Periapical Microsurgery: An *In Vivo* Evaluation of Endodontic Root-End Filling Materials

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Abstract

The purpose of this study was to assess the healing of periapical tissues using three different materials (IRM [L.D. Caulk Inc, Dentsply International Inc, Milford, DE], Geristore [Den-Mat, Santa Maria, CA], and MTA [ProRoot MTA; Dentsply Tulsa Dental Specialties, Tulsa, OK]) after endodontic microsurgery in an animal model. Using beagle dogs as a study model, 48 bicuspids were accessed, instrumented, and intentionally infected. The surgical procedures were performed after 30 days following the radiographic confirmation of periapical radiolucencies. The root canals were still infected and had no disinfection procedure carried out. The root ends were resected, retrograde preparations were completed, and the experimental materials were placed under surgical operating microscopy. After a period of 6 months, digital radiographic images of the periradicular areas were taken. The samples were prepared for histologic evaluation. Although Geristore showed no radiographic difference when compared with the other groups, it showed the least favorable healing in the histologic evaluation. Our histologic and radiographic results showed no statistical difference between MTA and IRM. *(J Endod 2009;35:357–362)*

Key Words

Apicoectomy, endodontic microsurgery, Geristore, IRM, MTA

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Periradicular surgery is an important part of the modern endodontic practice (1). Current surgical endodontic protocols (2) along with contemporary retrofilling materials (IRM [L.D. Caulk Inc, Dentsply International Inc, Milford, DE], Super-EBA [Super-EBA: Bosworth Company, Skokie, IL], Retroplast [Retroplast Trading ApS, Roervig, Denmark], and MTA [ProRoot MTA; Dentsply Tulsa Dental Specialties, Tulsa, OK]) have shown excellent success rates (3-5). Some of the main specifications that endodontists look for in a retrofilling material are sealing ability, handling properties, working time, radiopacity, antibacterial activity, biocompatibility, and the induction of the periodontal ligament (PDL) (6).

The sealing ability of various retrofilling materials has been studied in both *in vitro* and *in vivo* designs (7). The conclusions of *in vitro* studies have often been inconsistent, partly because the results within the study are nonreproducible resulting in high standard deviations (8, 9). Some *in vivo* clinical studies comparing the outcome of periradicular surgery involving the placement of various root-end–filling materials (4, 5, 10, 11) are often difficult to compare because of different evaluation criteria and observation periods used by the different authors. The use of animal models for *in vivo* studies (specifically the canine species) is well documented (12-14). The advantage of this type of research is the potential for histologic assessment at the end of the experiment. In order to adequately test the *in vivo* efficacy, a microbial challenge has to be present in the canal system similar to a clinical case (13). Therefore, additional *in vivo* endodontic surgery studies using a microbial challenge in the canal are needed.

IRM, MTA, and Geristore (Den-Mat, Santa Maria, CA) are three currently available materials that each have desirable properties as a retrofilling material. IRM has the benefit of being cost-effective, easy to mix, and easy to handle. Several studies have shown positive outcomes using this material in periradicular surgery (5, 11, 13, 15). MTA has recently become very popular because of several studies showing a good sealing ability (16, 17) and biocompatibility (18, 19), and it has been attributed with the unique potential to induce or attach to the newly regenerating periodontal ligament (18, 20). Nonetheless, MTA has the disadvantages of being costly and technique sensitive. Rud et al (4, 21) introduced resins to periradicular surgery with Retroplast obtaining great results. However, Retroplast is not available to clinicians in North America. Geristore is a hybrid ionomer composite material available in North America that has potentially similar properties. Data on Geristore are limited, but it appears to be very promising (22-24). To date, no studies have directly compared Geristore, IRM, and MTA. The purpose of the present study was to evaluate the postsurgical periapical healing response of three retrofilling materials after 6 months using a modern endodontic surgical protocol (2) in beagle dogs.

Material and Methods

Approval for this study was obtained from the Institutional Animal Care and Use Committee of the University of North Carolina at Chapel Hill. Forty-eight premolar teeth in six purpose-bred beagle dogs of approximately 3 years of age were randomly assigned to one of three different treatment groups or to a control group.

