A comparison of the marginal adaptation of retrograde techniques: A scanning electron microscopic study

John P. Tanzilli, D.D.S., Donald Raphael, D.D.S., M.S.,** and Richard M. Moodnik, D.D.S.*** East Meadow, N. Y.*

NASSAU COUNTY MEDICAL CENTER

An investigation of the most popular retrograde techniques for their marginal adaptation to dentin was attempted. Forty extracted maxillary central incisors were instrumented and obturated, and various apical procedures were performed. The scanning electron microscope was used to record the results. Retrograde amalgam, heat-sealed gutta-percha, and the apicoectomy control showed average marginal defects from 22 μm to 104 μm, while cold-burnished gutta-percha exhibited an average defect of only 1.8 μm. The marginal defect produced by cold-burnished gutta-percha is less than one tenth as large as the best of the other techniques.

Apicoectomy and retrograde filling constitute an accepted method of sealing root canals. Various materials for retrograde filling have been advocated, including Cavit,[1] zinc oxide—eugenol,[2] gold foil,[3] polycarboxylate cement,[4] stailine,[5] amalgam,[6] and gutta-percha. The materials that appear to have the most use are retrograde amalgam and heat-sealed gutta-percha.

The advantages of amalgam are that it is easy to manipulate, it is available in most dental offices, it is radiopaque, it is well tolerated by tissues, and it seals acceptably well.[7] The use of zinc-free amalgam has been advocated by Omnell,[8] who showed electrolysis with precipitation of zinc carbonate around a zinc-containing amalgam retrofilling. However, Jorgensen[9] has noted that zinc-free amalgam tends to corrode more readily than amalgam containing zinc. Kopp and Kresberg[3] listed several disadvantages of amalgam: introduction of mercury into the periapical tissues, introduction of a nonsterile material into the body, corrosion, and a slow setting time that allows contamination by fluids. Also, Moodnik and colleagues[10] have used the scanning electron microscope to show defects in the amalgam-dentin interface on both immediately processed in vitro retrofillings and successful "aged" in vivo retrofillings. The defects ranged in size from 6 μm to 150 μm.

The advocates of heat-sealed gutta-percha believe that gutta-percha exhibits none of the disadvantages of amalgam and that it is well tolerated by the periapical tissues.[11] In a study by Barry and associates,[12] the seals afforded by heat-sealed gutta-percha and retrograde amalgam were not significantly different from each other. One possible disadvantage of the heat-seal technique is that gutta-percha expands when heated and, when the hot instrument is removed, some of the gutta-percha adheres to it and the remainder may recede from the canal walls upon cooling. Also, the technique does not allow for removal of debris that may exist in the apical portion of the root canal.

The purpose of this investigation is to examine the adaptability of retrograde amalgam, heat-sealed gutta-percha, and cold-burnished gutta-percha to the dentin—retrograde material interface of the root canal.

METHODS AND MATERIAL

Forty freshly extracted human maxillary central incisors were mechanically instrumented and irrigated. Instrumentation was carried to a size 60 file at the apex, and sterile saline solution was used as the irrigant. The canals were filled with laterally condensed gutta-percha* and sealer.† Radiographs were taken from both a buccolingual and a mesiodistal orientation to ensure the clinical criteria of complete obturation of the root

*Assistant Attending, Division of Endodontics.
**Senior Endodontic Resident.
***Director, Division of Endodontics.

*Mynol Gutta-Percha, Mynol, Inc., Broomall, Pa.
†Tubli-Seal, Kerr Sybron Corp., Romulus, Mich.

