Diagnosis and treatment of accidental root perforations

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A review of endodontic and periodontal aspects on the prognosis, diagnosis, prevention, and treatment of accidental root perforations is presented. Successful treatment depends mainly on proper diagnosis and immediate sealing of the perforation to eliminate risk of infection. A classification of root perforations is presented in the review to assist the clinician in making a proper choice of treatment protocol.

Introduction

Root perforation is an artificial communication between the root canal system to the supporting tissues of teeth or to the oral cavity (1). Often, the cause is iatrogenic as a result of misaligned use of rotary burs during endodontic access preparation and search for root canal orifices (2–4). Accidental root perforation may also complicate the endodontic treatment per se, for example, during efforts to negotiate calcified and curved canals as well as following lateral extension of the canal preparation to a so-called strip-perforation (5). Inappropriate post space preparation for permanent restoration of endodontically treated teeth is yet another common iatrogenic cause of root perforation (3). Non-iatrogenic causes, including root resorption and caries (4, 6–9), will not be addressed in this review.

Accidental root perforations, which may have serious implications, occur in approximately 2–12% of endodontically treated teeth (4, 10–14). Bacterial infection emanating either from the root canal or the periodontal tissues, or both, prevents healing and brings about inflammatory sequels where exposure of the supporting tissues is inflicted. Thus, painful conditions, suppurations resulting in tender teeth, abscesses, and fistulae including bone resorptive processes may follow. Down-growth of gingival epithelium to the perforation site can emerge, especially when accidental perforations occur in the crestal area by lateral perforation or perforation in furcations of two- and multi-rooted teeth.

Once an infectious process has established itself at the perforation site, prognosis for treatment is precarious and the complication may prompt extraction of the affected tooth (10, 15). Yet, if discovered early and properly managed, prolonged survival of the tooth is possible. This review relates specifically to the diagnosis and the impact of various factors on the prognosis, as well as the principles for treatment of root perforations. It also discusses measures for prevention.

Factors of significance to prognosis for treatment

Whether or not a root perforation can be successfully treated depends on whether the perforation can be repaired such that bacterial infection of the perforation site can either be prevented or eliminated (16). A number of factors including time from the perforation to detection, size, and shape of the perforation as well as its location impact the potentials to control infection at the perforation site.

Time

Indeed, numerous experimental studies have demonstrated that time is a most critical factor determining outcome of treatment, with immediate closure carrying the best prognosis. Lantz & Persson (17–19) produced root perforations in dogs that were treated either immediately or after some delay. The most
favorable healing response was evidenced when perforations were sealed immediately. Seltzer et al. (20) treated 22 perforations in monkeys at intervals from immediately to 10 months post-perforation. While the periodontium was damaged in all teeth, the most severe tissue destruction was in the untreated perforations and in teeth where treatment was delayed. Beavers et al. (16) observed consistent periodontal healing following treatment of experimentally produced root perforations in a monkey model. The high success rate was attributed to the immediate obturation of the perforations and the aseptic technique used. Others supporting these results found that delay in repair of perforations decreased the prognosis for healing (21, 22). However, Benenati et al. (23) observed that a delay in repairing perforations with amalgam did not influence the prognosis, if the perforation site had been kept aseptic in the time interval from its inception.

Consequently, to minimize the potential for emergence of infection of the perforation site, these studies infer that the best time to repair root perforations is immediately after occurrence. Proper treatment of the perforation may not always be possible, due to lack of time, lack of experience of the operator, and proper equipment. The perforation is then best maintained by an adequate, bacterially tight temporary seal, and referral to a specialist for as rapid a treatment as possible.

**Size**

Large-sized perforations may not respond to repair as well as smaller ones (24). Himel et al. (25) evaluated the effect of three materials on healing of perforations of the pulp chamber floor of mandibular molars in dogs, and found that the larger teeth with proportionally smaller perforations showed a better healing response. Large perforations are more likely to occur during operative procedures, when aggressive burs are used, causing more traumatic injuries to the surrounding tissues. Furthermore, large perforations can cause the problem of an incomplete seal of the defect, thus allowing continuous bacterial irritation of the perforation area (26). Small perforations clearly are easier to repair and therefore provide potential for predictable healing.

