An evaluation of the use of amalgam, Cavit, and calcium hydroxide in the repair of furcation perforations

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The purpose of this study was to compare the clinical, radiographic, and histologic changes that occur in response to three of the most commonly used materials to repair furcation perforations. The results of the experiment showed that amalgam was superior to Cavit and calcium hydroxide as a sealing material of furcation perforations. The most severe reactions occurred in the control group where the perforations were not filled.

INTRODUCTION AND REVIEW OF THE LITERATURE

In the practice of endodontics, occasionally procedural accidents are encountered that will affect the prognosis of the root canal treatment. One of these procedural accidents is endodontic perforation.

Perforation of the floor or wall of the pulp chamber, or of the root, sometimes occurs as a result of a number of causes: misdirection of a bur in attempting to gain access to the pulp chamber, during the placement of posts and pins while searching for an elusive root canal, or failure to follow the apical curvature during root canal instrumentation.

Periodontal tissue reaction to experimentally produced perforations in dogs,[1-9] and monkeys,[10-11] and the clinical investigations of accidental root perforations in humans[12-19] have been studied. In general, all the investigators agree that the prognosis for root perforations in the apical and middle third of the root is much better than perforations in the cervical third of the root or in the floor of the pulp chamber. They also recommend that perforations be filled immediately.

The correction of perforations can be achieved using either an intracoronal or surgical approach. The latter is not recommended for the repair of furcation perforations because the area is usually surgically inaccessible, especially if the perforation was lingually situated in a mandibular molar, or if it is located in the trifurcation area of a maxillary molar. Also, the surgical approach will usually lead to chronic pocket formation and periodontal furcation involvement.[20]

The purpose of this study was to compare the clinical, radiographic, and histologic changes that occur in the periodontal tissues in response to three of the most commonly used materials to repair furcation perforations.

MATERIALS AND METHODS

Four dogs of varying breeds, unselected as to sex, ranging in age from one to three years, were used in this study. All the dogs had clinically and radiographically healthy periodontium. The experiments were performed on the mandibular and maxillary premolars and molars with a total of 64 perforations.

Routine operating room sterility was used. The dogs were premedicated with atropine sulfate and anesthetized with sodium nembutal. A rubber dam was applied, and entrance to the pulp chamber was achieved. The pulp was then extirpated, and the canals prepared according to Weine.[21] Sterile saline solution was used for irrigation as needed. The canals were dried with sterile paper points and filled to the level of the pulp chamber with Cavit, using a pressure syringe (Pulpdent Corporation, Brookline, Mass). The chamber was cleaned from all debris, then a no. 4 round bur was used to perforate the furcation area. Care was taken to minimize traumatic injury to the periodontium. The site of the perforation was cleaned and rinsed with saline solution. Bleeding was con-

Table 1 • Evaluation of variables.

S\V*	Inflammation	Bone resorption	New bone formation	Cementum or dentin resorption	Epithelium
0	None	Less than 1 mm†	None	None	None
1	Mild	1 to 1.9 mm	Osteoblast bordering bony trabecule, but no evidence of newly formed bone	Extended less than 1 mm	Present in the furcation area
2	Moderate	2 to 2.9 mm	Evidence of newly formed bone	Extended 1 to 1.9 mm	N/A
3	Severe	3 to 3.9 mm	N/A‡	Extended 2 to 2.9 mm	N/A
4	N/A	4 mm or more	N/A‡	Extended 3 mm or more	N/A

*S = significance; V = variable

†The perforation exit was the reference point to all measurements

‡N/A = Not applicable.

trolled by using a cotton pellet soaked with epinephrine 1:1000.

The 64 teeth were apportioned into four equal groups according to the material used to fill the perforation site. Amalgam, Cavit, and calcium hydroxide were used to randomly fill the furcation perforations of three teeth in each quadrant. The fourth tooth was used as a control, where the perforation sites were covered with a dry cotton pellet. The occlusal preparations of all the teeth were filled with amalgam, and postoperative radiographs were taken. Periodically during the next three months, the teeth were examined clinically and radiographically.

