

Treatment of the Immature Tooth with a Non-Vital Pulp and Apical Periodontitis

Martin Trope, DMD^{a,b,*}

KEYWORDS

- Sodium hypochlorite • Calcium hydroxide
- Revascularization • Periodontitis • Mineral trioxide aggregate

The immature root with a necrotic pulp and apical periodontitis (**Fig. 1**) presents multiple challenges to successful treatment.

1. The infected root canal space cannot be disinfected with the standard root canal protocol with the aggressive use of endodontic files.
2. Once the microbial phase of the treatment is complete, filling the root canal is difficult because the open apex provides no barrier for stopping the root filling material before impinging on the periodontal tissues.
3. Even when the challenges described earlier are overcome, the roots of these teeth are thin with a higher susceptibility to fracture.

These problems are overcome by using a disinfection protocol that does not include root canal instrumentation, stimulating the formation of a hard tissue barrier or providing an artificial apical barrier to allow for optimal filling of the canal, and reinforcing the weakened root against fracture during and after an apical stop is provided.

TRADITIONAL TECHNIQUE

Disinfection of the Canal

Because in most cases nonvital teeth are infected,^{1,2} the first phase of treatment is to disinfect the root canal system to ensure periapical healing.^{2,3} The canal length is estimated with a parallel preoperative radiograph, and after access to the canal is made, a file is placed to this length. After the length has been confirmed radiographically, depending on the thickness of the remaining dentinal walls either a very light filing or no

^a University of Pennsylvania, Philadelphia, PA 19104, USA

^b University of North Carolina School of Dentistry, Chapel Hill, NC 27599, USA

* 1601 Walnut Street, Suite 401, Philadelphia, PA 19102.

E-mail address: martintrope@gmail.com

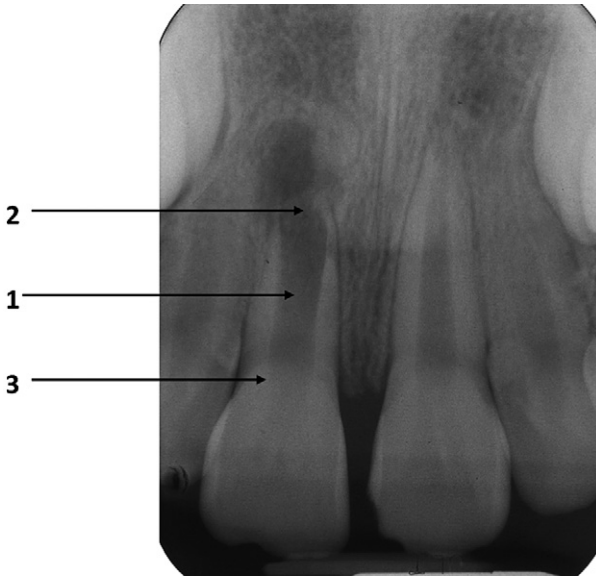


Fig. 1. The immature root with a necrotic pulp and apical periodontitis presents multiple challenges to successful treatment. (1) The infected root canal space cannot be disinfected with the standard root canal protocol with the aggressive use of endodontic files. (2) Once the microbial phase of treatment is complete, filling the root canal is difficult because the open apex provides no barrier for stopping the root filling material before impinging on the periodontal tissues. (3) Even if the challenges described earlier are overcome, the roots of these teeth are thin with a higher-than-normal susceptibility to fracture.

filing is performed with copious irrigation with 0.5% sodium hypochlorite.^{4,5} A lower strength of sodium hypochlorite is used because of the danger of placing it through the apex of immature teeth. The lower strength of sodium hypochlorite is compensated by the volume of the irrigant used. An irrigation needle that can passively reach close to the apical length is useful in disinfecting the canals of immature teeth. The intra-canal medication is placed when the irrigant leaving the canal is clean of debris. Newer irrigation protocols such as EndoVac⁶ (Discus Dental, Culver City, CA, USA) or use of ultrasound⁷ may be useful in immature canals.