**Location**

The most important parameter affecting treatment prognosis is the location along the root surface. A perforation occurring relatively close to the crestal bone and the epithelial attachment is critical as it may lead to bacterial contamination from the oral environment along the gingival sulcus. Furthermore, apical migration of the epithelium to the perforation site can be expected, creating a periodontal defect (3, 17–20, 26–30). Once the periodontal pocket is formed, persistent inflammation of the perforation site is most likely maintained by continuous ingress of irritants from the pocket (26, 27). These perforations have a poor treatment prognosis from a periodontal aspect, and treatment from the inside of the root canal, even if adequately performed, cannot normally improve the condition.

Perforations of the furcation areas of multi-rooted teeth are similarly critical (3, 7, 17–19, 27, 31, 32) (Fig. 1A). At times, they are especially troublesome as the inflammatory process may cause rapid and extensive destruction of the periodontal tissues that ultimately leads to a permanent communication with the oral cavity and a persistently suppurating lesion (20, 24). Nevertheless, a high healing rate was attained in the treatment of experimental furcation perforations in monkeys (16). In 24 teeth of two monkeys, furcation perforations were sealed with either hard-setting calcium hydroxide or Teflon disks. All procedures were performed under strict aseptic conditions after extirpating the pulps, and the access cavities were sealed with hand-mixed zinc oxide eugenol cement and amalgam. Furcation perforations showed evidence of histologic healing after various time periods with no epithelial migration to the wound site (Fig. 1B, C). An additional set of lateral perforations exhibited similar evidence of periodontal tissue healing following treatment. According to the graphic illustrations given, the furcation perforations were produced in the middle of the pulpal floor and directly into the crestal bone. The fact that the epithelial attachment was not compromised may explain the high success rate, as well as the strict asepsis and the atraumatic preparation of the experimental perforations. The long-term healing response was not studied in this report.

Hartwell & England (30) had a high clinical success rate following repair of furcation perforations in monkeys using freeze-dried bone. However, histologically, a layer of epithelium was found immediately beneath the perforation with no bone healing in any of the samples. From the radiographs presented in the study, the perforation defects were located at the crestal bone level and thus susceptible to epithelial migration.
Perforations, coronal to the crestal bone, are easy to access and seal, and teeth may be restored without periodontal involvement. For a good prognosis, there should be sufficient sound tooth structure for an adequate restoration.

Perforations, apical to the crestal bone and epithelial attachment, are considered to have a good treatment prognosis when adequate endodontic treatment is rendered and the main canal is accessible. In these cases, the risk of periodontal involvement is reduced, making the prognosis good (16, 20).

Classification of root perforations

Based on the factors impacting the outcome of treatment considered above, the following classification of root perforations, proposed by Fuss & Trope (1), may assist the clinician to select a treatment strategy:

**Fresh perforation** – treated immediately or shortly after occurrence under aseptic conditions, *Good Prognosis*.

**Old perforation** – previously not treated with likely bacterial infection, *Questionable Prognosis*.

**Small perforation** (smaller than #20 endodontic instrument) – mechanical damage to tissue is minimal with easy sealing opportunity, *Good Prognosis*.

**Large perforation** – done during post preparation, with significant tissue damage and obvious difficulty in providing an adequate seal, salivary contamination, or coronal leakage along temporary restoration, *Questionable Prognosis*.

**Coronal perforation** – coronal to the level of crestal bone and epithelial attachment with minimal damage to the supporting tissues and easy access, *Good Prognosis*.

**Crestal perforation** – at the level of the epithelial attachment into the crestal bone, *Questionable Prognosis*.

**Apical perforation** – apical to the crestal bone and the epithelial attachment, *Good Prognosis*.

In multi-rooted teeth where the furcation is perforated, the prognosis differs according to the factors described for single-rooted teeth.