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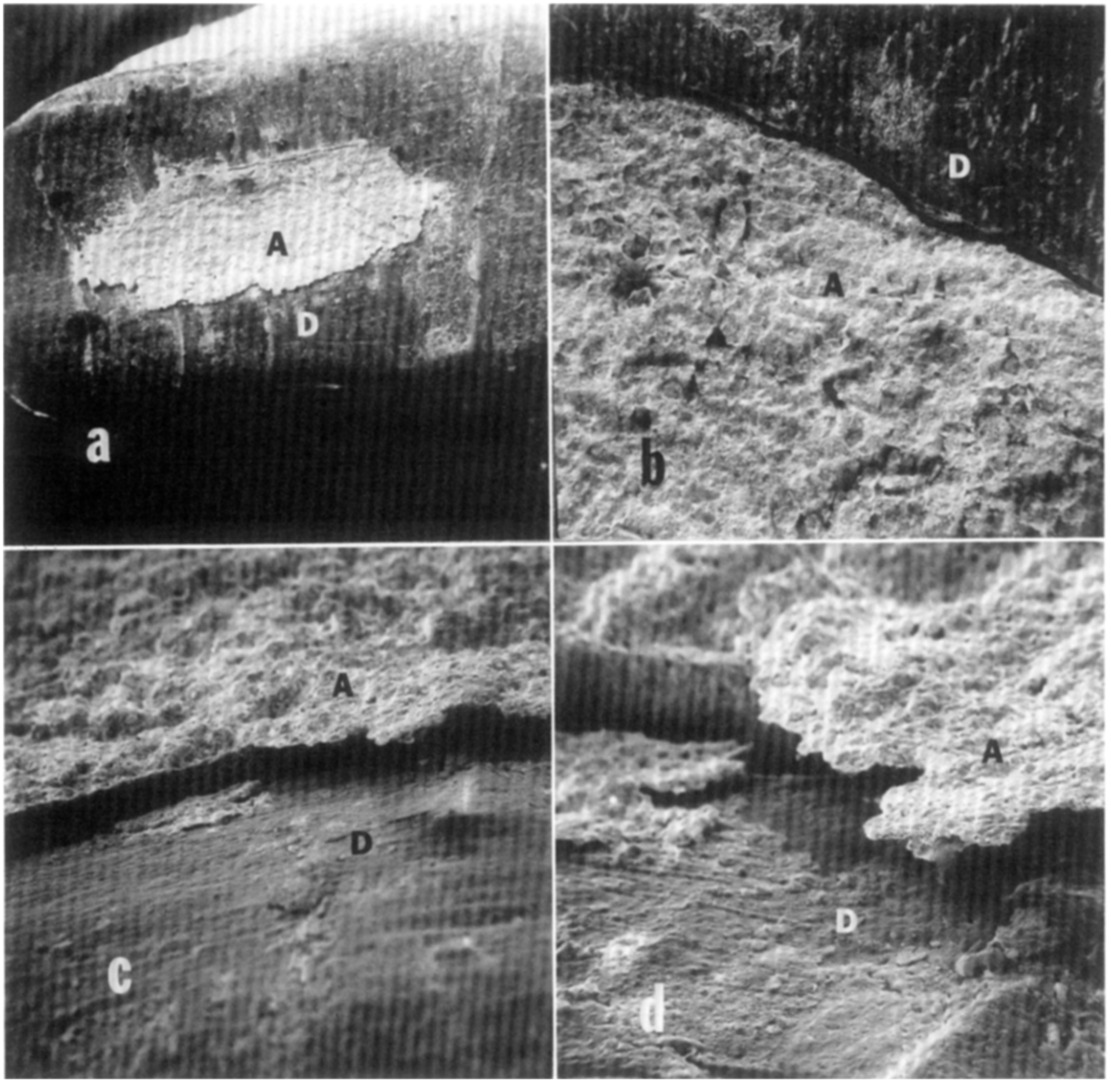

Fig. 1. Scanning micrographs of retrograde amalgam. *A*, amalgam. *D*, Dentin. **a,** Direct view of burnished amalgam, (Original Magnification, ×20.) **b,** Defect at amalgam dentin interface, (Original magnification, ×100.) **c,** Lifting of amalgam from the root canal (Original magnification, ×200.) **d,** Unsupported shelf of amalgam. (Original magnification ×500.)

canal. The apicoectomy was performed by beveling the apical 2 mm. of the root with a 700 high-speed carbide bur and water spray.