The canal is dried with paper points, and a creamy mix of calcium hydroxide is spun into the canal with a lentulospiral instrument. The disinfecting action of calcium hydroxide (in addition to instrumentation and irrigation) is effective after its application for at least 1 week,⁸ so that the continuation of treatment can take place any time after 1 week. Further treatment should not be delayed for more than 1 month because the calcium hydroxide could be washed out by tissue fluids through the open apex, leaving the canal susceptible to reinfection.

A new disinfection medicament has been used when revascularization is attempted (discussed in later section). This medicament has been extensively studied by Sato and colleagues⁹ and Hoshino and colleagues.¹⁰ It comprises metronidazole, ciprofloxacin, and minocycline in a saline or glycerin vehicle. A recent study by Windley and colleagues¹¹ showed the effectiveness of the tri-antibiotic paste when used for a month on immature infected dog teeth that had been irrigated with only sodium hypochlorite.

Hard Tissue Apical Barrier

Traditional method

The formation of the hard tissue barrier at the apex requires an environment similar to that required for hard tissue formation in vital pulp therapy, that is a mild inflammatory stimulus to initiate healing and a bacteria-free environment to ensure that the inflammation is not progressive.

As with vital pulp therapy, calcium hydroxide is used for this procedure.^{12–14} Pure calcium hydroxide powder is mixed with sterile saline (or anesthetic solution) to a thick (powdery) consistency (**Fig. 2**). Ready mixed commercially available calcium hydroxide can also be used. The calcium hydroxide is packed against the apical soft tissue with a plugger or a thick point to initiate hard tissue formation. This step is followed by backfilling with calcium hydroxide to completely fill the canal thus ensuring a bacteria-free canal with little chance of reinfection during the 6 to 18 months required for the hard tissue formation at the apex. The calcium hydroxide is meticulously removed from the access cavity to the level of the root orifices, and a well-sealing temporary filling is placed. When a radiograph is taken, the canal should seem to have become calcified, indicating that the entire canal has been filled with the calcium hydroxide (**Fig. 3**). Because calcium hydroxide washout is evaluated by its relative radiodensity in the canal, it is prudent to use a calcium hydroxide mixture without the addition of a radiopaque substance such as barium sulfate. These additives do not wash out as readily as calcium hydroxide, so if they are present in the canal, evaluation of washout is not possible.

At 3 months' interval a radiograph is taken to evaluate if a hard tissue barrier has formed and if the calcium hydroxide has washed out of the canal. This is assessed to have occurred if the canal can be seen again radiographically. If calcium hydroxide washout is seen, it is replaced as before. If no washout is evident, it can be left intact for another 3 months. Excessive calcium hydroxide dressing changes should be avoided if possible because the initial toxicity of the material is believed to delay healing.¹⁵

When completion of a hard tissue barrier is suspected, the calcium hydroxide is washed out of the canal with sodium hypochlorite and a radiograph is taken to evaluate the radiodensity of the apical stop. A file that can easily reach the apex is used to gently probe for a stop at the apex. The canal is filled after the presence of

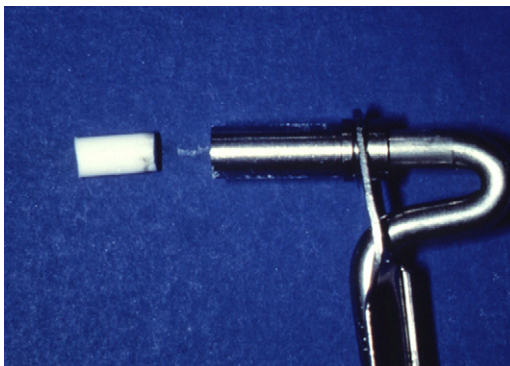


Fig. 2. Pure calcium hydroxide powder mixed with sterile saline (or anesthetic solution) to a thick (powdery) consistency.