Determination of the presence and location of root perforation

As accurate detection of root perforations and determination of location are crucial to the treatment outcome, certain signs, and tools must be recognized in making the diagnosis. Sudden bleeding and pain during instrumentation of root canals or post preparations in teeth are warning signals of a potential root perforation. The appearance of blood on paper points

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![Fig. 1](image_url). A histologic section is seen in (A) of a tooth with an old (infected) furcation perforation that resulted in inflammation, bone resorption, and proliferation of the epithelium in the perforation area. Microphotographs of tissue sections in (B) and (C) are from the study of Beavers et al. (16). (B) Tissue defect immediately after bur penetration of the furcation in a mandibular molar. Forty-two days following immediate seal of the perforation in (C) with a teflon disk and zinc oxide eugenol cement resulted in a healing response. Note emerging bone fill of the perforation along with cellular cementum formation on the canal walls and absence of epithelial proliferation (microphotographs in (B) and (C) kindly provided by Dr G. Bergenholtz).
may also be indicative, but unreliable as bleeding may originate from the apical foramen or from residues of vital pulp tissue. To enhance radiographic detection, it has been proposed to place a highly radiopaque calcium-hydroxide paste, by inclusion of barium sulfate, in the root canal (33). However, caution should be exercised in crestal perforations as this measure can result in extrusion of the material into the periodontal tissues and cause unnecessary mechanical and chemical irritation impairing the treatment prognosis (Fig. 2). Radiographs taken at different angles with radiopaque instruments in the root canal are a better option and may confirm the presence of a root perforation (Fig. 3). However, when the perforation is located at the buccal

Fig. 2. Case demonstrates a treatment attempt of an old large crestal perforation that resulted in root resorption (A). Calcium hydroxide placed in the root canal was extruded into the resorption cavity (B). One week post-treatment, necrosis of the mucosa adjacent to the perforation area is obvious (C).

Fig. 3. Radiograph of a maxillary right incisor with a post in the root canal and a radiolucent area in the coronal third of the root (A). In an angulated view, penetration of the post to the periodontal tissue can be seen (B).
or palatal aspects of the root, the diagnostic value of radiographs is limited (Fig. 4). Anatomical structures, as well as radiopaque materials superimposing on the image of the root, may also obscure the perforation site.

Electronic apex locators (EALs) can accurately determine the location of root perforations, making them significantly more reliable than radiographs (34). After root instrumentation, it is recommended that the working length be verified with EALs. Readings, that are significantly shorter than the original length can be an indication of perforation (34).

A dental operating microscope is another helpful tool (35, 36) effective in detecting root perforations during orthograde root canal therapy and in surgical endodontic treatments. High magnification with coaxial illumination allows precise detection and visualization of perforations along straight non-curved root canals.

A narrow isolated periodontal defect is a possible sign of periodontal breakthrough due to root perforation. Probing the gingival sulcus to reveal possible communication with the oral cavity is recommended in such teeth. To determine locally isolated vertical bone losses, periodontal probing should be carried out by walking the probe around the tooth while pressing gently on the floor of the sulcus (37). In the presence of narrow isolated periodontal defects, differential diagnosis from vertical root fracture should be made with explorative surgery (38, 39).

**Treatment aspects**

**Measures for prevention**

Care should always be exercised during endodontic and operative procedures to prevent the complication of a root perforation. The following precautions may serve as general guidelines.

**Before accessing root canals**

The crown-root alignment should always be evaluated and bony eminences noticed. Often, palpation is useful to detect the direction of the root relative to the crown. Careful examination of radiographs is important to evaluate the shape and depth of the pulp chamber and width of the furcation floor. Indeed, adequate knowledge is needed of the location and dimensions of the pulp chamber (40). Attention should also be given to root inclination, the long tooth axis, the shape, number and degree of canal curvatures, presence of calcifications, and type of previous restorations. Additional radiographs of good diagnostic quality should be taken from other angles if needed (41).