The teeth were divided into four groups. Group I was prepared for retrograde amalgam. A Class I preparation was made into the apical gutta-percha with a No. 33½ high-speed inverted-cone carbide bur to a depth of 2 mm. Amalgam* was condensed, carved, and burnished into the cavity. Group II was composed of heat-sealed gutta-percha. After the apex was beveled, a warm plastic instrument was carried over the gutta-percha in an attempt to seal the apex. Group III contained the cold-burnished specimens. In this group, after the apex was beveled, a 27-28s ball burnished was used to compress and burnish the gutta-percha back into the canal space. Group IV was the control group in which the apex was left untouched after beveling.

The coronal portion was cut off with a No. 700 high-speed carbide bur and water spray, so that only the apical 8 mm. remained. The apices were now placed,

*Kerr Spheralloy Spher-a-Caps, Kerr Sybron Corp., Romulus, Mich.

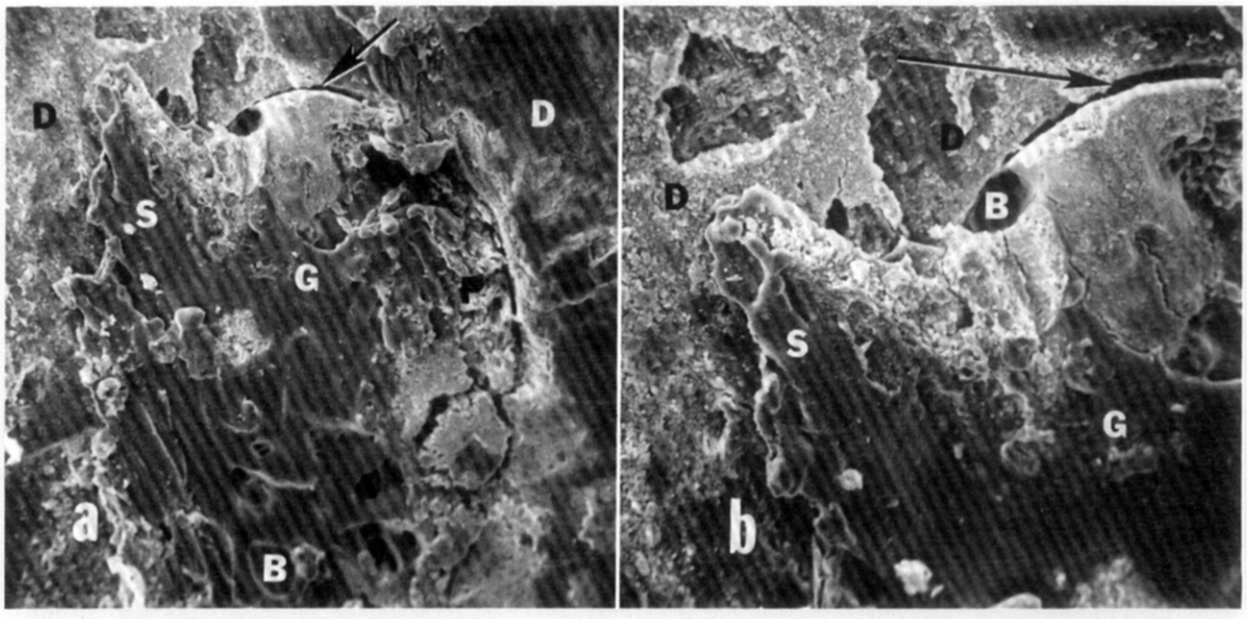

Fig. 2. Scanning micrographs of heat-sealed gutta-percha. *G*, Gutta-percha. *D*, Dentin. *B*, Blisters. *P*, Pull-away zone. *S*, Smeared layer of gutta-percha. Arrow indicates the defect at the gutta-percha—dentin interface. (Original magnifications: **a**, ×100; **b**, ×200.)