After three months, the animals were killed with intravenous injection of saturated potassium chloride solution. The teeth and surrounding structures were taken out in block sections. These were fixed in 10% formalin and prepared for histologic examination. Longitudinal serial sections 4 μm thick were cut in a mesiodistal direction, stained with hematoxylin-eosin, and examined by means of an ordinary light microscope.

Radiographic and histologic evaluation

The evaluations of the radiographs were made by three different observers not involved in the study, who made the readings without knowing the experimental, groups.

The histologic sections were given code numbers and evaluated by an independent pathologist.

Statistical analysis of the histologic data

Each histologic section was examined for the degree of inflammation, bone, cementum and dentin resorption, new bone formation, and apical proliferation of the crevicular epithelium. The criteria for the evaluation of the aforementioned variables are presented in Table 1. The nonparametric sign test was used to analyze the data.

RESULTS

Clinical and radiographic observations:

The clinical and radiographic results are summarized in Tables 2 and 3. In the evaluation of the radiographic results (Fig 1), a slight widening of the periodontal membrane was considered normal.

HISTOLOGIC OBSERVATIONS

The different variables were statistically analyzed, and the significant difference of the comparisons of the different groups is presented in Table 4.

Group 1 (amalgam)

Inflammation. The microscopic picture was generally characterized by mild to moderate chronic granulomatous inflammation (Fig 2), consisting mainly of lymphocytes, histiocytes, some plasma cells, and few scattered polymorphonuclear leukocytes. The zone of inflammation was surrounded by striations of collagen fibers.

Bone resorption. The resorption was localized mainly to the area in proximity to the perforation site. No evidence of wide involvement of the medullary portion of bone was evident.

New bone formation. In six cases (37.5%), new bone had been elabo-

Table 2 • Clinical results of total number of teeth with clinical periodontal furcation involvement.

Observation period (months)	Group 1 Amalgam	Group 2 Cavit	Group 3 Calcium Hydroxide	Group 4 Control
1	1	2	10	8
2	1	4	12	9
3	1	4	12	9

Table 3 • Radiographic results of total number of teeth with interradicular radiolucent areas.

Observation period (months)	Group 1 Amalgam	Group 2 Cavit	Group 3 Calcium hydroxide	Group 4 Control
1	0	4	13	8
2	2	5	14	8
3	2	7	14	8

rated adjacent to the collagen fiber capsule. The rest of the specimen showed osteoblasts bordering the bony trabeculae in a linear arrangement (Fig 3).

Cementum and dentin resorption. In six cases (37.5%), localized resorption of small areas of cementum and dentin was evident. Those were concomitantly repaired by cementoid and osteoid depositions.

Epithelium. Epithelium was not seen in the furcation area of any tooth.

Group 2 (Cavit)

Inflammation. In 12 cases (75%), there was a rather mild to moderate chronic inflammatory reaction (Fig 4). Scattered lymphocytes, histiocytes, and plasma cells could be seen around the perforation exits. Moderate to severe inflammatory reactions were present in the remaining sections of this group (Fig 5).

Bone resorption. Crestal bone resorption occurred in every case. The resorption was mainly localized to the vicinity of the perforation.

New bone formation. There was no new bone formation evident in this group. In the majority of the cases (10), no evidence of active osteoblastic activity was observed. The rest of the sections showed osteoblasts bordering the bony trabeculae.

Cementum and dentin resorption. Areas of diffuse cementum and dentin resorption were noted in ten cases (62.5%). Repair of some of these areas with secondary cementum was seen.

Epithelium. Granulomatous lesions covered with stratified squamous epithelium were present in the bifurcation areas of three teeth. The epithelium had begun to proliferate along both sides of the root forming a periodontal pocket.

Group 3 (calcium hydroxide)

Inflammation. In 12 cases (75%), there was rather moderate chronic inflammatory reaction (Fig 6). This consisted mainly of histiocytes, lymphocytes, and some plasma cells. Three sections showed severe, chronic inflammatory cell infiltrate and few scattered polymorphonuclear leukocytes. Only one section was mildly infiltrated with chronic inflammatory cells. Granulomatous giant cells foreign body reaction was evident in most of the cases.

