using a #557 carbide bur in a high-speed handpiece with water spray coolant. Each bur was used to prepare only 15 cavities. Preparation outline form was ovoid, and cavosurface margins were butt joint and entirely within enamel. No mechanical undercuts were placed. All preparations were made in as uniform a manner as possible. Just prior to treatment, each preparation was cleansed with 3% hydrogen peroxide for 10 seconds, rinsed, and dried. Five test groups, each consisting of 20 specimens, were treated with the same cavity linings as used with the retention test groups. The cavities were restored by condensing Tytin into the preparation and carving the restoration flush to the external surface of the tooth. Following preparation, the specimens were stored for 24 hours in distilled water at 37 °C. They were then thermocycled and stored under the same conditions as were previously described. After thermocycling, the specimens were stored in distilled water at 37 °C.

Microleakage testing was performed five days after specimen preparation. The specimens were prepared according to the technique of Phillips and others (1961). The specimens were immersed for 24 hours in a 2% aqueous solution of a fluorescent dye (Zyglo Penetrant ZL-54, MagnaFlux Corp, Chicago, IL 60656) and stored at 37 °C. Each tooth was sectioned buccolingually using a sectioning machine to produce a longitudinal cut through the restoration. The facial surfaces of the restorations were coated with dark nail polish to reduce scattered illumination from dye exposure. The specimens were mounted flat on a piece of card stock to allow the examiners to view the cavity margins from the same angle. The specimens were illuminated by two ultraviolet light lamps (Blak-Ray, Ultra-Violet Products, Inc, San Gabriel, CA 91776). Aluminum cones were positioned over the lamps to direct the light toward the specimens and to eliminate scattered illumination. Two independent evaluators examined the cavities with the aid of a stereomicroscope at X25 magnification and scored the degree of microleakage according to a standard as shown in Figure 3. The diagram corresponds to the following degrees of dye penetration: 1 = no penetration; 2 = penetration up to one-half of the distance from the margin to the axial wall; 3 = penetration from the margin to the axial wall; 4 = penetration along the axial wall.

Occlusal and gingival wall measurements were made for each specimen. The examiners evaluated the specimens three times.

The Pearson correlation method was employed to evaluate for interevaluator and intraevaluator agreement. Because no significant difference was found for the interevaluator and intraevaluator evaluations, the majority score for each of the two margins of each specimen was used. Ridit analysis was performed to obtain ridit means and standard deviations for the occlusal and gingival margins for each of the five groups. Variances for the occlusal and gingival margins within each group were determined to be homogeneous by Bartlett's test, and one-way analysis of variance at the 0.05 probability level indicated that no significant differences existed between the two margins for any of the treatment groups. As a consequence, the occlusal and gingival scores within each treatment group were combined to produce a sample size of 40, and new ridit means and standard deviations were calculated. Since Bartlett's test found these new variances to be nonhomogeneous, Welch's test was performed to determine if significant differences existed between the groups at the 0.05 probability level. Multiple comparisons were carried out using the Newman-Keuls test.

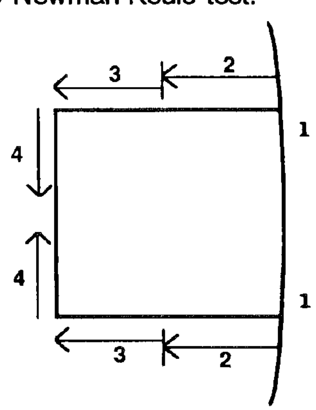

FIG 3. *Standard used in the evaluation of microleakage*

RESULTS

Retention Test

The mean loads at failure for the five treatment groups are presented in Table 1. Analysis of variance indicated a significant difference between the groups at the 0.05 probability level. Multiple comparisons revealed that the Panavia EX and Amalgambond groups exhibited significantly higher mean loads at failure than did the other three groups. Furthermore, the Prisma Universal Bond 2 group had a significantly higher mean failure load than did the Copalite group and the group that received no treatment.