apex down, on a 2 by 2 inch sterile gauze pad soaked with physiologic saline solution in a sealed jar to ensure 100 percent humidity. The jars were kept in an incubator at 37° C for one month to allow for the set of the sealer and amalgam and to ensure dimensional stability of all materials. The specimens were now air dried and mounted on aluminum stubs with colloidal silver. They then were placed on a rotating table in a high-vacuum evaporator, coated with 200A of carbon and 200A of gold-pallidium, and examined with a scanning electron microscope* operated at 20 kv. Three hundred photomicrographs of the specimens were taken at various magnifications ranging from ×20 to ×50. The photomicrographs were compared and evaluated by three independent observers.

RESULTS

The retrograde amalgam produced relatively uniform defects along the amalgam-dentin interface (Fig. 1, *a*, and *b*). The largest noted was 31 μm, the smallest was 10 μm, and the average defect was 22 μm. A lifting of the amalgam outward from the retrograde preparation was observed (Fig. 1, *c*). The amount of lifting of the amalgam ranged from a maximum of 44.5 μm to a minimum of 29.5 μm, with the average displacement being 37 μm. This lifting did not improve the adaptability of the amalgam to the dentin. Unsupported ledges of amalgam are clearly seen (Fig. 1, *d*).

*Cambridge Stereoscan, Mark IIA, London.

To discuss the results of the heat-sealed gutta-percha, three terms must be defined. *Defect* refers to the relatively constant spacing between the material and the dentin, *blister* refers to the circular holes that form after application of heat, and *pullaway* refers to the void probably caused by the heated instrument pulling the gutta-percha away from the dentin. The results revealed defects from 2.5 to 10 μm (Fig. 2, *b*), pullaways as large as 311 μm, with an average spacing of 104 μm (Fig. 2, *a*), and blisters with a diameter averaging 62 μm and as high as 109 μm (Fig. 2, *a*). Some of these blisters were located at the dentin—gutta-percha interface (Fig. 2, *b*). A "smear" of gutta-percha over the dentin was observed, with the margins being invisible beneath the smear (Fig. 2, *b*).

The cold-burnished gutta-percha displayed uniformly superior adaptation to the dentinal walls, with the largest defect being 5.6 μm and the average being 1.8 μm (Fig. 3, *b*). A doming effect was noted on all specimens (Fig. 3, *c*) although there were no unsupported areas or pulling-away of gutta-percha observed.

The control teeth in which only an apicoectomy was performed, had defects as large as 69.5 μm with an average defect of 28 μm (Fig. 4, *a* and *b*). Blistering was noted but was significantly less than when heat-sealed gutta-percha was used (Fig. 4, *b* and *c*). The gutta-percha appears as if it flowed from one point to the other with a rolled appearance (Fig. 4, *a* and *c*), and yet distinct margins without smears are seen (Fig. 4, *a*, *b*, and *c*).