**During access preparation**

The use of magnification is advantageous to observe canal orifices and the coronal alignment of the root canal. A rubber dam should not be placed before access...
preparations in teeth with narrow or calcified pulp chambers (41, 42), in re-treatments, and when accessing crowned teeth. In such cases, the pulp chamber may not readily be seen, as calcification processes induced by the previous treatment may have altered its normal anatomy. Krasner & Rankow (43) studied 500 extracted, permanent human teeth and found that the pulp chamber was always centrally located at the level of the cemento-enamel junction (CEJ). The CEJ was the most consistent anatomic landmark observed. They proposed to ignore the clinical crown contour as a guide in directing the access preparation and instead use the CEJ. Radiographs taken during the access preparation with a bur in place may be helpful.

Kvinnsland et al. (3) found that in maxillary anterior teeth, all perforations were located at the labial root aspect due to the operator’s underestimation of the palatal root inclination in the upper jaw.

**During root canal preparation**

Overzealous use of rotary instrumentation can cause apical or crestal perforations of the root canal wall, also called 'strip perforation' (5). Hence, large tapered instruments and Gates–Glidden (GG) burs should therefore be used with caution (44). Modern flexible nickel titanium instruments along with copious irrigation and lubrication were proposed for curved canals to prevent apical perforations (45, 46).

**During post preparation**

Utmost care should always be exercised during post preparations so that root canals are not overextended. Generally speaking, a safe preparation is best attained with the surgical microscope immediately after completion of a root canal filling. Kuttler et al. (47) examined the effects of post space preparation with GG drills on residual dentin thickness in distal roots of mandibular molars *in vitro* and found that such post space preparation carries a significant risk of perforation (7.3% with GG #4). Kvinnsland et al. (3) observed that more than half of the perforations in their cases of root perforation occurred during post-preparation procedures.

**Treatment by an orthograde approach**

As early as 1903, Peeso (48) stated that successful management of root perforations is dependent on early diagnosis of the defect, choice of treatment, materials used, host response, and the experience of the practitioner. These factors are also valid today. No doubt, the rationale for orthograde treatment of root perforations is the same as that of conservative endodontic therapy, i.e. prevention and treatment of periapical inflammation. This may be achieved by measures aimed to control infection of the perforation site, or if already infected, by using procedures that can disinfect the site and provide the best possible seal against penetration of bacterial elements.

Fresh perforations that occur during either operative or endodontic procedures are followed by hemorrhage. The first step then is to control the hemorrhage by pressure or irrigation (49). Subsequently, the perforation should be adequately sealed. The efficacy of a sealing material depends primarily on scalability and biocompatibility and thus ability to support osteogenesis and cementogenesis. It may also be advantageous that the material is relatively inexpensive, radiopaque, and bacteriostatic (50). In certain instances, it could also be beneficial to use a resorbable matrix in which a sealing material can be condensed (25, 51).

No material offers all of these properties. In search for the ideal material, numerous sealing materials and techniques have been tested over the years with varying success, including amalgam (17, 18, 23, 26, 28, 52–54), phosphate cement (17, 18), gutta-percha (3, 17, 18, 23, 27, 31), zinc oxide eugenol (4, 20, 56), SuperEBA (55), dentin chips (27), AH-26 (27), various formulations of calcium hydroxide (26–28, 56), Cavit (7, 12, 17, 18, 22, 28, 29), tricalcium phosphate (13, 25, 26), hydroxyapatite (26, 54, 57), glass ionomer cement (53, 58), resin-ionomer (59), mineral trioxide aggregate (MTA) (60, 61), tin foil (62), and indium foil (63, 64). Yet, the material factor must be regarded as only one of several critical factors (discussed above) that is significant to the outcome of treatment (54). Clearly, the selection of material must be related to the type of perforation. Consequently, an apical perforation should be treated according to routine endodontic principles and sealed with root canal filling materials. Infected apical perforations may be medicated with an antibacterial intracanal dressing before obturation. It has been suggested that large apical perforations should be treated similar to teeth with immature apices, i.e. with long-term calcium hydroxide treatment to achieve a hard tissue barrier (1, 7, 8). When the original canal is not accessible and
Apical periodontitis has emerged, root end resection may be the treatment of choice.