Bone resorption. The interradicular crestal bone was considerably resorbed in all but one case. The bone was resorbed in a crater-like fashion (Fig 7). The bone was resorbed along the root surface forming a periodontal pocket.

New bone formation. The only evidence of osteoblastic activity was seen in six cases (37.5%) where osteo-

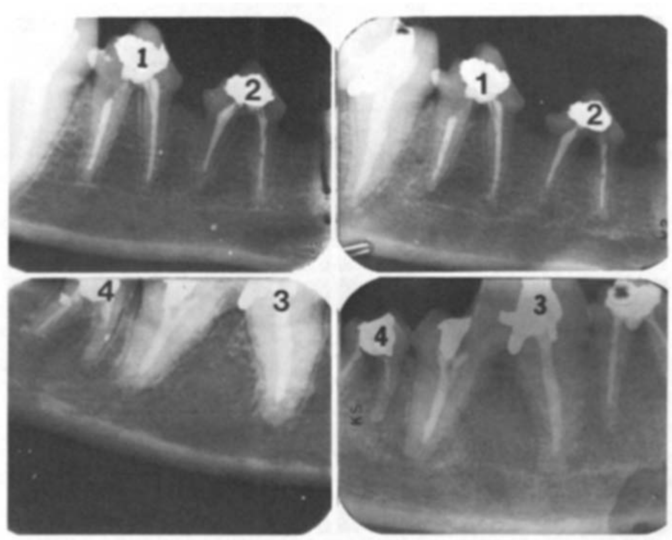

Fig 1—Left, top and bottom, immediate postoperative radiographs of tooth 1: perforation filled with calcium hydroxide; tooth 2: perforation filled with Cavit; tooth 3: perforation filled with amalgam; tooth 4: control. Right, top and bottom, three months postoperative radiographs.

blasts were actively bordering the bony trabeculae.

Cementum and dentin resorption. Areas of diffuse cementum and dentin resorption were noted in nine cases (51.25%). Apposition of new cementum in areas of previous resorption was also seen.

Epithelium. Granulomatous lesions covered with stratified squamous epithelium were present in the bifurcation areas of seven teeth (Fig 6). The epithelium had begun to proliferate along the inner side of the roots, thereby forming a periodontal pocket.

Group 4 (control)

Inflammation. The microscopic picture was generally characterized by large pathologic bony cavities (Fig 8). These were surrounded by moderate to severe chronic inflammatory cell infiltrate. The medullary portion of bone was involved. Soft tissue overgrowth was noticed in some cases into the pulp chamber.

Bone resorption. Bone resorption was pronounced in this group. It was more pronounced in the maxillary than the mandibular sections.

New bone formation. Very few cases (3) showed evidence of osteoblastic activity bordering the bony trabeculae.

Cementum and dentin resorption. Areas of cementum and dentin resorption were seen along the inner side of the root surfaces of the mandibular teeth. In the maxillary controls, the resorptive areas occurred at the under-surface of the trifurcation area. The roots did not show any areas of resorption. Repair of the resorbed areas was not evident.

Table 4 • Histological results.

	Differences between groups					
Variable	1-2	1-3	1-4	2-3	2-4	3-4
Inflammation	NS*	Sig‡	Sig§	Sig§	Sig§	NS
Bone resorption	NS	Sig‡	Sig	Sig*	Sig	Sig
New bone formation	Sig§	Sig§	Sig§	NS	NS	NS
Cementum and dentin resorption	NS	NS	Sig	NS	NS	NS
Epithelium	NS	Sig§	NS	NS	NS	NS

