

# Regenerative Potential of Dental Pulp

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## Abstract

The regenerative potential of dental pulp, particularly in mature teeth, has been considered extremely limited. However, our improved understanding of pulpal inflammation and repair and improved dental materials and technologies make vital pulp therapy a viable alternative to root canal treatment. This article explores our knowledge in this regard and the future potential of saving or even regenerating the pulp as a routine dental procedure. (*J Endod* 2008;34:S13-S17)

## Key Words

Pulp, regeneration, revascularization, vital

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## The Importance of Vital Pulp

Although it is easy to understand the value of a vital pulp when the tooth is immature and underdeveloped, it is also important to understand its value in a fully formed tooth. Endodontic disease is apical periodontitis, and as such, the biologic rationale for endodontics is the prevention or treatment of apical periodontitis. For apical periodontitis to be present, the root canal must contain a necrotic infected pulp (1). Therefore, the vital (noninfected) pulp ensures no apical periodontitis. Thus, maintaining the vital pulp prevents apical periodontitis, and the potential to regenerate an injured or necrotic pulp would be the best root filling possible.

## The Pulp's Regenerative Potential

### The Unexposed Pulp

The inflamed pulp unexposed by caries or trauma always has the potential to be repaired. Although our diagnostic ability to differentiate a vital from a necrotic pulp is good, differentiating between reversibly and irreversibly inflamed pulp remains an educated guess at best (2). We do know, however, that the younger the pulp, the better its repair potential.

### The Exposed Pulp

Treatment of the exposed pulp remains quite controversial, with different approaches endorsed by different dental specialties. Vital therapy (ie, pulp capping, partial or full pulpotomy) on traumatically exposed pulps is very successful (3), whereas vital pulp therapy on the cariously exposed tooth is not nearly as successful (4). The difference in success rates is explained by the status of the pulp at the time of the procedure (Fig. 1). Capping the healthy pulp gives very high success rates, whereas capping the inflamed pulp results in lower and less predictable success (Fig. 2) (5, 6, 7). On the other hand, with a carious exposure the area and depth of inflammation are very unpredictable, and pulp capping at the superficial exposure site is popular. Thus, it is very likely that we would be capping an inflamed pulp, and more failures (necrotic pulps) would result.

Another extremely important factor in the success of treating a vital exposure is the coronal seal after the pulp capping/pulpotomy (8). Cox et al. (8) showed that the pulp can withstand the toxicity of most dental materials, and that what was previously interpreted as toxicity was, in fact, due to the material not sealing adequately. Therefore, it is considered essential that a well-sealed coronal seal be placed over the vital pulp therapy. This is considered much more important than the material used on the vital pulp.

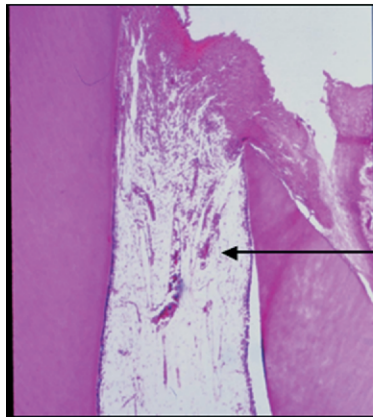
## Approaches to Treatment of Carious Exposure in the Immature Tooth

### Pediatric Dentistry

Because the young vital pulp has such good potential for repair, it is considered reasonable to perform an indirect or direct pulp cap on a carious exposure as long as a good coronal restoration can be placed (9). The rationale for this approach is that most young pulps can heal as long as the coronal restoration does not allow leakage of additional inflammatory stimulants or microorganisms.

### Endodontics

Pulpal inflammation is usually superficial and is unlikely to extend past the canal orifices, and the healing potential is good if a healthy pulp is treated. Hence, the optimal approach is to perform a full pulpotomy (thus removing the coronally inflamed pulp) and treating the presumably healthy pulp at the canal orifices. When the root canal has



**Minimal  
Inflammation**

**Figure 1.** Histologic section of a pulp after a traumatic exposure 24 hours previously. Only about 1 mm of superficial pulp is inflamed.

developed thick dentinal walls and the apices are closed, a full pulpectomy can be performed (Fig. 3).

### Revascularization of Infected Pulp Space

#### Pulp Revascularization

Revascularization of an immature necrotic tooth has many potential advantages.