Management of crestal root perforations

Treatment of crestal perforations carries a guarded prognosis because of their proximity to the epithelial attachment. For sealing, any biocompatible material with a short setting time and good sealability should be selected (1). Orthodontic extrusion has been recommended for single-rooted teeth to bring the perforation to a coronal position, where it can be sealed externally without surgical intervention.

Perforations in the furcal region of molars are particularly challenging. Large furcation perforations make the control of sealing material hazardous, and risk of extrusion of the filling material into periodontal tissues is common (1), an additional complication that significantly impairs the chances for a desirable periodontal healing (23, 27, 54).

For large perforations, an internal matrix technique has been suggested (24, 30, 53–55). The defect (perforations in the furcation area and in straight canals) should then be directly accessible and visualized for the successful use of this technique (Fig. 5). The internal matrix must, of course, be sterile, possible to manipulate, and should not produce inflammation (24). Materials suggested in the literature are hydroxylapatite (24), decalcified freeze-dried bone (30), plaster of Paris (calcium sulfate) (53), hydroxyapatite + calcium sulfate (54), and resorbable collagen with MTA (65). Petersson et al. (27) and Bogaerts (55) have stated that materials based on calcium hydroxide as a main ingredient are not suitable for crestal and furcation perforations because of the initial inflammatory response to these materials, which could lead to breakdown of the supporting tissues and subsequent pocket formation (25, 28).

Resin-modified flowable glass ionomer cement can be used as an artificial floor barrier without risk of pushing the material into the supporting tissues (Figs 6 and 7). Furthermore, other materials can be added and condensed to improve sealability with minimal inflammatory response (identical healing for glass ionomer cements when used alone or over calcium sulfate or hydroxyapatite barrier) (66).

MTA has recently been proposed for repair of root perforations (67) (Fig. 8). Several *in vitro* studies on MTA have demonstrated its sealing ability (67–69). When used to repair perforations in animal models,
minimal or no inflammation was presented and, in addition, cementum repair occurred at the material interface (60, 61). It is reasonable to assume that the high surface pH of MTA supports repair and hard tissue formation in a similar fashion as calcium hydroxide. Thus, Holland et al. (70) have proposed that calcium oxide in MTA reacts with tissue fluids to form calcium hydroxide, which in turn may encourage hard tissue deposition.

It should be noted that there are no comparative human studies to demonstrate the superiority of MTA to other materials. Yet, numerous case reports exist in the literature showing excellent healing results with MTA when used as a vehicle for repair of root perforations.

Fig. 6. Case of a mandibular first molar with an old furcation perforation (A). In spite of the poor prognosis, treatment was initiated by post removal, gentle saline irrigation, and sealing the defect with a glass ionomer cement (Chelon Silve, 3M-Espe, Seefeld, Germany). The cement, with a setting time of 5 min, served as a barrier to avoid contamination during retreatment of the root canals. Radiograph in B is 3 years post-treatment and demonstrates resolution of both the apical and furcation lesions. A piece of the post displaced into the periodontal tissues during treatment remains (from Fuss & Trope (1)).

Fig. 7. Radiograph of a mandibular molar with an old large furcation perforation. It was deemed possible to resolve the lesion as there was no pocket probing depth to the furcation (A). The amalgam was gently removed through the root canal and the large perforation was sealed with glass ionomer cement. Thirty months following treatment, repair in the furcation is evident (B). Note that the material was not pushed into the periodontal tissues in spite of the large perforation defect (from Fuss & Trope (1)).
perforations (71, 72). A disadvantage is the prolonged setting time that requires two appointments to complete root canal therapy with permanent sealing. The cost of this material is substantial.

Several studies have shown that MTA is microscopically identical and chemically similar to Portland cement (73–75). Both materials show comparable biocompatibility and histologic tissue responses (76–78). Thus, Portland cement should be considered in future research.

### Treatment by a surgical approach

Indications for surgical intervention are large perforations, perforations as a result of resorption, failure of healing after non-surgical repair (4), non-surgically inaccessible perforations, extensive coronal restorations (7), when concomitant management of the periodontium is indicated (8), and large overfilling of the defect (31). The purpose of surgical treatment is to achieve a tight and permanent seal that will prevent bacteria and their byproducts in the root canal from entering the surrounding periodontal tissues (79–81).