*NS = Not significant $P > .05$

†Sig = Significant

‡ = $0.01 < P \leq .05$

§ = $P \leq .01$

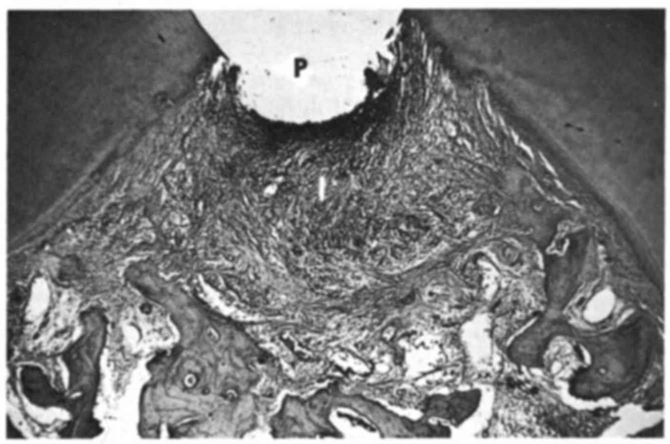

Fig 2—Group 1 (amalgam). Photomicrograph showing furcation perforation (P), with adjacent area of moderate inflammatory response and minimal bone resorption (I). The inflammatory response is composed primarily of chronic inflammatory cells, histocytes, lymphocytes, and plasma cells (H&E), orig mag ×300).

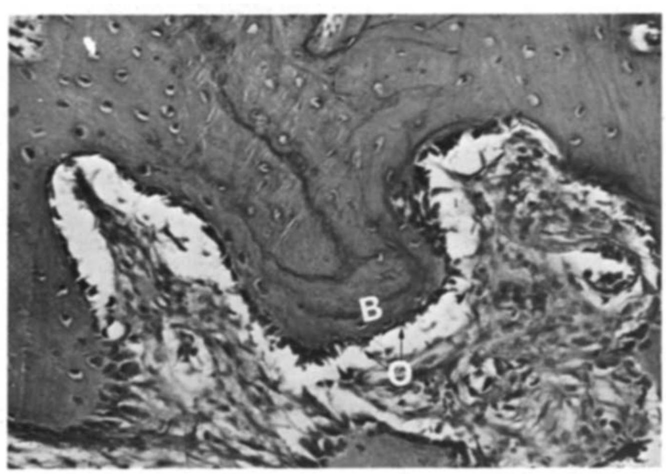

Fig 3—Group 1 (amalgam). Photomicrograph shows osteoblasts (O) and new bone formation (B). (Note artifactual spaces between bone and cellular marrow created by fixation.) (H&E, orig mag ×3,000).

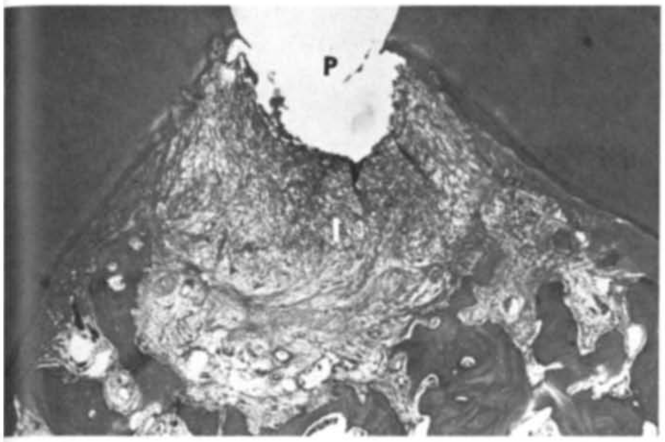

Fig 4—Group 2 (Cavit). Photomicrograph shows perforation (P) with moderate inflammatory response composed of lymphocytes and plasma cells (I) and modest bone resorption. This response was similar to that seen in group 1, (Fig 2). (H&E, orig mag ×300).