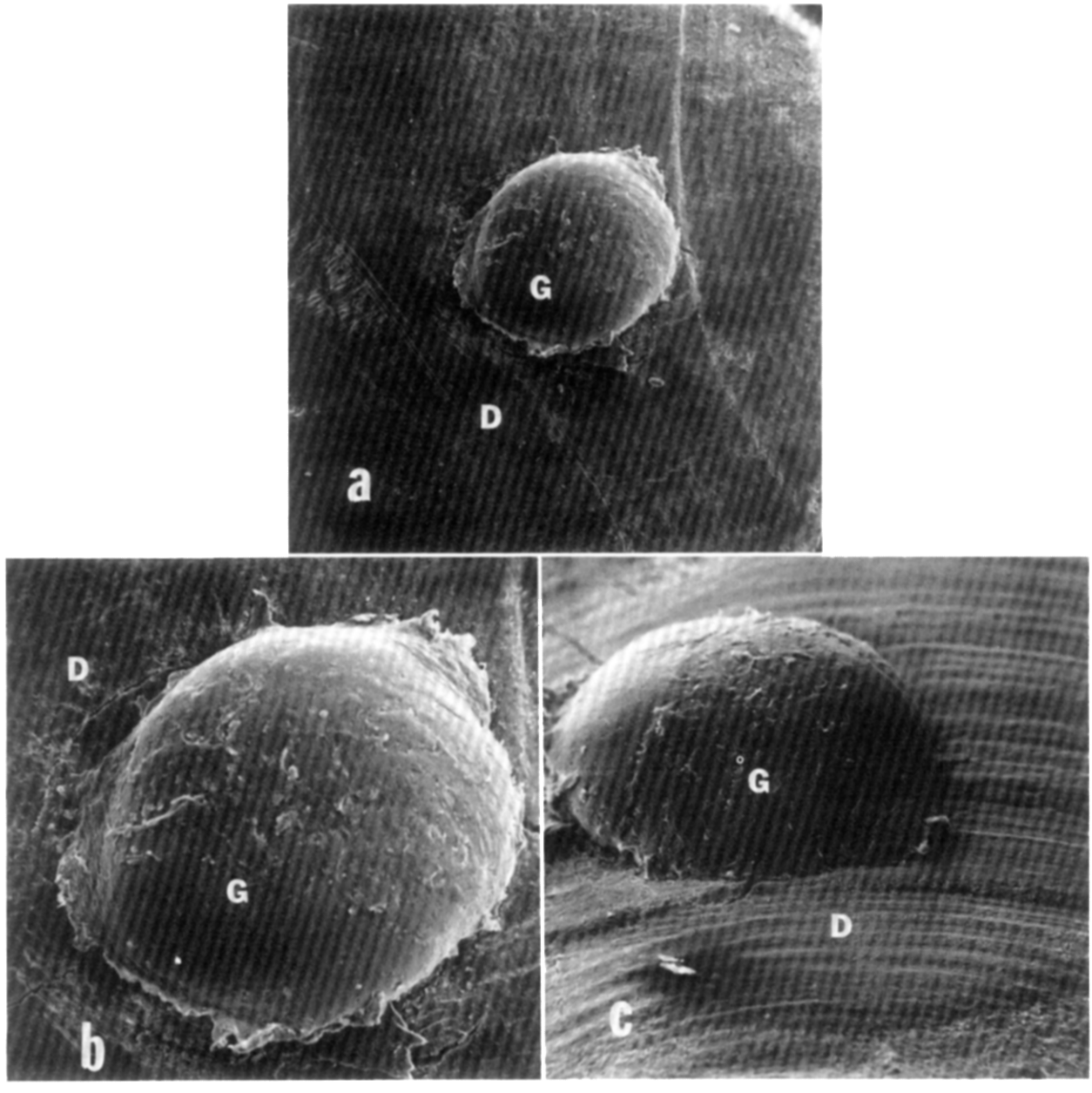

Fig. 3. a to c, Scanning micrographs of cold-burnished gutta-percha. *G*, Gutta-percha. *D*, Dentin. **a,** Direct view of cold-burnished gutta-percha showing close adaptation of gutta-percha to dentin. (Original magnification, ×50.) **b,** Higher magnification of section shown in **a.** (Original magnification, ×100.) **c,** Side view of root apex showing doming of gutta-percha. (Original magnification, ×100.)

A summary of the results of this study can be found in Table I.