Presurgical Phase

Randomization of teeth was conducted within each animal between the four groups (IRM, Geristore, MTA, and control). Dogs were put under general anesthesia

including induction by sodium pentothal (Abbott Laboratories, North Chicago, IL) (13.5 mg/kg administered intravenously), followed with intubation and maintenance with isoflurane (Halocarbon Laboratories, River Edge, NJ) supplemented with local anesthesia (bupivacaine plain 0.5%, Abbott Laboratories). All lower premolars were removed from occlusion, the pulps of all roots were mechanically exposed with a no. 2 round carbide bur (Brassler USA, Savannah, GA) in a high-speed handpiece (Midwest, Mondovi, WI), and the access was completed under nonaseptic conditions. Canals were instrumented to a size 40/04 NiTi with Profile GT files (Dentsply Tulsa Dental, Tulsa, OK). Supragingival plaque scaled from the dog's autologous teeth was mixed with saline (0.9% sodium chloride; Hospira Inc, Lake Forest, IL) and was introduced into the canals with a lentulospiral (Dentsply Maillefer, Johnson City, TN). Round sponges (Dentsply Maillefer) soaked in the plaque solution were placed on the floor of the chamber. The access was then closed with IRM. Radiographs of all teeth were exposed (Gendex GX 770; Gendex Dental Systems, Lake Zurich, IL) using a digital sensor (Visualix eHD, Gendex Dental Systems), custom-bite registrations (Regisil; Dentsply Caulk, Milford, DE), and paralleling devices (Dentsply Rinn, Elgin, IL). These radiographic aids were used for all subsequent radiographs to replicate the alignment and position of the films and x-ray beam for direct comparison of the radiographs with minimal distortion or magnification. Analgesics were administered to the animals (torbugesic 0.2 mg/kg, Butorphanol Tartrate; Fort Dodge Animal Health, Fort Dodge, IA) postoperatively after all procedures. The dogs were monitored for potential complications in the postoperative period.

At approximately 30 days, periapical radiolucencies were detected radiographically, showing evidence of apical periodontitis. All previously infected teeth were reaccessed with the animals under general and local anesthesia. After removal of the IRM and sponge, the canals were rinsed with a saline solution. No canal debridement or disinfection was performed at this stage. The canals were dried with paper points, and a gutta-percha cone was then inserted into each canal, approximating the apex as much as possible in order to provide a matrix to pack against for a dense retrofilling (13). The access were conditioned (GC Cavity Conditioner; GC Corporation, Tokyo, Japan) and sealed permanently with glass ionomer cement (Fuji IX GP, GC Corporation).

Surgical Phase

Once the accesses of all the lower premolars were sealed with glass ionomer, the surgical phase was carried out. Under a surgical operating microscope (OPMI Pico; Carl Zeiss Meditec, Inc, Dublin, CA), a periosteal flap was reflected and bone cavities were prepared (2, 25). Granulation tissue was noted and curetted from the periapical region of each root; 3 mm of the root ends were resected as perpendicular as possible to the long axis of the tooth (26). Retrograde cavities of 3 mm depth were prepared with a Satelec P5 ultrasonic unit (Dentsply Maillefer) at a medium power setting with CT surgical ultrasonic tips (SybronEndo Corporation, Orange, CA). Racellet epinephrine pellets (Pascal Co, Bellevue, WA) were applied with pressure in the area for 5 minutes to obtain hemostasis before retrofilling (27). After hemostasis, the retrocavities were rinsed and dried with the Stropko-irrigator (SybronEndo Corporation, Orange, CA), and groups were treated as follows:

1. Group 1, IRM: IRM was mixed following the manufacturer's instructions. The cement was then packed with a flat plastic instrument. After setting, the excess material was carefully removed and polished with a carbide polishing bur (28).
2. Group 2, Geristore: a circumferential cavity design within the root tip as described by Rud et al (21) provided an increased dentinal surface for bonding of the material. An H379 football shape carbide bur (Brassler USA, Savannah, GA) was used to create the concave finish of the retro preparation. Geristore was then placed using the automix syringe delivery tip, following the manufacturer's instructions. Although Geristore is marketed with the Tenure (Den-Mat, Santa Maria, CA) bonding agent, manufacturer instructions indicate that the use of this bonding agent is optional because of the self-adhesive properties of Geristore. Therefore, no etching or bonding were used in placement of this material.
3. Group 3, white ProRoot MTA: white ProRoot MTA was mixed following the manufacturer's instructions and placed into the retro prep with the MAP system (Roydent Dental Products, Johnson City, TN).
4. Control group: in each dog, two teeth with apical periodontitis were resected, polished with a carbide bur, and left without retrofilling material.

The flaps were repositioned and secured with interrupted 5.0 Chromic Gut sutures (Hu-Friedy Manufacturing Company, Inc, Chicago, IL). After repositioning of the flaps, radiographs were taken using the custom-bite registrations and paralleling devices.

