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SCIENTIFIC ARTICLES

Apical Leakage Associated with Retrofilling Techniques: A Dye Study

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This in vitro study utilized methylene blue dye to evaluate the extent of apical microleakage following reverse filling procedures. Forty human canine root canals were biomechanically prepared and obturated with laterally condensed gutta-percha and Roth's 801 Elite grade zinc oxide and eugenol sealer. The surfaces of the specimens were covered with red enamel paint, leaving only the apical foramen in a patent condition. The roots were then apically resected and randomly placed into one of four groups. The specimens in each group received the following treatment: group A—cold-burnished gutta-percha; group B—reverse amalgam fillings without varnish; group C—reverse amalgam fillings with varnish in cavity preparation only; and group D—reverse amalgam fillings with varnish in cavity preparation and on beveled root surface. All roots were submerged in 1% methylene blue dye for 2 wk and sectioned longitudinally, and the depth of linear dye penetration was measured. Significantly less leakage occurred when the cavity preparation and the beveled root surface were coated with varnish prior to placement of an amalgam restoration.

Although nonsurgical endodontic procedures have been shown to be successful (1), treatment failures sometimes occur. When this happens, nonsurgical retreatment may be indicated. If retreatment is not possible, surgical intervention may be performed as an alternative to tooth loss.

The goal of endodontic surgery is to achieve an apical seal of the root canal system. The literature offers a diversity of opinion as to how this can best be accomplished. Because of the many dissimilarities in both selection of material and methodologies used, the results of most reports cannot be compared directly with one another. Harrison and Todd (2) examined the effect of rotary resection of roots on the sealing property of both gutta-percha and silver cones with sealer and determined that root resection with a rotary instrument in a high-speed handpiece would not adversely affect the apical seal of a canal well obturated with gutta-percha and sealer. Moodnik et al. (3) utilized the scanning electron microscope to examine four retrograde amalgam fillings. Micrographs showed defects ranging from 6 to 150 μm at the amalgam-dentin interface. The significance of these defects was not determined. Tanzilli et al. (4) found that cold-burnished gutta-percha at the resected end of a well-debrided and well-obturated root canal gave the smoothest appearance and had 90% better marginal adaptation than either amalgam or heat-sealed gutta-percha. Kaplan et al. (5) evaluated the sealing effectiveness of apical amalgam fillings, heat-sealed gutta-percha, cold-burnished gutta-percha, and resected roots without reverse fillings. The cold-burnished gutta-percha fillings showed the least amount of leakage while the amalgam fillings had about twice as much leakage. Heat-sealed gutta-percha ranked next and the resected roots without reverse fills had the greatest leakage. Lin et al. (6), on the other hand, concluded that a reverse filling should be placed at the end of almost all roots requiring apical surgery because most failures of conventional root canal therapy are due to insufficient canal debridement (7). Delivanis et al. (8) evaluated the sealing effectiveness of Cavit, polycarboxylate cement, and amalgam as reverse filling materials and found amalgam to be the most effective material in limiting apical fluid penetration into the root canal. Barry et al. (9) also found amalgam to be superior to polycarboxylate cement when used as a reverse filling. Kos et al. (10) examined the sealing properties of poly-HEMA, zinc-free amalgam, and gutta-percha reverse fillings and concluded that amalgam and gutta-percha had poor sealing qualities when compared with poly-HEMA. Only poly-HEMA provided a microbially impervious seal.

When a cavity preparation and reverse fill are performed during an apical root resection procedure, the depth of the preparation has been shown to be a

significant factor in achieving an impregnable fluid seal. Weine (11) suggested that the minimum thickness for class I amalgam reverse fillings should be at least 1 mm, whereas Arens et al. (12) recommended a thickness of 3 mm. Tronstad et al. (13) found that the apical seal was significantly improved when a varnish was applied to the cavity prior to the placement of the reverse amalgam filling. Abdal et al. (14), evaluating marginal leakage at the apical filling/root canal interface, recommended that a cavity varnish be used in conjunction with retrofilling with conventional or high copper amalgams. Mattison et al. (15) concluded that 3 mm of amalgam significantly reduced apical leakage and that varnish applied to the cavity preparation further reduced leakage. Neither of the previous investigations considered the effect of varnish applied directly to the beveled root surface. The purposes of this study were to compare the effectiveness of cold-burnished gutta-percha and reverse amalgam fillings in limiting apical dye penetration and to evaluate the effectiveness of varnish in limiting dye penetration when applied to both the apical cavity preparation and beveled root surface.