DISCUSSION

According to Ingle and Beveridge,[6] "if the apex is not adequately sealed, a retrofilling is indicated." Their text also states: "The successful outcome of the case will depend on the condensation of the amalgam and complete apical seal." Weine[13] states: "It is wrong merely to curette the area or even perform an apicoectomy down to the point of filling without ensuring apical seal by way of the reverse fill. Unless the apical percolation that is causing the failure is eliminated by sealing, the removal of the granulomatous tissue will not produce successful results. This is particularly true when dealing with a silver point filling or a canal that had been overinstrumented. Small crevices or voids around the sealing material may be sufficient to harbor irritants capable of perpetuating the apical inflammation." Our purpose was to investigate which "apical

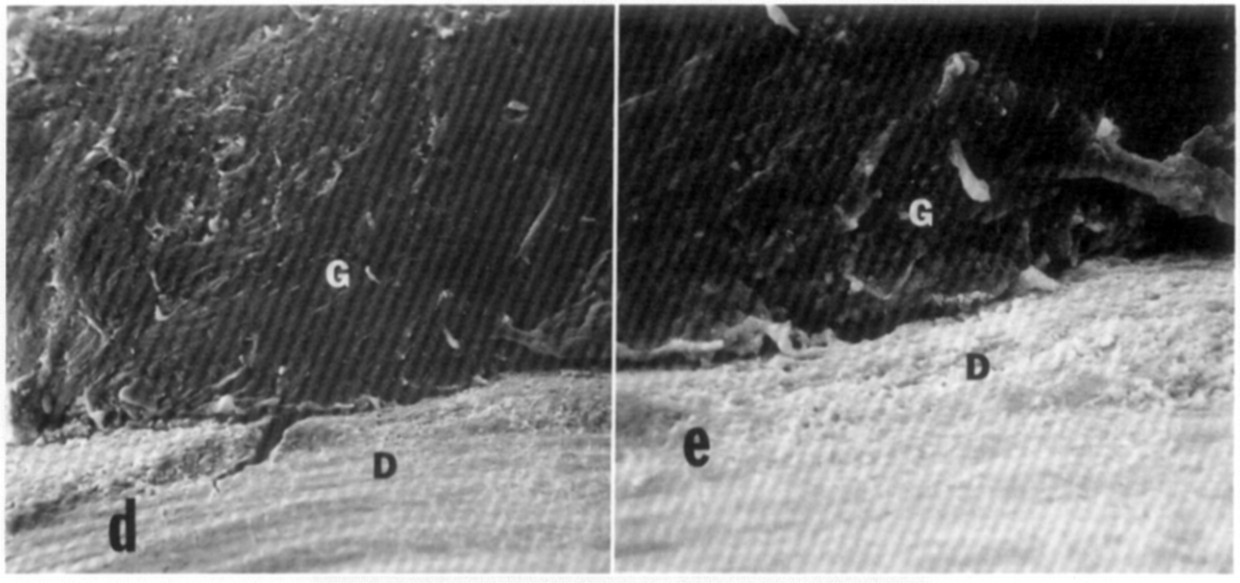

Fig. 3. d and e, Higher magnification of same area showing defect at gutta-percha—dentin interface. (Original magnifications: **d,** ×200; **e,** ×500.)

Table I. Measurements of spaces at dentin-retrograde material interface

Retrograde material	*Size of spacing*		
	Largest (microns)	*Smallest (microns)*	*Average (microns)*
Retrograde amalgam			
Defect	31	10	22
Lifting	44.5	29.5	37
Heat-sealed gutta-percha			
Defect	10.5	2.5	6.5
Pull-away	311	42	104
Blister	109	20	62
Cold-burnished gutta-percha			
Defect	5.6	0.6	1.8
Control (apicoectomy)			
Defect	69.5	1.0	28

seal'' afforded the best adaptation to the dentinal walls.

The implication that a retrograde amalgam ''seals'' the apex has been seriously questioned since Moodnik and associates[10] studied the retrograde amalgam—dentin interface with the scanning electron microscope. Defects from 6 μm to 150 μm were consistently found. The present study found the average defect to be 22 μm. The 37 μm average lifting of the amalgam from the dentin (Fig. 1, *c* and *d*) was also visible in Fig. 4 of the article by Moodnik and colleagues.[10] This lifting did not improve the dentin-amalgam marginal adaptation.