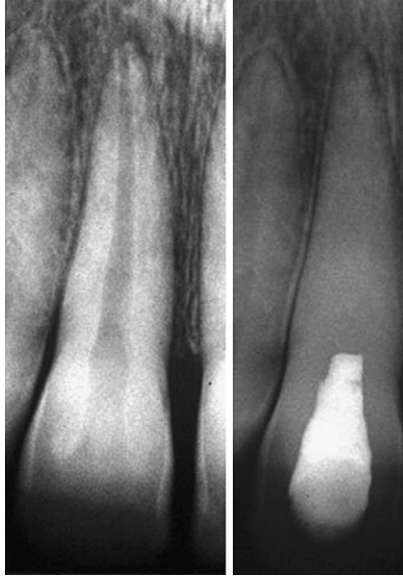


Fig. 3. The canal seems to have become calcified, indicating that the entire canal has been adequately filled with the calcium hydroxide. (Courtesy of Frederic Barnett, DMD, Philadelphia, PA.)

a hard tissue barrier is indicated radiographically and the barrier is probed with an instrument.

The hard tissue barrier that forms has been described as “Swiss cheese-like” (**Fig. 4**) because many soft tissue inclusions are still present inside the hard tissue during the time a barrier that can resist a filling material is formed. The soft filling material therefore often passes through the apex in the form of a sealer or filling material puff. The hard tissue barrier is formed at the site of healing of the periodontal granulation tissue. This site does not always conform to the radiographic apex of the tooth. Therefore when the presence of the hard tissue is felt with a point or file, it may be short of the radiographic apex of the tooth. It is important not to force the file to the radiographic apex so as to avoid destruction of the formed barrier.

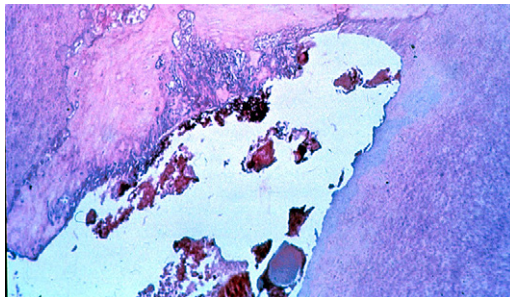


Fig. 4. Histologic appearance of a “Swiss cheese-like” apical hard tissue barrier. Note the soft tissue inclusions inside the hard tissue.

The traditional calcium hydroxide apexification technique has been extensively studied and is proved to have a high success rate.^{16,17} However, the technique has some disadvantages. The primary disadvantage is that it typically takes between 6 and 18 months for the body to form the hard tissue barrier. The patient needs to report every 3 months to evaluate whether the calcium hydroxide has washed out and/or the barrier is complete enough to provide a stop to a filling material. This requires patient compliance for up to 6 visits before the procedure is completed. It has also been shown that the use of calcium hydroxide weakens the resistance of the dentin to fracture.¹⁸ Thus it is common for the patient to sustain another injury and also fracture the root before the hard tissue barrier is formed (**Fig. 5**).

Mineral trioxide aggregate barrier

Mineral trioxide aggregate (MTA) is used to create a hard tissue barrier after the disinfection of the canal (**Fig. 6**). Calcium sulfate (or similar material) is pushed through the apex to provide a resorbable extraradicular barrier against which the MTA is packed. The MTA is mixed and placed into the apical 3 to 4 mm of the canal in a manner similar to the placement of calcium hydroxide. A wet cotton pellet can be placed against the MTA and left for at least 6 hours and then the entire canal filled with a root filling material or the filling can be placed immediately because the tissue fluids of the open apex may provide enough moisture to ensure that the MTA sets sufficiently. The cervical canal is then reinforced with composite resin to below the level of the marginal bone as described later in the article (see **Fig. 6**).

Several case reports have been published using this MTA apical barrier technique,^{19,20} and it has steadily gained popularity with clinicians. At present, there is no prospective long-term outcome study that compares the success rate of this technique with that of the traditional calcium hydroxide technique.



Fig. 5. Root that suffered a horizontal root fracture soon after root filling (*left*) and during the long-term calcium hydroxide treatment (*right*). (From Andreassen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root dressing may increase risk of root fracture. *Dent Traumatol* 2002;18(3):134–7; with permission.)