After surgery, each animal received an intramuscular injection of 10^6 units of penicillin G. In addition, for possible postsurgical pain, each animal was given an initial dose of 0.2 mg/kg meloxicam (Metacam, Boehringer Ingelhiem Vetmedica, Inc., St. Joseph, MO) by mouth and then 0.1 mg/kg by mouth for 3 days. They were placed on a soft diet and monitored for 1 week. Two months after surgery, each dog received a scaling and prophylaxis under general anesthesia.

Postsurgical Phase

Six months after surgery, the animals were sacrificed under deep general anesthesia and then prefused with 10% buffered formalin (Fisher Scientific, Fair Lawn, NJ). Radiographs were taken using the original custom-bite registrations and paralleling devices (Fig 1). The radiographs were assessed by two blinded evaluators as follows: 0: healed, complete healing of the periapical radiolucency with a healthy lamina dura; 1: healing, reduction of the periapical radiolucency size (healing is not complete); 2: uncertain, no apparent changes in the size of the periapical radiolucency; and 3: failure, increase of the periapical radiolucency size or loss of tooth.

Jaw blocks containing the treated teeth were resected, fixed in 10% buffered formalin, and decalcified in 10% EDTA. After 4 weeks, decalcification was assessed per tactile needle pressure and radiographs. The

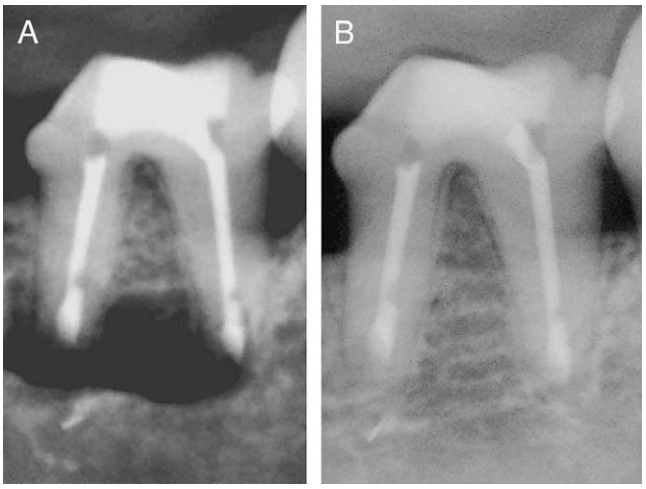


Figure 1. Radiographs. Postsurgical (A) versus 6-month follow-up (B).

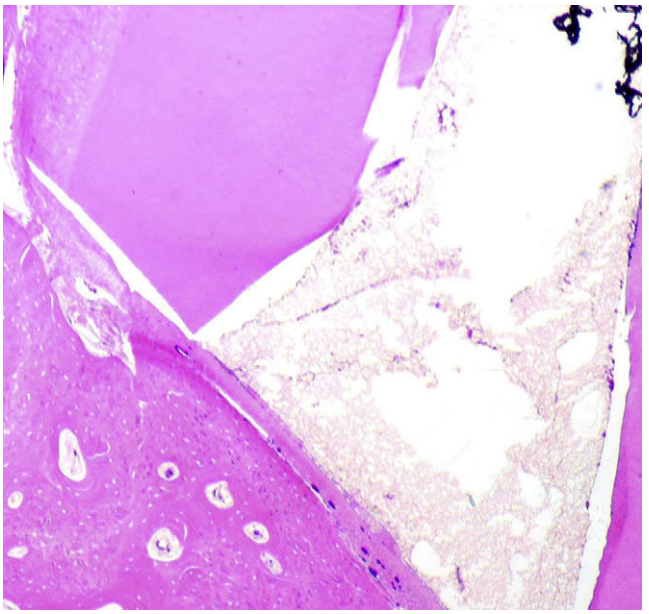


Figure 2. IRM healed.

samples were prepared for routine histologic evaluation. The cuts that showed the root canal system, the apical filling material, and the surrounding tissues were stained with hematoxylin and eosin. The prepared histologic slides (Figs. 2-5) were then examined under light microscopy at 2× and 10× magnifications by two blinded evaluators as follows: (1) absence of inflammation with presence of PDL and (2) presence of inflammation with absence of PDL.