MATERIALS AND METHODS

Forty maxillary canine teeth were obtained from the University of Florida College of Dentistry Oral Surgery Clinic. All teeth had roots that were completely formed. The age, sex, and ethnic background of the patients and the reasons for extraction were not recorded. Immediately after extraction, the teeth were placed in deionized water with thymol and maintained in this medium until tooth preparation was begun.

All anatomical crowns were resected and working lengths were determined for the remaining roots by placing a #15 K-type file into each canal to the point where the file tip extended ½ mm beyond the apical foramen. This length was then reduced by 1½ mm to become the working length. Root canals were prepared using a reaming motion to a #55 K-type file with 5.25% sodium hypochlorite as the irrigant. Canal walls were flared 4 mm short of the working length with #2 and #3 Gates Glidden drills. After instrumentation, a #15 K-type file was again passed ½ mm through the apical foramen to ensure patency. All canals were obturated with laterally condensed gutta-percha and Roth's Elite Grade 801 zinc oxide and eugenol sealer (Roth Drug Co., Chicago, IL). The coronal portion of each root canal was sealed with IRM and red enamal paint (Testors, Rockford, IL) was applied to all root surfaces with a fine artist's brush. Radiographs were taken from both a buccolingual and a mesiodistal direction to ensure complete obturation of the root canals.

A root resection was performed on the apical 2 mm of each specimen with a #169L high-speed bur and water coolant. All cuts were made on a 45-degree lingual-labial angle. The specimens were randomly placed into one of four groups, each with 10 roots. The roots in group A received no further treatment other than cold burnishing of the apical gutta-percha as described by Tanzilli et al. (4). An apical cavity preparation was made in all remaining specimens. A #2 round bur in a slow-speed handpiece was used to create a 3-mm deep class I preparation. All cavity preparations were generally circular, approximately 2.0 mm in diameter, and were slightly undercut on their labial and lingual surfaces. The roots in group B had amalgam condensed into the cavity preparations. Two coats of varnish (Copalite; Bosworth, Skokie, IL) were applied with a fine-tipped artist brush to the walls and floor of the cavity preparations of the specimens in groups C and D. The beveled surface of the roots in group D also received a double layer of varnish. A fissure bur was used to remove varnish from the beveled end of the roots in group C. Dispersalloy (Johnson & Johnson, East Windsor, NY), mixed according to the manufacturer's directions, was condensed into the cavity preparations of all specimens in groups B through D.

Two additional teeth were used as controls. One root, used as a negative control, was prepared in the same manner as the test specimens in group B except that it was completely covered with red enamel paint. A second root, used as the positive control, was instrumented, obturated, apically resected, and had an apical cavity prepared. This control had no reverse amalgam filling and was not coated with paint.

All specimens were vertically suspended in individual glass vials by attaching their coronal surfaces to the inside of the vial cover with rope wax. The apical one half of each root was submerged in an aqueous solution of 1% methylene blue dye (Fischer Scientific, Fairlawn, NJ). All vials were placed into an incubator at 37°C for 2 wk. The specimens were then removed from their vials, rinsed under tap water for 15 min, and air dried. A #169L high-speed bur was used to cut parallel labial and lingual longitudinal grooves down the sides of each specimen. Care was taken to assure that the cuts did not enter the root canal space, the beveled root end, or the reverse amalgam fillings. Final separation of the specimens was accomplished by flexing a lab knife within the prepared grooves.

The linear depth of dye penetration was measured by using an illuminated ×7 power magnifying eyepiece that had a millimeter scale in the lens. Measurements were made from the filling material center at the beveled surface along the canal to the end point of dye penetration. The data were evaluated statistically by use of an analysis of variance and the Newman-Keuls test.