The distribution of failure modes for the

Table 1. Load at Failure (kg)

Cavity Treatment	Mean (SD)
Copalite	22 (7.51)
No varnish or liner	26 (6.86)
Prisma Universal Bond 2	31 (6.57)
Amalgambond	37 (5.88)
Panavia EX	37 (7.69)

N = 20
Vertical lines connect nonsignificant differences at the 0.05 probability level.

Table 2. Distribution of Failure Modes

		Mode of Failure		
Cavity Treatment	**N**	**A**	**M**	**C**
No varnish or liner	20	20	0	0
Copalite	20	17	3	0
Prisma Universal Bond 2	20	14	6	0
Panavia EX	20	7	13	0
Amalgambond	20	14	6	0

N: Total number of specimens
A: Adhesive failure
M: Adhesive and tooth structure cohesive failure
C: Tooth structure cohesive failure

treatment groups is presented in Table 2. The group that received no treatment exhibited an adhesive failure rate of 100%. The modes of failure for the Copalite group were 85% adhesive and 15% mixed. The Prisma Universal Bond 2 group showed 70% adhesive and 30% mixed failure rates while the Panavia EX group exhibited almost the reverse situation with a 35% adhesive rate of failure and a 65% mixed rate. The Amalgambond group experienced 70% adhesive and 30% mixed failure rates.

Microleakage Test

The distribution and degree of microleakage for the occlusal and gingival margins of each treatment group are presented in Table 3. Ridit means and standard deviations for the five treatment groups are presented in Table 4. Larger ridit means indicated a greater degree of leakage.

The rank orders of the mean loads at failure and microleakage for the five groups are shown in Table 5. Although an exact correlation between the results was not found, the Amalgambond group ranked first in both tests while the Copalite group ranked last.

DISCUSSION

The use of adhesive resins as lining agents with amalgam has recently been suggested (Staninec & Holt, 1988). One intent is to establish a bond between the amalgam and tooth structure that will improve retention. The significantly higher mean loads at failure for the Panavia EX and Amalgambond groups compared to the other three are consistent

Table 3. Distribution of the Degree of Leakage

		Leakage Categories			
Cavity Treatment	**N**	**1**	**2**	**3**	**4**
No varnish or liner	20	11	0	0	9
occlusal		10	0	0	10
gingival					
Copalite	20	0	13	1	6
occlusal		2	12	0	6
gingival					
Prisma Universal Bond 2	20	0	19	1	0
occlusal		0	16	3	1
gingival					
Panavia EX	20	0	20	0	0
occlusal		0	19	1	0
gingival					
Amalgambond	20	11	8	1	0
occlusal		11	9	0	0
gingival					

N: Total number of specimens

Table 4. Microleakage Scores

Cavity Treatment	Ridit Mean (SD)
No varnish or liner	0.50 (0.41)
Copalite	0.62 (0.22)
Prisma Universal Bond 2	0.56 (0.11)
Panavia EX	0.52 (0.05)
Amalgambond	0.30 (0.22)

Vertical line connects nonsignificant differences at the 0.01 probability level.

Ridit values: Category 1 = 0.11
Category 2 = 0.52
Category 3 = 0.82
Category 4 = 0.92

Table 5. Rank Orders According to Load at Failure and Microleakage

Cavity Treatment	Load at Failure	Microleakage
No varnish or liner	3	2
Copalite	4	5
Prisma Universal Bond 2	2	4
Panavia EX	1	3
Amalgambond	1	1

1 denotes the highest load at failure and the least leakage; 5 denotes the lowest load at failure and the most leakage.

with the findings of other researchers who have determined that adhesive resins have the ability to bond amalgam to both enamel and dentin. Staninec (1989) studied the effects of an adhesive resin liner and mechanical undercuts on the retention of amalgam in approximal cavity preparations placed in extracted human teeth. By measuring the mean force required to dislodge the restorations, he found that amalgams lined with the adhesive resin had significantly greater retention than those placed in preparations having mechanical undercuts.

