

Editor's note

After a year at the helm of Dental Traumatology I am more convinced than ever that a journal based exclusively on dental traumatology not only can survive but thrive as well. We seem to have turned a corner. After the understandable 'wait and see' attitude of some authors and readers, both submissions and subscribers increased sharply in the second half of last year. An important and popular feature of last years issues were the guidelines for treatment of dental injuries of the International Association of Dental Traumatology (IADT). This year I intend to replace the guidelines with review articles of invited authors. The aim of these reviews will be to present current information on a subject of interest to practitioners and researchers in the field of dental trauma. I hope you find these articles as useful as you did the treatment guidelines!!!

CLINICAL MANAGEMENT OF THE AVULSED TOOTH: PRESENT STRATEGIES and FUTURE DIRECTIONS

Abstract – The aim of this review article is to supplement the recently published International Association of Dental Traumatology (IADT) guidelines on treatment of the avulsed tooth. A thorough discussion on the reasoning behind each guideline is presented. In addition, the author's views on alternate treatment strategies and future directions, along with recent research on the subject of the avulsed tooth, are also presented.

Martin Trope

School of Dentistry, University of North Carolina, North Carolina, NC 27599, USA

Key words: avulsion; clinical management

Correspondence: Professor Martin Trope, J. B. Friedland Professor and Chair, Department of Endodontics, School of Dentistry, University of North Carolina, North Carolina, NC 27599, USA

Favorable healing after an avulsion injury requires quick emergency intervention followed by evaluation and possible treatment at decisive times during the healing phase. The urgency of the emergency visit and the multidisciplinary nature of follow-up evaluations require both the lay public and practitioners from different dental disciplines to possess a knowledge of the treatment strategies involved. The aim of this review is to present the rationale for the present guidelines and discuss possible future strategies for the treatment of the avulsed tooth.

Consequences of tooth avulsion

When a tooth is avulsed, attachment damage and pulp necrosis occurs. The tooth is 'separated' from the socket, mainly due to the tearing of the periodontal ligament which leaves viable periodontal ligament cells on most of the root surface. In addition, due to the crushing of the tooth against the socket, small localized cemental damage also occurs.

If the periodontal ligament left attached to the root surface does not dry out, the consequences of tooth avulsion are usually minimal (1, 2). The hydrated periodontal ligament cells will maintain their viability, allowing them to reattach on replantation without causing any more than minimal destructive inflammation. In addition, since the crushing injury is contained within a very localized area, inflammation stimulated by the damaged tissues will be correspondingly limited, meaning that healing with new replacement cementum is likely to occur after the initial inflammation has subsided (Fig. 1).

However, if excessive drying occurs before replantation, the damaged periodontal ligament cells will elicit a severe inflammatory response over a diffuse area on the root surface. Unlike the situation described above, where the area to be repaired after the initial inflammatory response is small, here a large area of root surface is affected meaning that must be repaired by new tissue. The slower moving cementoblasts cannot cover the entire root surface in time and

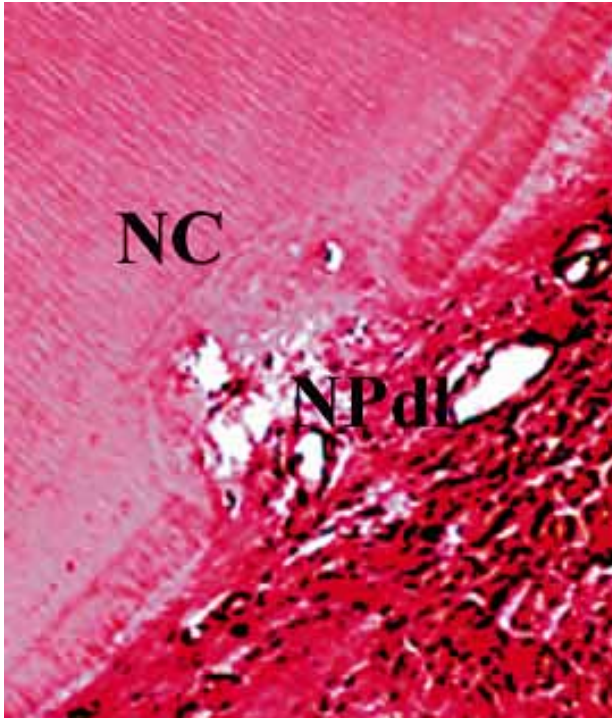


Fig. 1. Cemental healing. A previous resorptive defect is filled with new cementum (NC) and new periodontal ligament (NPdl).

it is likely that, in certain areas, bone will attach itself directly onto the root surface. In time, through physiologic bone re-contouring, the entire root will be replaced by bone; a process which has been termed osseous replacement or replacement resorption (3, 4) (Fig. 2).