RESULTS

The mean linear measurement values for apical dye penetration into the specimens in each group (Fig. 1) are shown in Table 1. Apical dye penetration was

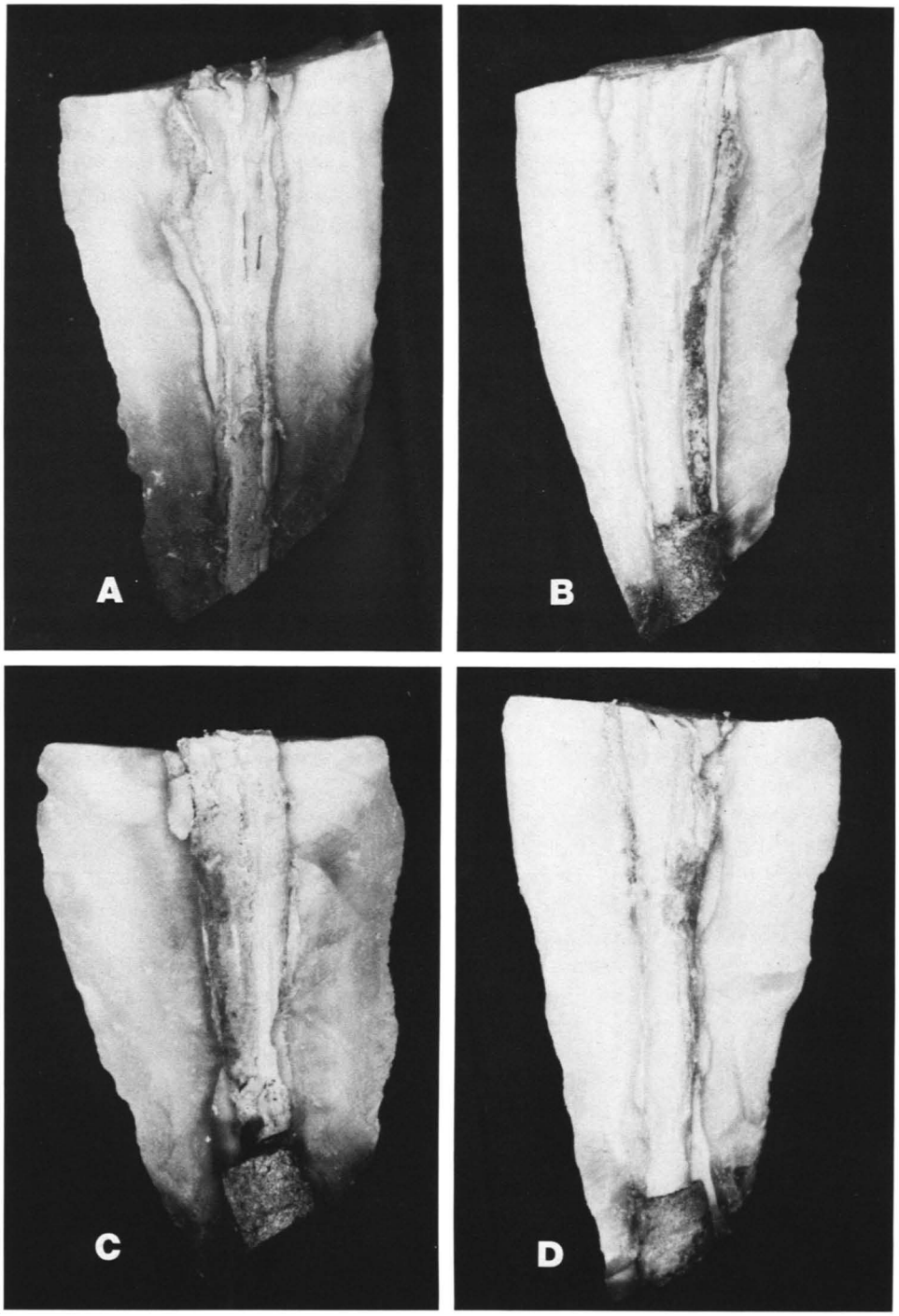

FIG 1. Longitudinally split specimens showing apical dye penetration. *A*, Apical root resection and cold-burnished gutta-percha. *B*, apical root resection and reverse amalgam fill. *C*, Apical root resection, varnish in cavity preparation, and reverse amalgam fill. *D*, Apical root resection, varnish in cavity preparation and on bevel, reverse amalgam fill.

TABLE 1. Linear dye penetration*

Group	Range	Mean	SD
A	3.4–12.2	6.90	2.870
B	2.0–3.2	2.77	0.447
C	1.6–5.4	2.80	1.070
D	0.6–1.4	1.00	0.250

* Measurements recorded in millimeters.

observed at the dentin-amalgam and dentin-gutta-percha interfaces and through the exposed dentinal tubules of the apical bevel. The positive control had the highest apical dye penetration values with no dye penetration observed in the negative control. The significance of the values between groups is shown in Table 2.