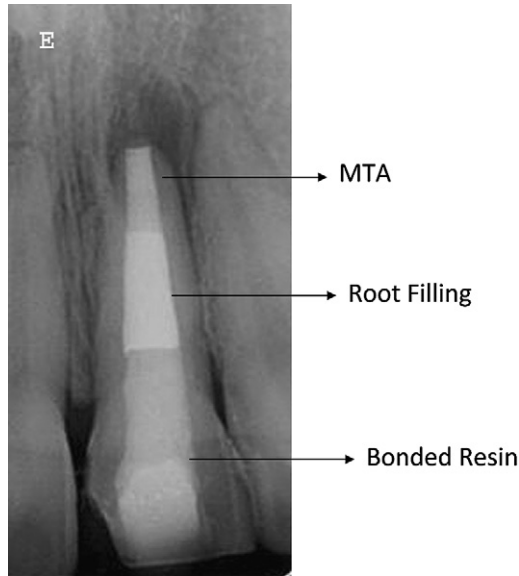


Fig. 6. Apexification with MTA. The canal is disinfected with light instrumentation, copious irrigation, and a creamy mix of calcium hydroxide for 1 month, calcium sulfate is placed through the apex as a barrier to the placement of MTA, and 4-mm MTA plug is placed at the apex. The body of the canal is filled with Resilon obturation system (Pentron Clinical Technologies, Wallingford, CT, USA), and a bonded resin is placed to below the cementoenamel junction to strengthen the root. (Courtesy of Marga Ree, DDS, MSc, Purmerend, Netherlands.)

Because the apical diameter is larger than the coronal diameter of most of the canals, a softened filling technique is indicated for these teeth. Care must be taken to avoid excessive lateral force during filling because of the thin walls of the root.

The apexification procedure has become a predictably successful procedure.^{16,17} However, the thin dentinal walls still present a clinical problem. Should secondary injuries occur, teeth with thin dentinal walls are more susceptible to fractures that render them nonrestorable. It has been reported that approximately 30% of these teeth will fracture during or after endodontic treatment (see **Fig. 5**).¹⁶ Some clinicians have therefore questioned the advisability of the apexification procedure and have opted for more radical treatment procedures, including extraction followed by extensive restorative procedures such as dental implants. Studies have shown that intracoronal bonded restorations can internally strengthen endodontically treated teeth and increase their resistance to fracture.^{21,22} Thus after root filling, the material should be removed to below the level of marginal bone and a bonded resin filling placed (see **Fig. 6**).

Routine recall evaluation should be performed to determine the success in the prevention or treatment of apical periodontitis. Restorative procedures should be assessed to ensure that they do not promote root fractures.

Periapical healing and the formation of a hard tissue barrier occurs predictably with long-term calcium hydroxide treatment (79%–96%).¹⁴ However, long-term survival is jeopardized by the fracture potential of the thin dentinal walls of these teeth. It is expected that the newer techniques of internally strengthening the teeth described earlier will increase their long-term survivability.

PULP REVASCULARIZATION

Revascularization of a necrotic pulp is considered possible only after avulsion of an immature permanent tooth. Skoglund and colleagues²³ showed in dog teeth that pulp revascularization was possible and took approximately 45 days (Fig. 7). The advantages of pulp revascularization lie in the possibility of further root development and reinforcement of dentinal walls by deposition of hard tissue thus strengthening the root against fracture. After reimplantation of an avulsed immature tooth, a unique set of circumstances exists that allows revascularization to take place. The young tooth has an open apex and is short; this allows new tissue to grow into the pulp space quickly. The pulp is necrotic but usually not degenerated and infected; thus it acts as a scaffold into which the new tissue can grow. The apical part of a pulp may remain vital and after reimplantation may proliferate coronally, replacing the necrotized portion of the pulp.²³⁻²⁶ In most cases, the crown of the tooth is intact and caries-free, ensuring that bacterial penetration into the pulp space through cracks²⁷ and defects is slow. Thus the race between the new tissue formation and infection of the pulp space favors the new tissue.