The use of heat-sealed gutta-percha is a technique that has widespread usage. The present study shows the three types of imperfections-defects, pull-aways, and blisters. When the dimensions of all three are considered, the heat seal has the poorest marginal adaptation of all the techniques investigated. The blisters are probably due to the heat placed on the gutta-percha. These can occur along the dentin—gutta-percha interface and leave large voids (Fig. 2, *b*). The heat also appears to cause a pulling-away from one margin and a smearing over the opposite margin. Barry, Heyman, and Elias[12] found that heat-sealed gutta-percha yielded a significantly inferior seal compared to the unaltered apex containing gutta-percha. They also state that ''if necrotic debris were the causative factor, then removal by means of the amalgam preparation would be the logical approach.'' However, both retrograde amalgam and heat-sealed gutta-percha give poor adaptation of the filling material to the dentin.

The cold-burnished gutta-percha gave the best marginal adaptation. The average defect of 1.8 μm is 90 percent smaller than the average of any of the other

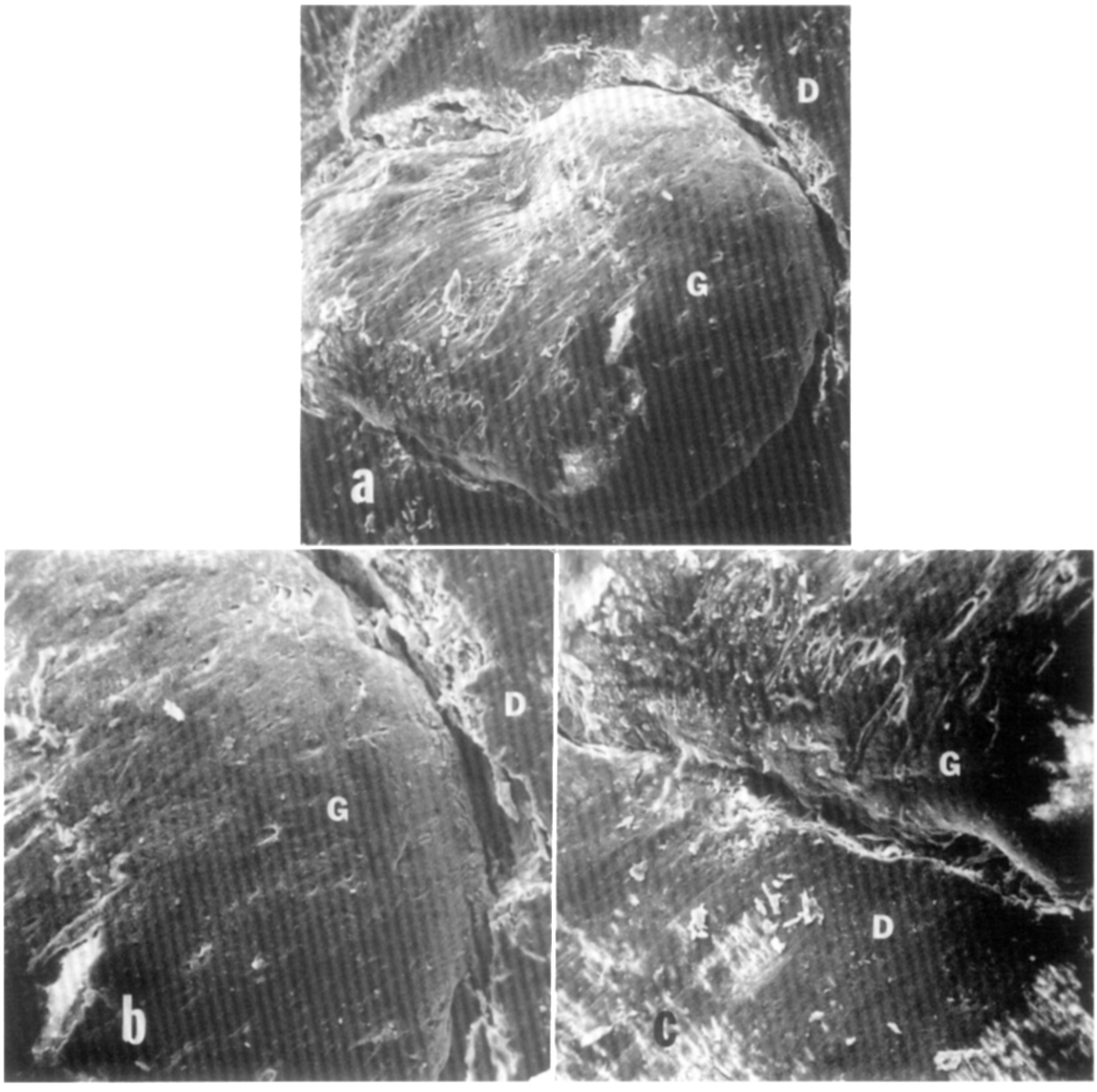

Fig. 4. Scanning micrographs of control apicoectomy. *G*, Gutta-percha, *D*, Dentin. **a,** Surface view of control tooth. Gutta-percha shows flow marks from right to left of picture. (Original magnification, ×100.) **b,** Defect showing gutta-percha pulled away from the dentin. (Original magnification, ×200.) **c,** Defect at gutta-percha—dentin interface on side toward which gutta-percha was pushed. (Original magnification, ×200.)

techniques investigated. The surface of the material appears smoothest compared to the amalgam, heat-sealed gutta-percha, and the apicoectomy control. A doming (Fig. 3, *c*) of the material was observed. This might be due to the elastic memory of the gutta-percha as dimensional stability was established.

The control specimens simply had an apicoectomy performed. The appearance suggested a comparison to the heat seal. Although water spray was used, it appears that the heat of the bur caused a pulling and blistering of the gutta-percha (Fig. 4, *a*). This was much smaller in degree compared to the heat seal, and the average defect was 28 μm.