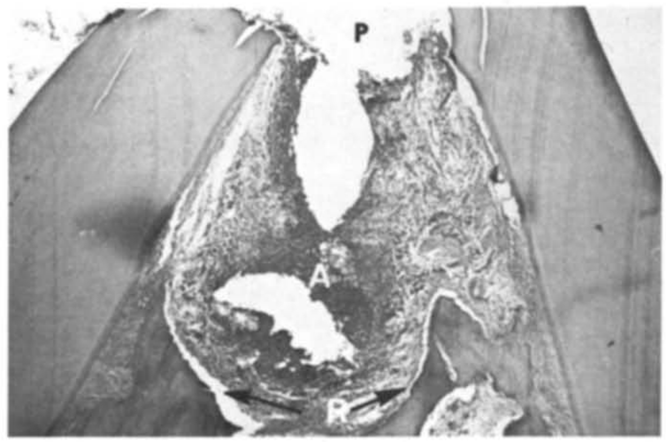

Fig 5—Group 2 (Cavit). Photomicrograph shows inflammatory response to perforation (P) in furcation. Abscess formation (A) and moderate bone resorption (R) are seen (arrows). Both chronic and acute inflammatory cells were seen in this response. (H&E, orig mag ×300).

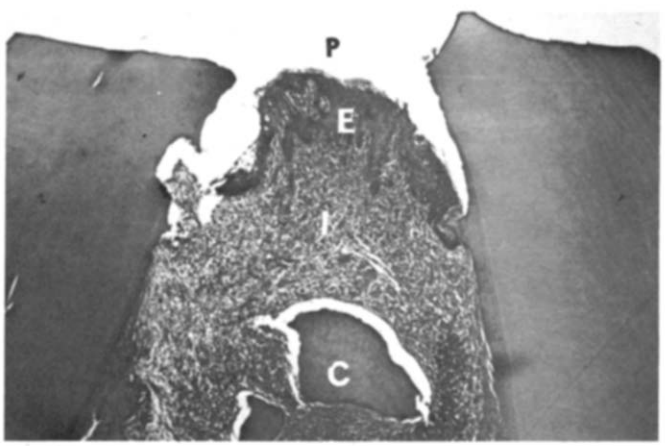

Fig 6—Group 3 (calcium hydroxide). Photomicrograph shows furcation perforation (P) with moderate to severe inflammatory response (I), composed primarily of lymphocytes and plasma cells. Note presence of sulcular-epithelium (E) and calcific debris (C). Other responses in this group were similar to those seen in group 2, (Fig 5). (H&E, orig mag ×300).

Epithelium. Granulomatous lesions covered with stratified squamous epithelium were present in the bifurcation areas of two teeth. The epithelium had proliferated apically along the entire side of the roots forming a deep periodontal pocket.

DISCUSSION

The prognosis of a tooth with an endodontic perforation depends on several factors: the location of the perforation in relation to the gingival sulcus,[1,3-5,9,11] the time lapse before the perforation is repaired,[1-6,11] the adequacy of the perforation seal,[11] the sterility of the perforation,[1,16] and as indicated from this study, the material used to repair the perforation.

It has been emphasized that coronally situated traumatic perforations, both in the furcation areas and close to the marginal bone level, have a very poor prognosis.[1,3-5,9,11] This has been confirmed by this study with the large number of teeth that developed periodontal furcation involvement.

In the present study, the possible role of bacterial contamination was not investigated. However, the presence of extensive inflammation, presence of sinus tract or furcation involvement in a large number of sealed and unsealed perforations, alludes to the possibility of infection. Several authors[1,16] have emphasized the importance of following aseptic procedures in sealing the perforations. Lantz and Persson[5] cultured enterococci and coliform rods from unfilled perforations that had failed to heal.