Data Analysis

All data were entered into a Microsoft Office Excel Program (Microsoft Corporation, Redmond, WA). Data analysis was performed using SAS/STAT software (SAS Institute Inc. Cary, NC). Within each of the six dogs, the teeth (eight lower premolars) were considered as the treatment units. Stratified analysis by dog, jaw side, and tooth location was performed. Fisher exact tests and Mantel-Haenszel tests were used to compare proportions. Analyses were performed for possible associations between the tooth location ("TOOTH response"), the

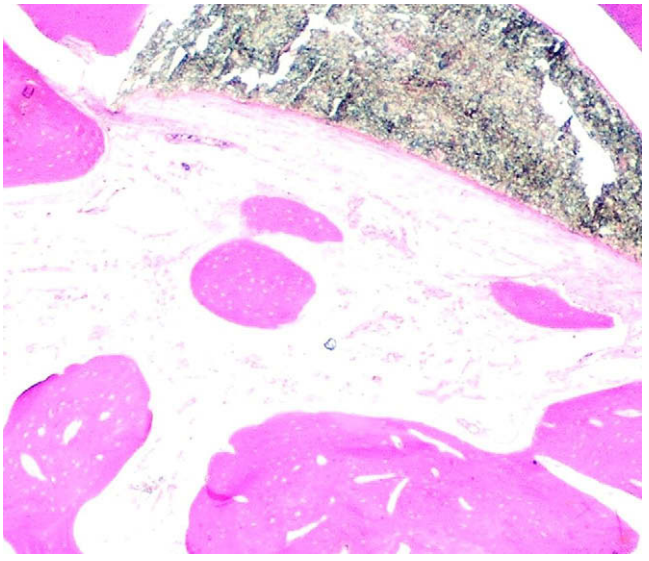


Figure 3. Geristore healed.

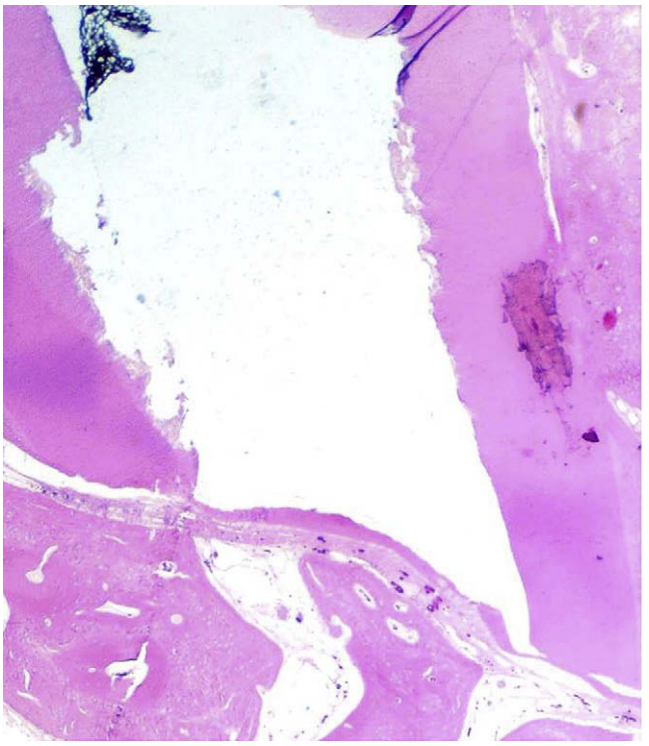


Figure 4. MTA healed.