Revascularization of the pulp space in a necrotic infected tooth with apical periodontitis has been considered to be impossible. Nygaard Ostby²⁸ successfully regenerated pulps after vital pulp removal in immature teeth, but he was unsuccessful when the pulp space was infected. However, if the canal is effectively disinfected, a scaffold into which new tissue can grow is provided, and the coronal access is effectively sealed, revascularization should occur as in an avulsed immature tooth.

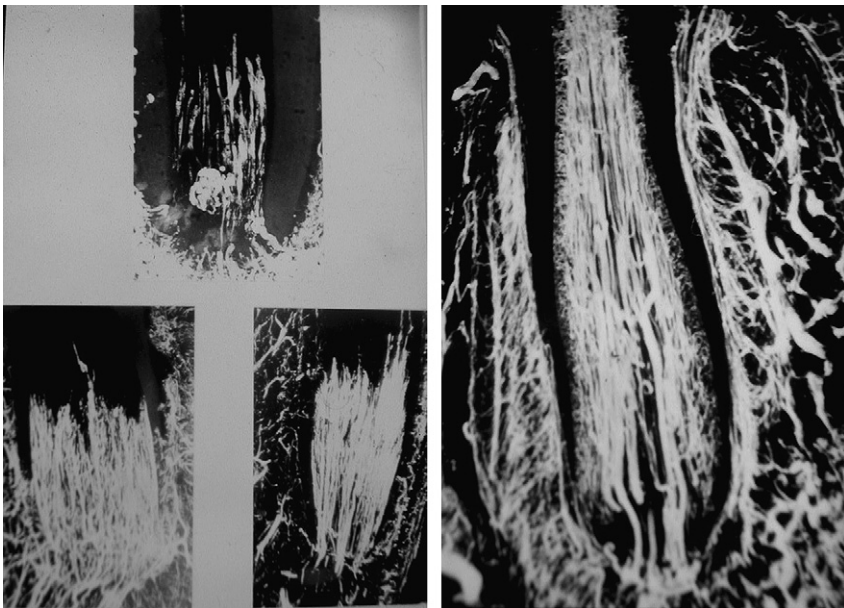


Fig. 7. Revascularization of immature dog teeth during a period of 45 days. The teeth were extracted and immediately replanted. Over the course of 45 days, the blood supply moved into the pulp space. (From Skoglund A, Tronstad L, Wallenius K. A microradiographic study of vascular changes in replanted and autotransplanted teeth in young dogs. *Oral Surg Oral Med Oral Pathol* 1978;45(1):23; with permission.)

A case report by Banchs and Trope²⁹ has reproduced results in cases reported by others that indicate that it may be possible to replicate the unique circumstances of an avulsed tooth to revascularize the pulp in infected necrotic immature roots.^{25,26}

The case (**Fig. 8**) describes the treatment of an immature second lower right premolar tooth with radiographic and clinical signs of apical periodontitis with the presence of a sinus tract. The canal was disinfected without mechanical instrumentation but with copious irrigation with 5.25% sodium hypochlorite and the use of a tri-antibiotic mixture.^{9,11}

A blood clot was produced to the level of the cementoenamel junction to provide a scaffold for the ingrowth of new tissue, followed by a double seal of MTA in the cervical area and a bonded resin coronal restoration above it. With clinical and radiographic evidence of healing at 22 days, the large radiolucency had disappeared within 7 months, and at the 24th month recall it was obvious that the root walls were thick and the development of the root below the restoration was similar to the adjacent and contralateral teeth. The author's group has confirmed the potent antibacterial properties of the tri-antibiotic paste used in this case.¹¹

Some variations on the original tri-antibiotic paste mixture have been used with good success (**Fig. 9**).³⁰ These variations were tried because of the staining of the dentin by the antibiotic minocycline (**Fig. 10**). Either the minocycline is left out thus using a bi-antibiotic paste or cefaclor is used as a substitute for the minocycline.³⁰