As can be seen in Table 1, mean failure loads for the two systems were found to be the same. This differs from the results of other investigators. Shimizu and others (1986) and Cooley, McCourt and Train (1989) found that a 4-META-based adhesive produced a stronger bond to amalgam than did Panavia. These differences in bonding between systems may well be due to differences in study design. The first group of researchers, for example, was primarily concerned with the evaluation of adhesiveness of these resins to tooth structure when the enamel and dentin were altered by surface treatments with fluoride and intermediate lining materials such as glass-ionomer cements. The design of the second study was directed toward measurement of the ability of the resins to adhere to amalgam alloy where the surface had been altered with diamond burs or an air polisher. These variations in design and intent make direct comparisons between the studies difficult.

The mean failure load for the Prisma Universal Bond 2 group was significantly higher than for the Copalite and untreated groups. This result is difficult to compare with other studies because most investigators have limited their evaluations to systems such as Panavia and 4-META resins that claim to bond to metals. The manufacturers of Prisma Universal Bond 2 do not make such a claim.

Although the difference was not significant, the mean load at failure of the untreated group was higher than that of the Copalite-treated group. The lower value for the Copalite group may have been due to the ability of the varnish to fill in irregularities in the cavity walls produced by the cutting action of the bur. Such irregularities may increase mechanical retention.

In addition to providing a bond between amalgam and tooth structure, adhesive resins have been proposed as liners in hopes that they would reduce the degree of microleakage that normally occurs at the interface between amalgam and tooth structure.

As indicated in Table 4, the use of Amalgambond resulted in significantly less leakage than did the other liners. Comparison of this result with previous studies is difficult because the use of 4-META resins to reduce leakage with amalgam has been rather limited. Cooley and Tseng (1991) evaluated the ability of Amalgambond to reduce leakage at both the occlusal and gingival margins of class 5 amalgam restorations in extracted human molars. They found significantly less leakage for the Amalgambond-treated teeth compared to those treated with a traditional cavity varnish. Varga, Matsumura and Masuhara (1986) also found that a 4-META-based adhesive significantly reduced microleakage when used as a liner with amalgam.

The finding that Panavia EX and Prisma Universal Bond 2 did not significantly reduce leakage when compared to the control group differs from the results of other investigators. Shimizu and others (1987) and Staninec and Holt (1988) found that the use of Panavia as an amalgam liner reduced leakage when compared to an unlined treatment group. Yu, Wei and Xu (1987), Ben-Amar and others (1987), and Liberman, Matalon and Gorfil (1989) similarly found that other adhesive resins were efficacious in reducing the degree of leakage around amalgam restorations.

Another finding of this investigation that is contrary to the results of other similar studies (Newman, 1984; Kelsey & Panneton, 1988; Murray, Yates & Williams, 1983; Sneed, Hembree & Welsh, 1984) is that the Copalite-treated group exhibited more leakage than did the untreated group. Although the differences were statistically significant, there was a numerical difference in ridit means.

For the most part, the evaluators had little difficulty is assigning specimens to a category indicating their degree of leakage. However, one unusual pattern of fluorescence was noted. In a few instances, fluorescence was clearly visible along the axial wall of the restoration with no visible sign of dye penetration along either the occlusal or gingival walls (Fig 4). One explanation is that leakage occurred from the pulp chamber to the axial wall. However, careful examination of the pulp chambers of the involved specimens yielded no sign whatever of dye presence. Other possible explanations not so easily disproved are that leakage occurred out of the plane of sectioning or that leakage did occur at the occlusal or gingival margins but the dye was not present in sufficient amounts to produce fluoresence. The latter explanation, if true, would bode poorly for the future of the fluorescent dye technique as a means of microleakage detection.

The possibility that fluorescent dye may not be capable of detecting small amounts of leakage coupled with the results indicating that Copalite was ineffective in reducing leakage when compared to the untreated control group brings into question the efficacy of this marker as an indicator of leakage. Adding to these concerns are the rather large standard deviations seen with some of the treatment groups. The control group in particular had a large standard deviation that reflected the fact that 21 of its leakage scores were in Category 1, and the remaining were in Category 4. Additional research needs to be done to address these concerns.