TABLE 2. Neuman-Keuls test

Paired Comparisons–Leakage Differences ($p < 0.05$)	
Significant	Not Significant
A versus B	B versus C
A versus C	
A versus D	
B versus D	
C versus D	

The test specimens in which the apical gutta-percha was cold burnished showed significantly ($p < 0.05$) more dye penetration than did the specimens that received reverse amalgam fillings. Significantly ($p < 0.05$) less dye penetration was observed when varnish was applied to both the cavity preparation and the beveled root surface. There were no significant differences ($p < 0.05$) in dye penetration between the group with cavity varnish and amalgam and the group without cavity varnish and amalgam.

DISCUSSION

Successful endodontic therapy depends to a great extent upon establishing an apical seal of the root canal system. For many years it had been felt that if there was any possibility that the apical seal was inadequate, a reverse amalgam filling should be placed during a surgical procedure. Currently the preferred method of sealing the apical canal during endodontic surgery is to trim back a well-filled heavily condensed gutta-percha root canal filling (11). This philosophy seems to be based on the findings of Moodnik et al. (3), Tanzilli et al. (4), and Kaplan et al. (5). These studies concluded that cold-burnished gutta-percha had a superior marginal adaptation and allowed less than one half the dye penetration that amalgam retrofillings did. The results of the present investigation question the use of cold-burnished gutta-percha as an apical sealing procedure because this technique consistently produced the greatest amount of linear apical dye penetration of the methods tested. Possible reasons for the differences between the present study and those of Moodnik et al. (3), Tanzilli et al. (4), and Kaplan et al. (5) include differences in methods of evaluation and differences in times that materials were tested. The Tanzilli and Kaplan studies evaluated materials 1-month after insertion whereas this study evaluated materials immediately after placement and prior to final set. The latter time was selected because it closely depicts the actual exposure of materials to fluids in the clinical setting. The Moodnik and Tanzilli scanning electron microscopic investigations provide surface information which may not be consistent throughout the depth of the materials tested. They also provide no insight into the potential for leakage through exposed apical dentinal tubules which was evident in the present study. Kaplan examined marginal leakage at the apical dentin-filling material interface; the present study evaluated leakage at the apical dentin-material interface and through the beveled root surface. The Kaplan study made apical cavity preparations 2-mm deep as compared with the present study that used 3-mm deep cavity preparations. This additional depth may have been responsible for the better results obtained with amalgam. This finding is in agreement with Mattison et al. (15) who concluded that 3 mm of amalgam significantly reduced apical leakage. Beatty (16) also demonstrated that the apical amalgam seal is enhanced if the cavity preparation is extended coronally into the root canal to at least the height of the bevel. This preparation and filling technique was found to restrict apical fluid penetration into the root canal space through exposed dentinal tubules and represents another reason for routinely placing an apical amalgam during endodontic surgery procedures (Fig. 2).

Tronstad et al. (13) have recommended that a cavity varnish be routinely used before placement of apical amalgam fillings. The application of varnish to the cavity prior to the insertion of amalgam is believed to prevent initial marginal leakage. The leakage at the amalgam-tooth interface becomes considerably reduced with time because of the accumulation of corrosion products in the gap from the γ-2 phase (17–19). The results of the present investigation disagree with the findings of Tronstad et al. (13). The presence or absence of varnish in the apical cavity preparation was found to result in no significant differences in apical dye penetration. Possible reasons for the differences in results in the two studies include differences in methods used and in evaluations used. Tronstad used an isotope to measure leakage; we used a dye. Matloff et al. (20) have shown that within the same specimens dye penetrates further than does an isotope. This could be one reason for differences in results. A second reason was that Tronstad sectioned the apical root end flat or perpendicular to the long axis of the tooth rather than on a bevel. This may have resulted in the exposure of fewer dentinal tubules and their avenues for potential leakage. Finally, it was noted in the present study that a good portion of the bevel became covered with varnish when it was applied to the cavity preparation. This excess material was removed from the beveled surface with a fissure bur. If varnish remained undetected on the beveled surface of the specimens in the Tronstad study, then their findings would correspond to those of group D of the present study where significantly less apical dye penetration was found when the cavity preparation and the beveled root surface were both coated with varnish prior to placement of amalgam. Similar results were recently obtained by Pinks and Beatty (21) following placement of a dentin bonding material (Scotch