Pulpal necrosis always occurs after an avulsion injury. While the necrotic pulp itself is of no consequence, the necrotic tissue is extremely susceptible to bacterial contamination. If revascularization does not occur or effective endodontic therapy is not carried out, the pulp space will inevitably become infected. The combination of bacteria in the root canal and cemental damage on the external surface of the root results in an external inflammatory resorption that can be very serious and lead to the rapid loss of the tooth (5) (Fig. 3).

Thus, the effects experienced after tooth avulsion has occurred, appear directly related to the severity and surface area of the inflammation on the root surface, and the resultant damaged root surface that must be repaired. Treatment strategies should always be considered in the context of limiting the extent of the peri-radicular inflammation, thus tipping the balance toward favorable (cemental) rather than unfavorable (osseous replacement or inflammatory resorption) healing.

Treatment Objectives

Treatment is directed at avoiding or minimizing the resultant inflammation which occurs as a direct result of the two main consequences of the avulsed tooth, namely attachment damage and pulpal infection.

Attachment damage as a direct result of the avulsion injury cannot be avoided. However, considerable damage, primarily caused by drying, can additionally occur to the periodontal membrane in the time that the tooth is out of the mouth. Treatment is directed

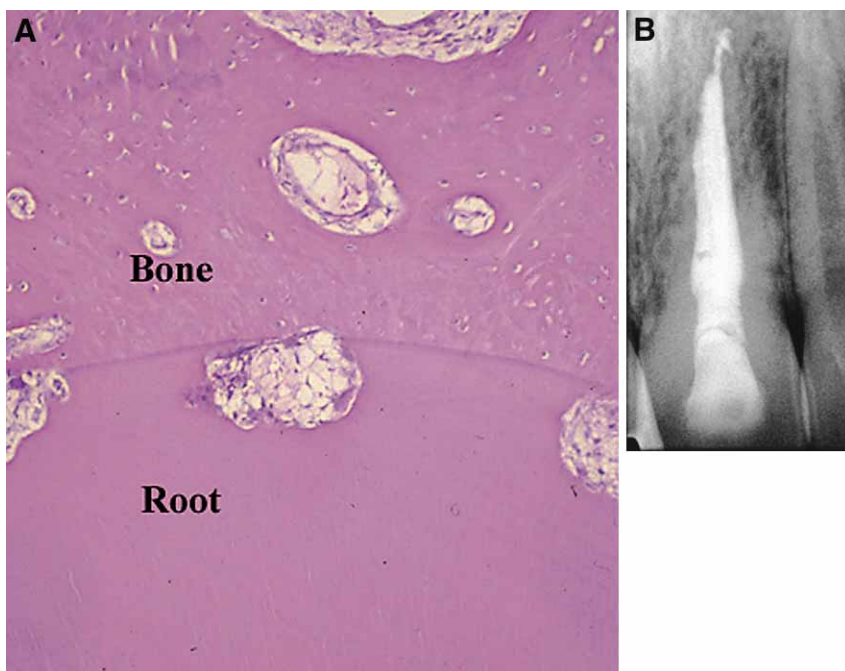


Fig. 2. Osseous replacement. A. Histologic slide showing bone directly attached to the root and areas of both bone and root undergoing active resorption. Both areas will later be replaced with new bone; it is in this way that the entire root will eventually be replaced by bone. B. Radiographic picture. The root is being replaced by bone. The lamina dura is lost around the root as it becomes incorporated in the bone.