Before corrective surgery, root canals must be properly treated and permanently filled, if possible (8, 82, 83). When surgical intervention is needed in an apical perforation, resection of the apical root to sound root structure with an adequate filling is recommended (8, 82, 84). While Oswald (82) has stated that for crestal perforations surgical repair will almost certainly result in a loss of the epithelial attachment and pocket formation, Rud et al. (80) found that after sealing root perforation elsewhere with dentin-bonded resin-composite (Retroplast), bone regenerated and a periodontal ligament space was partly formed with a lamina dura against the material.

Before surgical intervention, the following parameters should be considered (8):
- amount of remaining bone,
- extent of osseous destruction,
- duration of the defect,
- periodontal disease status,
- soft tissue attachment level,
- patient’s oral hygiene, and
- surgeon’s expertise in tissue management.

Rud et al. (80) suggested that even if a small bridge of crestal bone remains, it should be preserved by all means. Accessibility to the perforation is a definitive factor to be decided upon before a surgical repair attempt. Buccal perforations are easy to repair, whereas lateral and lingual/palatal perforations especially offer substantial technical difficulties, which may make the operator abstain.

During surgical procedures, hemostasis is critical and may be achieved by various methods like profound anesthesia with a vasoconstriction agent (infiltration of 2% Lidocaine with 1:50,000 epinephrine), (8, 85) cotton pellets soaked in epinephrine, Gelfoam (86), calcium sulfate (53, 87), and CollaCote collagen sponges saturated with 2.25% racemic epinephrine (88). A Class I cavity is prepared and the preferred filling material is placed (8, 83).

Guided tissue regeneration has been attempted to manage perforations and offer the possibility of successful repair in surgical treatments by serving as a
barrier for apical migration of epithelium (89, 90). The technique is, however, both costly and technically demanding (89) and has only gained support by case reports (89–92), which calls for additional clinical studies before this technique can be advocated.

Intentional replantation

Intentional replantation may be considered when orthograde and surgical treatments are not possible, undesirable, or have already failed (93, 94). This procedure can be recommended as a substitute for surgical treatment when the perforation defect is too large for repair and when the perforation is inaccessible without excessive bone removal (24, 95).

Generally, intentional replantation is not recommended for teeth with periodontal disease, furcation involvement, or gingival inflammation (95, 96). However, recently, it was evaluated for treatment of periodontally involved teeth, with good results (97).

The procedure involves atraumatic tooth extraction to avoid excessive damage to the cementum and periodontal ligamentum. Replantation should be completed quickly to reduce the extra alveolar time and risk for external root resorption. After removal, the tooth should be kept in forceps and bathed gently in a balanced salt-solution. The dental operating microscope has the advantage of careful inspection of the root surface and perforation site. Modest or no post-operative pain can be expected following the procedure (96, 98) (Fig. 9).

Teeth with divergent or long and curved roots are not suitable for intentional replantation because of the risk of fracture during extraction. The advantages of this procedure are the short time involved and easy manipulation. It allows thorough examination of the root surface and adequate seal of the perforation defect.

The success rate reported in clinical follow-ups ranges from 80% to 90% for carefully performed procedures with proper case selection (93, 96, 98, 99). Several case reports present successful treatment (100–103), but no

![Fig. 9. Case of a mandibular first molar with an apical perforation of the mesial root subjected to intentional replantation (A). After careful luxation and extraction by forceps (B), the apical 3 mm were resected and prepared for retrograde fillings with IRM (C, D). The radiograph in E shows the reimplanted tooth. Twelve months post-operatively, periapical healing is evident (F).](image-url)
studies have evaluated the long-term success of intentional tooth replantation with root perforations. Inflammatory root resorption and ankylosis due to trauma to the periodontal ligament are complications that may occur after intentional replantation (96).

References

34. Fuss Z, Assooline LS, Kaufman AY. Determination of location of root perforations by electronic apex