It has been shown that under certain conditions revascularization can be achieved in young teeth that have been traumatically avulsed, leaving a necrotic but uninfected pulp. Skoglund et al. (10) demonstrated that in extracted dog teeth, pulpal revascularization started immediately after reimplantation and was completed after approximately 45 days (Fig. 4). It is important to understand the biologic features permitting revascularization in young avulsed teeth, so that we might attempt to reproduce these unique conditions when the pulp space is infected. The immature avulsed tooth has an open apex, short root, and intact but necrotic pulp tissue. Therefore, the new tissue has easy access to the root canal system and a relatively short distance for proliferation to reach the coronal pulp horns. It has been experimentally shown that the apical portion of a pulp might remain vital and proliferate coronally after reimplantation, replacing the necrotized coronal portion of the pulp (11–13). The speed with which the tissue completely revascularizes the pulp space is important because bacteria from the outside are continually attempting to enter the pulp space, and the presence of vital pulpal tissue greatly slows or prevents the bacterial penetration into this tissue compartment. The ischemically necrotic pulp that is unique to an avulsion injury acts as a scaffold into which the new tissue grows, and the

fact that the crown is usually intact (rather than carious or with an access cavity) slows bacterial penetration because their only access to the pulp is through cracks (14) or enamel defects. Thus, the race between proliferation of new tissue and infection of the pulp space favors the new tissue.

Revascularization of the pulp space in a necrotic, infected tooth with apical periodontitis was attempted by Nygaard-Ostby and Hjortdal (15) in the 1960s but was mostly unsuccessful. However, the materials and instruments available 40–50 years ago were probably not sufficient to create an environment similar to the avulsed tooth, ie, a canal that is free of bacteria, containing a scaffold for new tissue to grow and to be largely resistant to further bacterial penetration. With currently available technologies it could be possible to effectively disinfect an infected pulp, artificially place a scaffold, and then effectively seal the access cavity to resist subsequent infection.

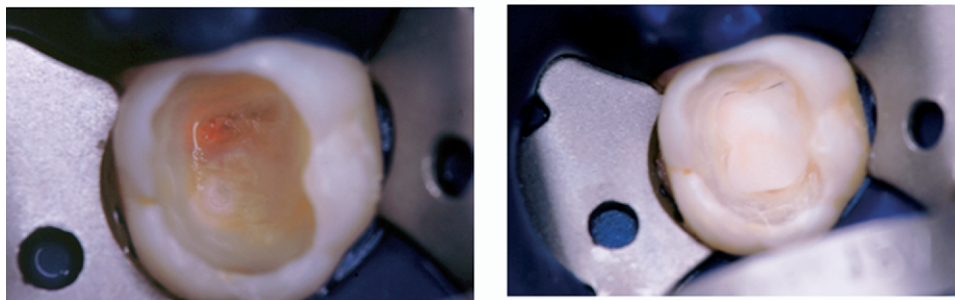
A recent case report by Banchs and Trope (16) has reproduced results in cases reported by others, indicating that it might be possible to replicate the unique circumstances of an avulsed tooth to revascularize the pulp in infected necrotic immature roots (11–13). Our case (Fig. 5) described the treatment of an immature second lower right premolar 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 mixture of ciprofloxacin, metronidazole, and minocycline (17), mixed as described in Fig. 6.

A blood clot was produced to the level of the cemento-enamel junction to provide a scaffold for the ingrowth of new tissue followed by a double seal of mineral trioxide aggregate in the cervical area and a bonded resin coronal restoration above it. Clinical and radiographic evidence of healing was observed as early as 22 days. The large radiolucency had disappeared within 2 months, and at the 24-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 antibacterial effectiveness of the triantibiotic paste reported by Hoshino et al. (17) was confirmed by our group in a dog model with infected immature roots (18). In addition, our group demonstrated in dogs that the potential for revascularization does exist (Fig. 7), and that the blood clot was essential as a scaffold (19). At this point, we are unsure of which factors in the blood clot are important. When these factors are isolated, they can be incorporated into a synthetic scaffold that will be easier to for clinicians to manipulate compared with a blood clot.

The procedure described in this section can be attempted in most cases. If no signs of regeneration are present after 3 months, then more traditional treatment methods can be initiated.

### Carious Exposure



**Figure 2.** Carious exposure caused by caries. The underlying inflamed pulp is removed, and a partial pulpotomy is performed on the remaining healthy pulp with calcium hydroxide (Courtesy Dr. Francisco Banchs).

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