Current and Future strategies for treating avulsed teeth

towards minimizing this damage (and the resultant inflammation) so that the fewest possible complications result. When severe additional damage cannot be avoided and osseous replacement of the root is considered certain, steps are taken to slow the replacement of the root by bone to maintain the tooth in the mouth for as long as possible.

In the open apex tooth, all efforts are made to promote revascularization of the pulp, thereby avoiding pulp space infection. When revascularization fails in the open apex tooth or is not possible in the closed apex tooth, all treatment efforts are made to prevent or eliminate toxins from the root canal space.

Clinical Management

Emergency Treatment at the Accident Site

Replant if possible or place in an appropriate storage medium. The damage that occurred to the attachment apparatus during the initial injury is unavoidable but usually minimal. However, all efforts are made to minimize necrosis of the remaining periodontal ligament while the tooth is out of the mouth. Pulpal sequelae are not a concern initially and are dealt with at a later state of the treatment.

The single most important factor to ensure a favorable outcome after replantation is the **speed** with which the tooth is replanted (6, 7). Of utmost importance is the prevention of drying, which causes loss of normal physiologic metabolism and morphology of the periodontal ligament cells (2, 7). Every effort should be made to replant the tooth within the first 15–20 min (8). This usually requires emergency personnel at the site of the injury with some knowledge of treatment protocol. The dentist should communicate clearly with the person at the site of the accident. Ideally, information on how to deal with such a situation should have already been given to the person who is likely to be on-site in an environment where such an accident is likely to occur, such as at school or on the playing field; for example, educational presentations for school nurses or athletics trainers. However, failing this, the information can be given over the phone. The aim is to replant a clean tooth with an undamaged root surface as gently as possible which means that the patient should be brought to the office immediately. If doubt exists that the tooth can be replanted adequately, the tooth should be quickly stored in an appropriate medium until the patient can get to the dental office for replantation. Suggested storage media in order of preference are; milk, saliva, either in the vestibule of the mouth or in a container into which the patient spits, physiologic saline or water (9). Water is the least desirable storage medium because the hypotonic environment causes rapid cell lysis and increased inflammation on replantation (10).