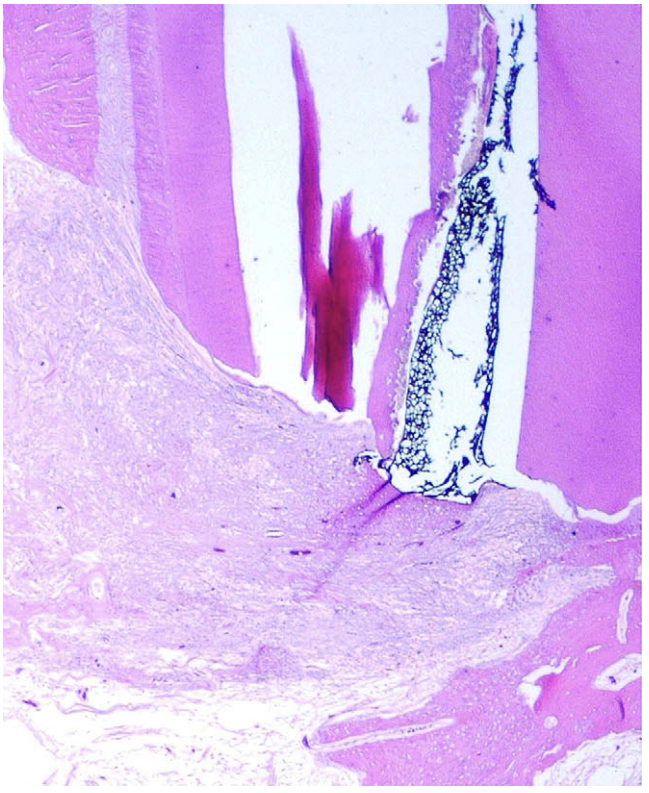
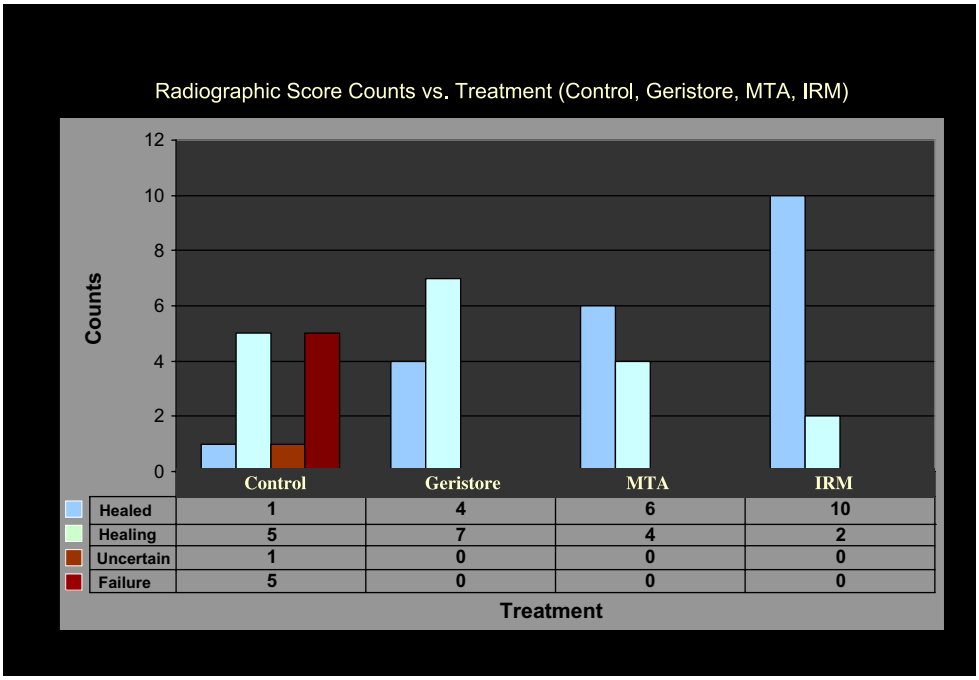


Figure 5. Positive control.

Table 1. Radiographic outcome



jaw side ("JAW response"), and dogs ("DOG response"). A p value of less than 0.05 was considered to be statistically significant.