Clinical observations (Table 2) showed that the tissue responded best

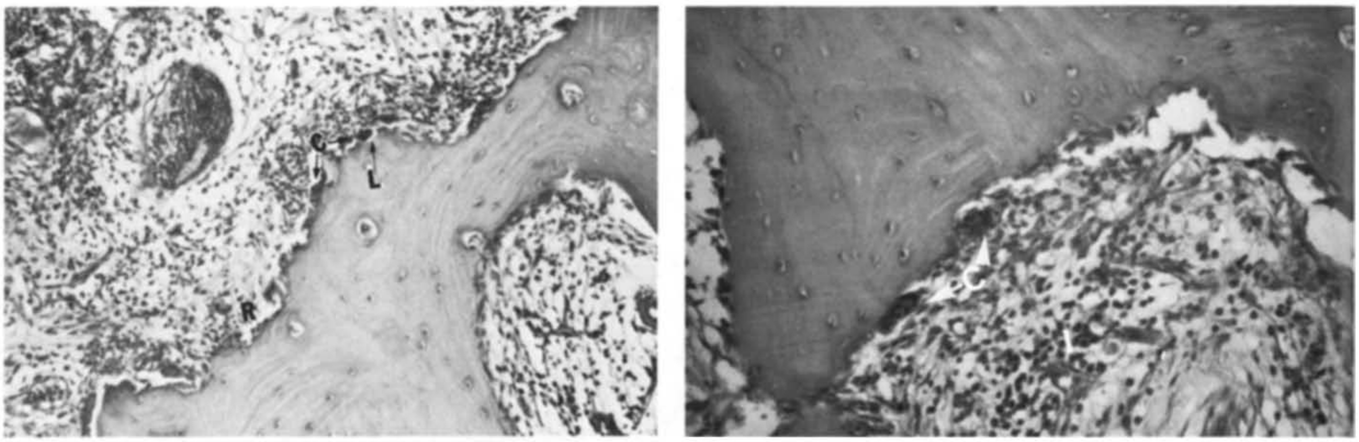

Fig 7—Group 3 (calcium hydroxide). Left, photomicrograph shows acute and chronic inflammatory response with extensive bone resorption (R). Note presence of osteoclastic cells (C) within resorption (Howships) lacunae (L) (H&E, orig mag ×1,200). Right, higher magnification of same area of bone resorption. Note acute and chronic inflammatory cell infiltrate (I) and multinucleated osteoclasts (C). (H&E, orig mag ×1,000).

when amalgam was used to seal the perforations, followed by Cavit, and then calcium hydroxide. The control group showed less clinical furcation involvement than the calcium hydroxide group because eight teeth in the control group were maxillary second molars, and the perforations in these cases, based on the closeness of the buccal roots, were made more toward the palate than the other cases. Probably if the observation period had been longer, they would have developed clinical involvement of the trifurcation area.

The radiographic observations agreed with the clinical findings. As shown in Table 3, the smallest number of teeth that showed interradicular resorption was in the amalgam group. Seven teeth developed interradicular radiolucent areas in the Cavit group, as did 14 teeth in the calcium hydroxide group. The control group showed fewer radiolucent areas than the calcium hydroxide group because the maxillary control teeth, which had resorbed bone in the trifurcation areas, as confirmed from the histologic examination, were overlapped by the radiopacity of the palatal roots, and therefore did not show on the radiograph. All the mandibular control teeth showed progressive interradicular bone resorptions that sometimes reached the root apexes.

It appears from the clinical and radiographic observations of this study that most of the bone resorption and clinical exposure of the furcation areas seems to occur in the first two months and then slows down when the marginal bone level reaches the perforation exit. The explanation may be that because the furcation area is exposed to the oral cavity, it permits continuous drainage.

Evaluation of the histologic observations showed that inflammatory cell infiltration of the periodontal tissue, in response to Cavit, was less than the other groups, although the difference between Cavit and the response to filling with amalgam was not statistically significant.

McGivern[22] reported that Cavit was superior to amalgam as a root-end filling material. However, when Flanders and others[23] implanted Cavit and zinc-free amalgam in the subcutaneous tissues of rats, they reported that Cavit produced more irritation than amalgam. Furthermore, several investigators[24-27] reported that amalgam produced a better seal than Cavit when used as a reverse filling material, and that Cavit was unable to provide either a complete or permanent operation obturation as a reverse filling material. They attributed this to the dissolution and disintegration of the Cavit in tissue fluids, and also to resorption of Cavit by the body's defense mechanisms.