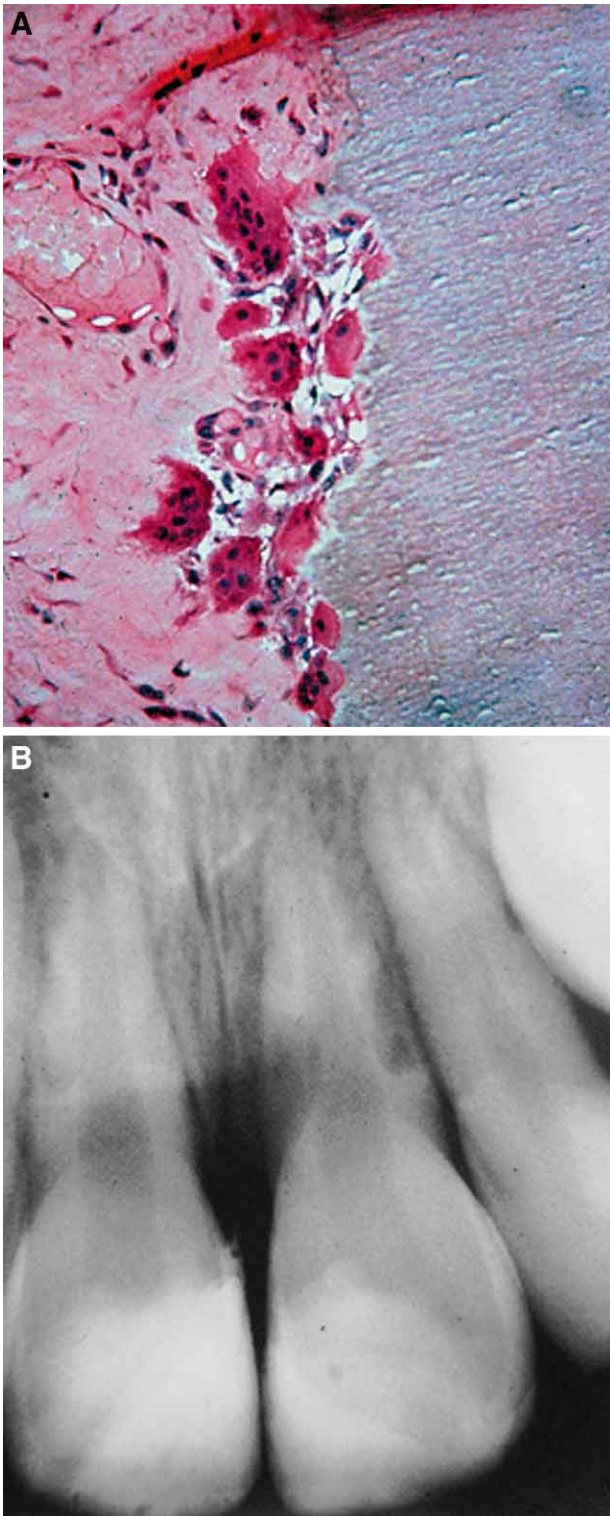


Fig. 3. External inflammatory root resorption due to pulpal infection. A. Histologic slide showing multinucleated clastic cells resorbing the root. B. Radiographic appearance showing resorption (lucency) of the root and adjacent bone.

Trope

Cell culture media in specialized transport containers, such as Hank's Balanced Salt Solution (HBSS) or ViaSpan®, have shown superior ability in maintaining the viability of the periodontal ligament fibers for extended periods (11). However, they are presently considered to be impractical as they are not generally available at the accident sites where injury is likely to occur. If we consider that more than 60% of avulsion injuries occur close to the home or school (12), it should be beneficial to have these media available in emergency kits at these two sites. In addition, it would not be unreasonable to have them in ambulances and places immediately accessible to other emergency personnel who are involved in situations where the injuries of the patient mean that the teeth might otherwise be sacrificed due to a more serious, even life-threatening, situation.

Management in the Dental Office

Emergency Visit

Prepare socket, prepare root, replant, functional splint, local and systemic antibiotics. Recognizing that the dental injury might be secondary to a more serious injury is essential. If, on examination, a serious injury is suspected, immediate referral to the appropriate expert is the first priority. The focus of the emergency visit is the attachment apparatus. The aim is to replant the tooth with a minimum of irreversibly damaged cells, as this will cause inflammation, and the maximal number of periodontal ligament cells that have the potential to regenerate and repair the damaged root surface.

Diagnosis and Treatment Planning. If the tooth was replanted at the site of injury, a complete history is taken to assess the likelihood of a favorable outcome. In addition, the position of the replanted tooth is assessed and adjusted if necessary. On rare occasions, the tooth may be 'gently' removed to prepare the root to increase the chances of a favorable outcome (see below).

If the patient's tooth is already out of the mouth, the storage medium should be evaluated and, if necessary, the tooth should be placed in a more appropriate medium. Hank's Balanced Salt Solution is presently considered the best medium for this purpose (Fig. 4). Milk or physiologic saline is also appropriate for storage purposes.

The medical and accident history is taken and a clinical exam carried out. The clinical examination should include an examination of the socket to ascertain if it is intact and suitable for replantation. This is accomplished by facial and palatal palpation. The socket is gently rinsed with saline (Fig. 5) and, when clear of the clot and debris, its walls are examined directly for the presence, absence, or collapse of the



Fig. 4. Avulsed tooth stored in Hank's Balanced Salt Solution (HBSS) whilst a history and clinical exam is being carried out.