The comparison of the techniques clearly shows that cold-burnished gutta-percha gives the best marginal adaptation. It introduces no additional foreign material into the body, and the problems of amalgam scatter and corrosion are eliminated. It is one of the techniques that reduce the amount of time the flap is left open. According to Weine,[13] the pain and edema following an apical

procedure are usually related directly to the amount of time the flap is elevated. One problem might be that the cold-burnishing technique as performed in this investigation did not allow for the cleansing of debris that may exist in the root canal. A study is currently in progress to evaluate the possible use of gutta-percha as a retrofilling material using a cold-burnishing technique.

CONCLUSION

Retrograde amalgam, heat-sealed gutta-percha, and the apicoectomy gave average voids of 22 μm to 104 μm, while the cold-burnished gutta-percha gave only a 1.8 μm marginal defect. The marginal adaptability of gutta-percha using a cold-burnishing technique is more than 90 percent better than any of the other techniques investigated.

SUMMARY

A scanning electron microscopic study of forty teeth compared the marginal adaptation of the material used to the dentin. The retrograde amalgam produced defects averaging 22 μm and a lifting-up of the amalgam from the dentin averaging 37 μm. Heat-sealed gutta-percha produced defects from 2.5 to 10.5 μm but showed blisters in the gutta-percha or on the interface with an average diameter of 62 μm and a pulling-away of the gutta-percha from the dentin averaging 104 μm. The cold-burnishing technique gave the smoothest appearance and had consistently good adaptation with an average defect of 1.8 μm. An apicoectomy with no further procedure served as the control and showed an average defect of 28 μm with blistering smaller than that caused by heat seal.

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Reprint requests to:
Dr. John P. Tanzilli
Department of Dentistry
Nassau County Medical Center
2201 Hempstead Turnpike
East Meadow, N. Y. 11554