A recent study on dogs demonstrated the potential for revascularization using a collagen-enhanced scaffold (**Fig. 11**). This study also indicated that it was the blood clot with or without the addition of the collagen-enhanced scaffold that seemed important for the stimulation of the revascularization process.³¹ The study also confirmed

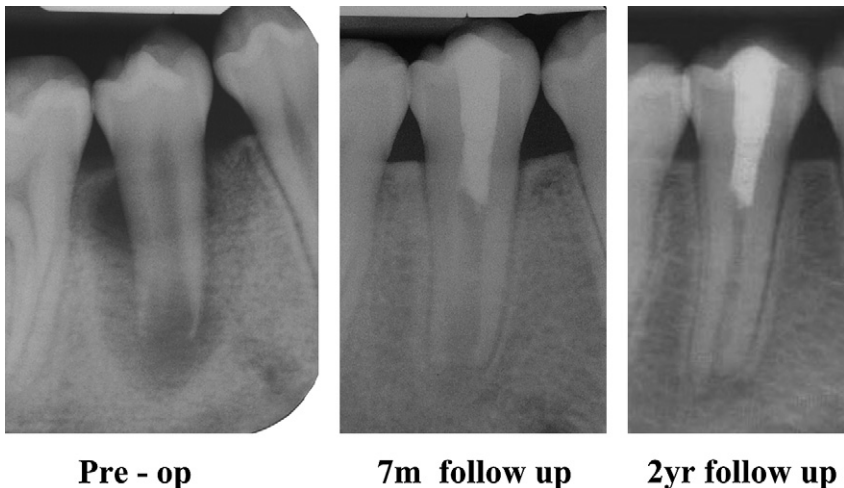
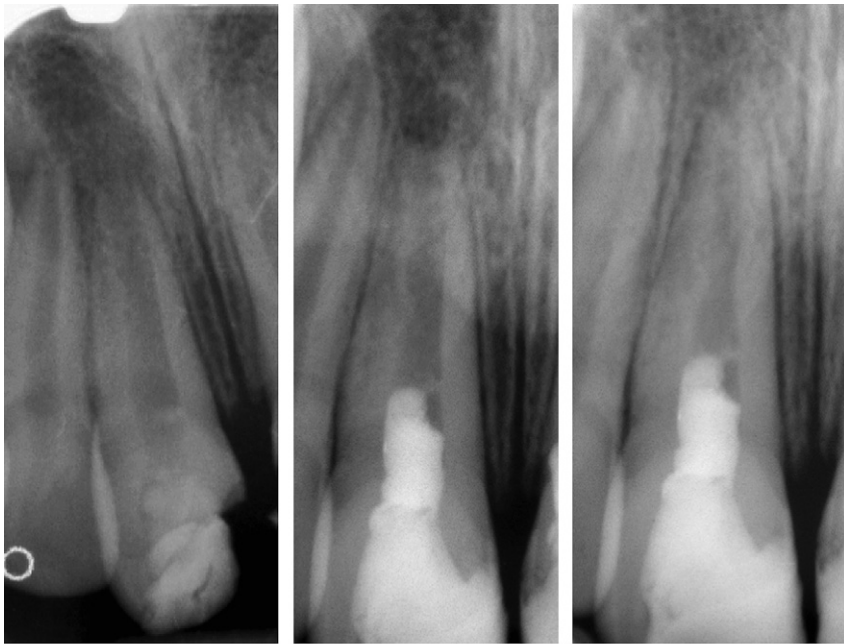


Fig. 8. Immature tooth with a necrotic infected canal with apical periodontitis. The canal is disinfected with copious irrigation with sodium hypochlorite and tri-antibiotic paste. After 4 weeks the antibiotic is removed, and a blood clot created in the canal space. The access is filled with an MTA base, and bonded resin above it. At 7 months the patient is asymptomatic, and the apex shows healing the apical periodontitis and some closure of the apex. At 24 months apical healing is obvious, and root wall thickening and root lengthening have occurred, indicating that the root canal has been revascularized with vital tissue. (*Adapted from Banchs F, Trope M. Revascularization of immature permanent teeth with apical periodontitis: new treatment protocol? J Endod 2004;30:196; with permission.*)