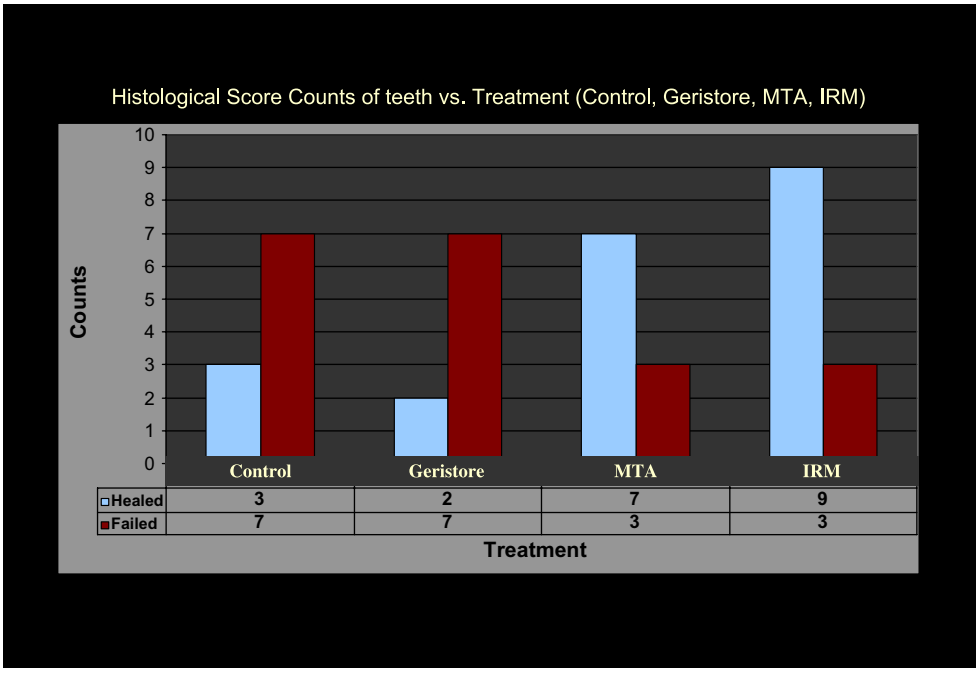
Results

Three teeth were not analyzed because of their periodontal condition at the time of surgery, and four additional teeth were lost during histologic processing and were not analyzed, leaving 41 teeth available for data analysis.

Radiographic Assessment of Healing

All teeth with retrofillings (Geristore, MTA, and IRM) had superior healing compared with the control group (Table 1). After performing

Table 2. Histological outcome



a stratified analysis by dog, jaw side, and tooth location, we did not find the response to differ by dog or jaw side. Looking at the healing between the first, second, third, and fourth premolars, the healing was better on posterior premolars compared with anterior premolars. Thus, tooth location was significant at the level of 0.05. Cochran-Mantel-Haenszel tests of association were then used for the treatment and the radiographic response, controlling for the tooth location and stratifying by dog. All experimental groups showed more favorable healing compared with the control group ($p < 0.009$). IRM showed a better healing response than Geristore ($p < 0.038$). There was no statistically significant difference between IRM and MTA ($p = 0.244$) and between MTA and Geristore ($p = 0.334$).

Histopathologic Assessment of Healing

IRM and MTA had a more favorable response then the control and the Geristore groups (Table 2). Cochran-Mantel-Haenszel tests of association were used for the treatment and the histologic responses controlling for the tooth location and stratifying by dog. Both IRM ($p < 0.038$) and MTA ($p < 0.008$) showed more favorable healing responses than Geristore. There was no statistical difference between IRM and MTA ($p = 0.765$).

Discussion

IRM has become a popular retrofilling material (10, 15). IRM has the advantage of being cost-effective, easy to mix, and easy to handle. According to the results of our study, both IRM and MTA resulted in better healing outcomes than Geristore. The positive outcome from IRM and MTA concurs with some previous *in vivo* human studies (3, 5, 29, 30).

MTA has been analyzed extensively, and several leakage studies have shown that this material provides a remarkable seal (16, 17) and a favorable biologic response (18, 19). MTA has previously been attributed with the unique potential to induce or attach to the newly regenerating periodontal ligament (18, 20). Some studies have shown this to be possible with Geristore (22, 24). In the present study, the proximity between all experimental materials and the newly developed periodontal ligament was histologically observed (Figs. 2-5).

Resins have already been shown to be an appropriate alternative retrofilling material (4, 21), and the resin bond was shown to be stable over a 9-year observation period (4). Several case reports have reported good outcomes along with favorable histologic healing using resin ionomers (22, 23). Moreover, a recent study by Camp et al (24) showed possible adhesion of human fibroblasts to this material. In our study, even though Geristore showed a favorable response radiographically, it often showed chronic inflammation on histologic examination. This highlights the limitation of radiographic imaging and the superior level of information provided by a histologic assessment (31, 32).

Previous work by Trope et al (13) showed similar results; Super EBA and IRM resulted in better healing than composite resin and glass ionomer. Comparing their results with other studies in which resins were used (4, 21), they explained that the difference in results might be caused by the cavity design or possible moisture at the time of surgery. We addressed these issues with a concave cavity design (21) and a dry cavity preparation that was confirmed under the dental operating dental microscope at the time of placement of our material. In our study, no etching or bonding was used with Geristore in order to minimize variables between the 3 materials as much as possible. The manufacturer states: "Geristore is a self-adhesive material. A bonding agent is not required; however, Tenure is recommended for increased bond strength." Further research is needed to assess the importance of the Tenure bonding system with Geristore, and further histologic research with an intracanal microbial challenge as performed in this study is warranted.

Conclusion

Geristore showed the least favorable healing results in the histologic evaluation even though it showed no radiographic difference when compared with the other experimental groups. Although IRM achieved the most favorable healing response both radiographically and histologically, these results were not statistically different from MTA. Positive histologic and radiographic outcomes showed that IRM and MTA are both suitable retrofilling materials for periradicular surgery, providing appropriate healing response from periapical tissues.

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