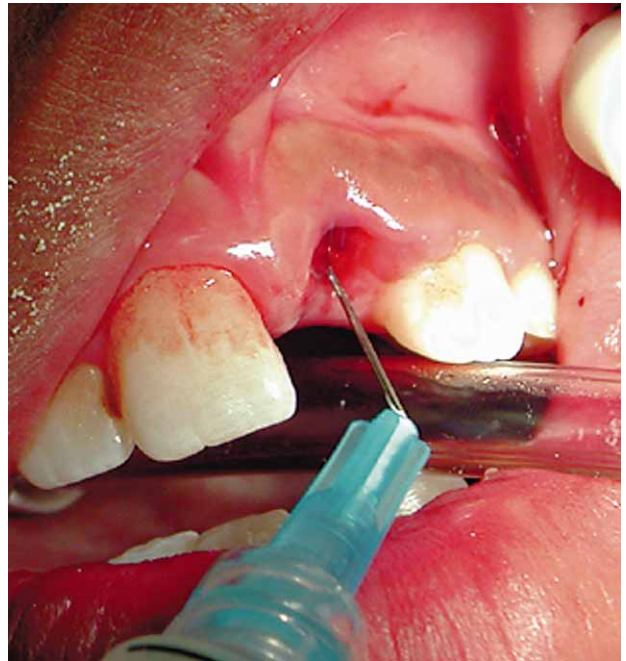


Fig. 5. Socket rinsed with sterile saline to allow for direct visual inspection manipulation and gentle replantation.

socket wall. Palpation of the socket and surrounding apical areas and pressure on the surrounding teeth are used to ascertain if an alveolar fracture is present in addition to the avulsion. Movement of a segment of bone as well as multiple teeth is suggestive of an alveolar fracture. The socket and surrounding areas, including the soft tissues, should be radiographed. Three vertical angulations are required for diagnosis of the presence of a horizontal root fracture in adjacent teeth (6). The remaining teeth in both the upper and lower jaws should be examined

for injuries, such as crown fractures, and any soft-tissue lacerations should be noted.

Preparation of the root

Preparation of the root is dependent on the maturity of the tooth (open vs. closed apex) and on the dry time of the tooth before it was placed in a storage medium. A dry time of 60 min is considered the point where survival of root periodontal ligament cells is unlikely.

Extra – oral dry time < 60 min

Closed Apex

The root should be rinsed of debris with water or saline and replanted in as gentle a fashion as possible.

If the tooth has a closed apex, revascularization is not possible (13) but, because the tooth was dry for less than 60 min (replanted or placed in appropriate medium), the chance for periodontal healing exists. Most importantly, the chance of a severe inflammatory response at the time of replantation is lessened. A dry time of less than 15–20 min is considered optimal where periodontal healing would be expected (1, 2, 8).

A continuing challenge is the treatment of the tooth that has been dry for more than 20 min (periodontal cell survival is assured) but less than 60 min (periodontal survival unlikely). In these cases, logic suggests that the root surface consist of some cells with the potential to regenerate and some that will act as inflammatory stimulators. Exciting new strategies are currently under investigation that may be extremely valuable in these cases. The use of Emdogain® (Biora, Malmö, Sweden) has been found to be valuable in cases that were considered hopeless in the past (see

Current and Future strategies for treating avulsed teeth

below) and this medicament may prove extremely valuable in the 20–60 minute dry time period. Studies are ongoing to evaluate its potential.

Open Apex

Soak in doxycycline for 5 min, gently rinse off debris, replant.

In an open apex tooth, revascularization of the pulp as well as continued root development is possible (Fig. 6). Cvek *et al.* (13) found in monkeys that soaking the tooth in doxycycline (1 mg in approximately 20 mL of physiologic saline) for 5 min before replantation significantly enhanced revascularization. This result was confirmed in dogs by Yanpiset *et al.* (14). While these animal studies do not provide us with a prediction of the rate of revascularization in humans, it is reasonable to expect that the same enhancement of revascularization that occurred in two animal species will occur in humans as well. As with the tooth with the closed apex, the open-apex tooth is then gently rinsed and replanted.

Extra-oral dry time > 60 min

Closed Apex

Remove the periodontal ligament by placing in acid for 5 min, soak in fluoride or cover the root with emdogain®, replant.

When the root has been dry for 60 min or more, the periodontal ligament cells are not expected to survive (1, 2). In these cases, the root should be prepared to be as resistant to resorption as possible (attempting to slow the osseous replacement process). These teeth should be soaked in acid for 5 min to remove all remaining periodontal ligament and thus remove the tissue that will initiate the inflammatory response on replantation. The tooth should then be soaked in 2% stannous fluoride for 5 min and replanted (15, 16).