The inflammatory reaction in response to filling with calcium hydroxide and in the control group was severe. The differences between groups 1 (amalgam) and 2 (Cavit) were more statistically significant than groups 3 (calcium hydroxide) and 4 (control). In a study of the biologic effects of root canal filling materials, Spångberg[28] reported that calcium hydroxide showed more cytotoxic effects than silver amalgam.

The least amount of bone resorption

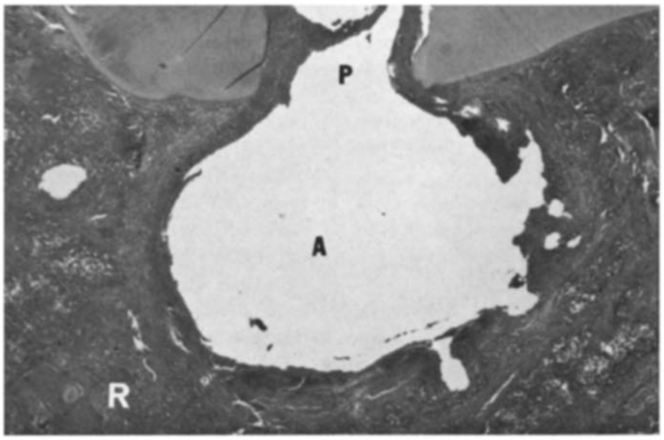

Fig 8—Group 4 (control). Photomicrograph shows typical response to maxillary furcation perforations (P) with abscess formation (A). Note extensive bone resorption (R) and cavitation. Mandibular responses in this group were similar to those seen in group 2 (Fig 5) or group 3 (Fig 6). (H&E, orig mag ×300).

was seen in the amalgam group, but the difference between the Cavit group, and amalgam group was not statistically significant. A significant amount of extensive bone resorption was seen in both the calcium hydroxide and control groups.

There was a significant amount of new bone formation in the amalgam group. Both Cavit and calcium hydroxide showed the same response. Osteoblasts could be seen bordering the bony trabeculae. However, the control group showed the least amount of osteoblastic activity. Although it was expected that new bone formation would be more pronounced in response to calcium hydroxide, this did not occur probably because of the severe inflammatory reaction, and the fact that a very little amount of the material was in contact with the periodontal tissue. Also, the material had poor sealing ability and could have been washed out after being exposed to the oral environment.

Cementum and dentin resorption was more pronounced in the Cavit, calcium hydroxide, and control groups than the amalgam group although the difference was not statistically significant.

Stratified squamous epithelium was observed occasionally in the furcation areas of teeth repaired with calcium hydroxide, Cavit, and in the control group. Previous investigators[4,5,11] reported that this was caused by apical proliferation of the crevicular epithelium, which was secondary to inflammation and subsequent lowering of the marginal bone level.

The development of extensive lesions of inflammation and bone resorption in the control group indicates that leaving the perforated region unfilled and exposed to microorganisms for a long period stimulates the proliferation of sulcular epithelium in an apical direction so that the underlying bone is destroyed. Even if the perforation is sealed, regeneration of the alveolar bone is not likely to occur.[1-6,11]

The results of this experiment indicate that among the different materials tested, amalgam appeared to be the best material for sealing furcation perforation, although the histologic difference between the amalgam and Cavit groups was not statistically significant. Failure of calcium hydroxide in almost every case was probably caused by its lower sealing ability.

Whether the presence of a lesion before repairing a perforation has any effect on the outcome of the tissue response to the preferred material needs further investigation.

SUMMARY AND CONCLUSIONS

The purpose of this study was to evaluate clinically, radiographically, and histologically, the changes in the periodontal tissue in response to using three different materials to repair perforations in the furcation areas. The following conclusions were drawn within the limits of the experimental results:

—Furcation perforations have poor prognosis.

—Some degree of inflammation and bone resorption must be expected as a response to trauma from the perforation, and to the materials used in this study, in sealing furcation perforations.

—Amalgam is superior to Cavit and calcium hydroxide as a sealing material for furcation perforations.

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