Pre-op

7 months

10 months

Fig. 9. Successful revascularization after failed Cvek pulpotomy. Cefaclor was substituted for minocycline in the tri-antibiotic paste. (Courtesy of Blayne Thibodeau, DMD, Saskatoon, Canada.)

that only in a few cases the pulp is actually the tissue that revascularizes the pulp space (see **Fig. 11**). Case-based studies have confirmed the viability of this procedure.^{32,33} Further studies are underway to find other potential synthetic matrices that will act as a more predictable scaffold for new ingrowth of tissue than the blood



Fig. 10. Discoloration after antibiotic placement. Minocycline in the tri-antibiotic paste seems to be the cause of the discoloration. The color of the root after placement of the paste including minocycline is shown (*first from left*). If Arestin (OraPharma, Inc, Warminster, PA, USA) is used as a substitute for the minocycline, the discoloration is markedly reduced (*third from left*). However cefaclor (*second from left*) or no additional antibiotic (*extreme right*) results in the least discoloration. (Courtesy of Dr Jared Buck, Philadelphia, PA.)

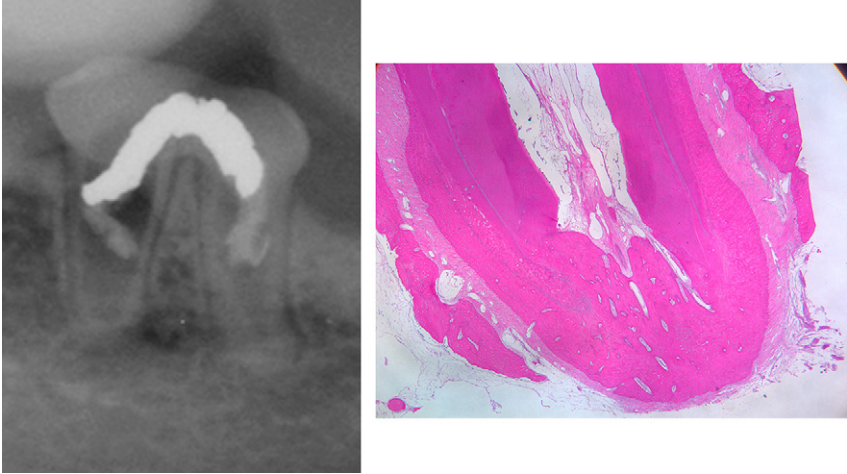


Fig. 11. Experimental confirmation that revascularization is possible. Radiograph on the left is after successful revascularization and root wall thickening. The histologic picture on the right shows cementum on the inner root wall, which is the reason for the thickening of the root. (From Thibodeau B, Teixeira F, Yamauchi M, et al. Pulp revascularization of immature dog teeth with apical periodontitis. *J Endod* 2007;33(6):680–9; with permission.)

clot that was used in previous cases. In addition, a synthetic matrix may allow easier and more predictable placement of the coronal seal than that provided by a fresh blood clot. The procedure described in this section can be attempted in most cases, and if after 3 months no signs of regeneration are present, the more traditional treatment methods can be initiated.

DISCUSSION POINTS

Regeneration Versus Revascularization

Cases such as those presented in this article have been described as examples of pulp regeneration and the beginning of stem cell technology in endodontics. It is important to distinguish between revascularization and pulp regeneration. At present, it is certain that the pulp space has returned to a vital state, but based on research in avulsed teeth and on a recent study on infected teeth, it is likely that the tissue in the pulp space is more similar to periodontal ligament than to pulp tissue (see [Fig. 11](#)).³¹ It seems that there is about a 30% chance of pulp tissue reentering the pulp space.³⁴ Future research will be needed to stimulate pulp regeneration from the pluripotential cells in the periapical region. Also, in an irreversible pulpitis case, instead of removing the entire pulp and replacing it with a synthetic filling material, partial resection of the pulp and regrowth with the help of a synthetic scaffold would be better.

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