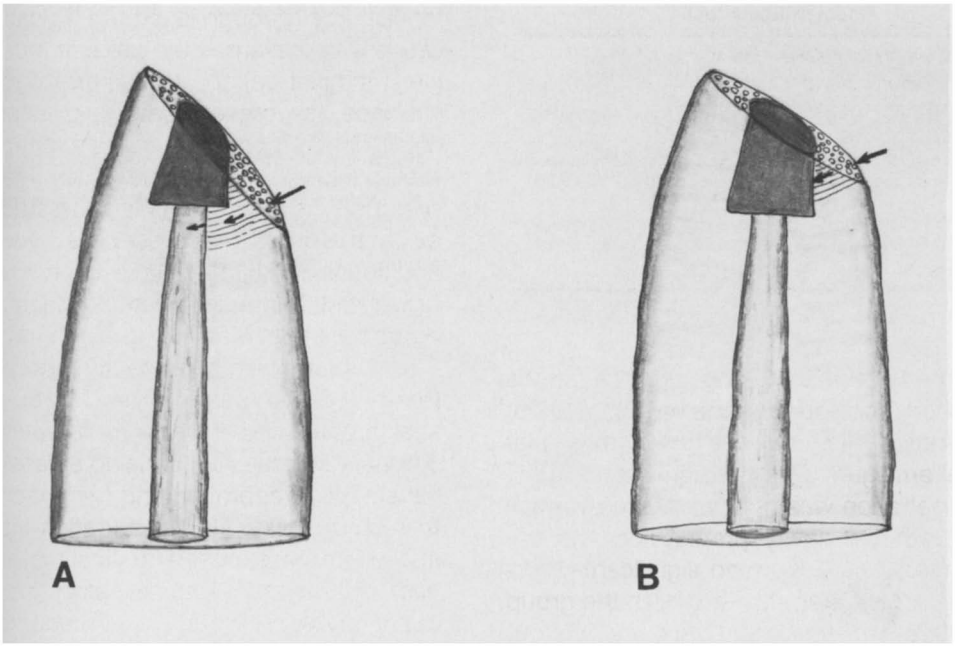

FIG 2. Leakage through dentinual tubules originating at beveled surface. *A*, Reverse amalgam filling does not extend coronally to height of bevel. *Arrows* indicate potential pathway for fluid penetration. *B*, Reverse amalgam filling extends coronally to height of bevel and blocks fluid penetration (*arrows*) into the root canal space.

Bond 3M, St. Paul, MN) in the apical cavity preparation and on the beveled root surface of extracted teeth.

Abdal et al. (14) and Mattison et al. (15) evaluated marginal leakage at the apical filling-root canal interface. Their studies concluded that significantly less leakage occurred when varnish was applied to a cavity preparation prior to amalgam placement. However, in their experimental design, the beveled root surfaces were covered with either nail varnish or nail polish prior to microleakage determinations. These studies therefore really evaluated apical leakage when both cavity preparations and beveled surfaces were sealed prior to amalgam placement and their results are in agreement with the group D findings of this investigation.

The present study does not advocate the use of varnish as a root end sealant. Such clinical application should only be considered after appropriate studies and in vivo evaluation. However, the fact that varnish was effective in limiting dye ingress suggests that the application of a biocompatable material to the beveled root end will enhance apical sealing. Additional research is needed to study the effects of exposed dentinal tubules on apical leakage and to find a biocompatible material which best seals these tubules. Such studies are currently in progress.

SUMMARY AND CONCLUSIONS

Methylene blue dye was used to evaluate the extent of apical microleakage following reverse filling procedures. Within the experimental confines of this in vitro study it appears that:

1. Apical dye penetration was significantly more with the cold-burnished gutta-percha technique.
2. Significantly less apical dye penetration occurred when the cavity preparation and the beveled root surface were coated with varnish prior to placement of the amalgam restoration.
3. The presence or absence of varnish in the apical cavity preparation resulted in no significant differences in apical dye penetration.

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Editor's note. It has been brought to my attention that some authors have been confused as to why their articles do not always appear in the issue that is designated on the galley proofs received from the publisher. Manuscripts are forwarded to the publisher from the editorial office and are redacted and assigned to whatever month that is current. Since there is a slight back log, the manuscripts are assigned to an issue according to received and accepted dates.

I hope this explanation clears up the confusion.