Future work may be directed toward determining if leakage is uniform or nonuniform at all points along a restoration's margins. Additionally the validity of using fluorescent dye as a leakage marker and its ability to detect small amounts of leakage should be confirmed or denied by comparing it with a well-tested tracer such as radioactive calcium.

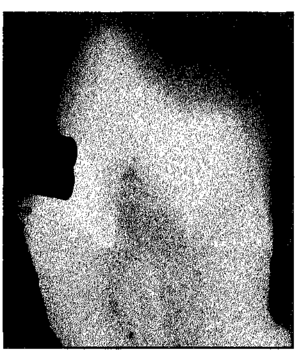

FIG 4. *Example of a specimen exhibiting axial wall leakage in the absence of occlusal and gingival margin leakage*

It is apparent from an examination of the results of these two tests that although a certain degree of correlation exists between them, it is not complete (Table 5). The Amalgambond group exhibited the least leakage and, along with the Panavia EX group, had the highest mean load at failure. The Copalite group had the most leakage and the lowest mean load at failure. The results indicate that only partial correlation exists between the two tests and that neither one should be used as an absolute predictor of the other.

CONCLUSIONS

1. Restorations placed in preparations lined with Amalgambond exhibited significantly less leakage than did restorations placed in unlined preparations or in those lined with Panavia EX, Prisma Universal Bond 2, or Copalite.
2. Restorations placed in preparations lined with Amalgambond or Panavia EX exhibited significantly greater retention than did restorations placed in unlined preparations or in those lined with Prisma Universal Bond 2 or Copalite.
3. Amalgambond has the potential for serving successfully as a cavity liner with amalgam restorations.

The opinions expressed herein are those of the authors and do not necessarily reflect the opinions of the Department of Defense or the United States Air Force.

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DEPARTMENTS

Letters

RETENTION GROOVES FOR THE CLASS 2 AMALGAM RESTORATION: NECESSITY OR HAZARD?

Dr Moore's conclusion does not stand up to clinical observation. After observing amalgam failures for 40 years, I have concluded that other than when the caries obliterates the cavity preparation, almost all failures are due to fracturing of the approximal portion of the class 2 amalgam.

If and when we can place an ideal amalgam in a caries-free mouth in a mature individual, then a very conservative preparation like Dr Miles Markley advocates can be used. This preparation does not extend beyond the contact area of the gingival or buccal-lingual; thus the approximal walls are parallel (determined by direction of enamel prisms).

When the more common type of caries is found and decalcification has extended out on the enamel, the extensions have to be carried out further on the buccal, lingual, and gingival. We are now dealing with walls that flare out in all directions, and the preparation is wider gingivally than occlusally, so the only retention that the amalgam has is the occlusal extension. If these are made deep enough and wide enough, the restoration may stay in, but only because of the presence of the bulk of the amalgam in the occlusal dovetail.

Grooves tend to undercut the supporting dentin from the enamel; thus the most conservative preparation is the Ferrier modified black type. The resistance is placed by enamel hatchets or bin angle chisels in a gradual slope to the axial wall.

I agree grooves should not be used, but retentive areas are very definitely needed.

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RESPONSE

With regard to the letter from Dr Jack G Seymour, which responded to "Retention Grooves for the Class 2 Amalgam Restoration: Necessity or Hazard?," it seems that Dr Seymour agrees with the major conclusion that retention grooves are usually not needed. I agree with Dr Seymour that other factors such as the size and design of the cavity preparation dictate the need for additional retention.

I am not sure exactly with which part of the conclusion that Dr Seymour disagreed. Perhaps his interpretation was that I did not support the use of any accessory retention beyond the box form. This was not my intention.

So far, I have not received any response to the article. I also have not received any response to the article in the *Journal of Dental Education* (Moore, 1992). I expected to receive at least some response. Perhaps it will come later. I have mentioned the article briefly on two occasions when I presented continuing education programs on esthetic dentistry, and verbal comments were all positive. Most dentists said that they did not routinely use grooves anyway. The survey seemed to indicate that the trend in schools was away from routine retention grooves.

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Reference: MOORE, D L (1992) Current teaching of proximal retention grooves for Class II amalgam preparations *Journal of Dental Education* **56** 131-134.

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