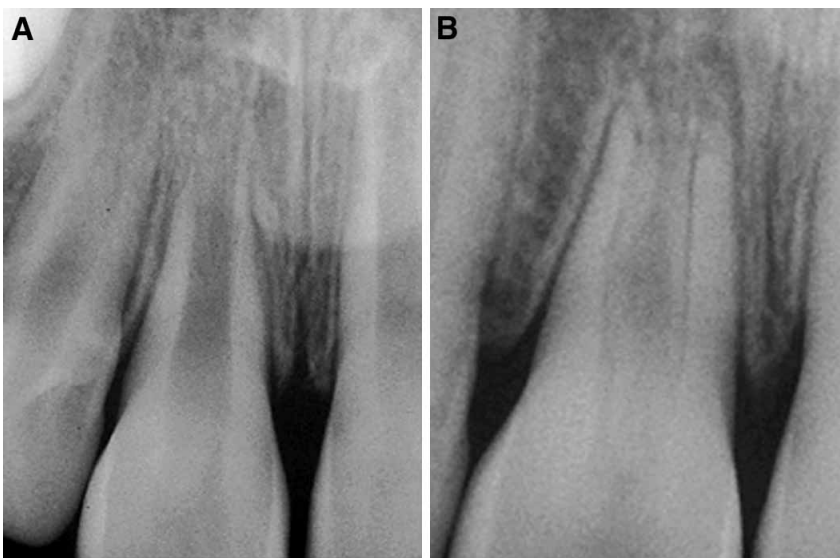


Fig. 6. Revascularization of an immature tooth. A. The stage of root development soon after replantation. B. One year later, it can be seen that the root has continued to develop and thicken.

Trope

Aledronate was found to have similar resorption slowing effects as fluoride when used topically (17) but further studies need to be carried out to evaluate whether its effectiveness is superior to fluoride and whether this justifies its added cost. Recent studies have found that Emdogain® (enamel matrix protein) may be extremely beneficial in teeth with extended extra oral dry times, not only to make the root more resistant to resorption but possibly to stimulate the formation of new periodontal ligament from the socket (18, 19)(Fig. 7).

If the tooth has been dry for more than 60 min and no consideration has been given to preserving the periodontal ligament, the endodontics may be performed extraorally. In the case of a tooth with a

closed apex, no advantage exists to this additional step at the emergency visit. However, in a tooth with an open apex the endodontic treatment, if performed after replantation, involves a long-term apexification procedure. In these cases, completing the root canal treatment extraorally, where a seal in the blunderbuss apex is easier to achieve, may be advantageous. When endodontic treatment is performed extraorally, it must be performed aseptically with the utmost care to achieve a root canal system that is free of bacteria.

Open apex

Replant? If yes, treat as with closed apex tooth. Endodontic treatment may be performed out of the mouth. Since these teeth are in young patients whose facial development is usually incomplete, many pediatric dentists consider the prognosis to be so poor and the potential complications of an ankylosed tooth so severe that they recommend that these teeth are not replanted. In fact, not to replant these teeth is the present recommendation of the International Association of Dental Trauma (20). However, considerable debate exists as to whether it would be beneficial to replant the root even though it will inevitably be lost due to resorption. If the patients are followed carefully and the root submerged at the appropriate time (21, 22), the height and, more importantly, the width of the alveolar bone will be maintained, allowing for easier permanent restoration at the appropriate time when the facial development of the child is complete. Studies are ongoing to evaluate whether the present recommendations should be changed.

Preparation of the socket

The socket should be left undisturbed before replantation (6). Emphasis is placed on the removal of obstacles within the socket to facilitate the replacement of the tooth into the socket (23). It should be lightly aspirated if a blood clot is present. If the alveolar bone has collapsed, a factor which may prevent replantation or cause it to be traumatic, a blunt instrument should be inserted carefully into the socket in an attempt to reposition the wall.

Splinting

A splinting technique that allows physiologic movement of the tooth during healing and that is in place for a minimal time period results in a decreased incidence of ankylosis (6, 23–25). Semi-rigid (physiologic) fixation for 7–10 days is recommended (6, 25). The splint should allow movement of the tooth, should have no memory (so the tooth is not moved during healing), and should not impinge on the gingiva and/or prevent maintenance of oral hygiene in the area (Fig. 8). Many splints satisfy the requirements of an

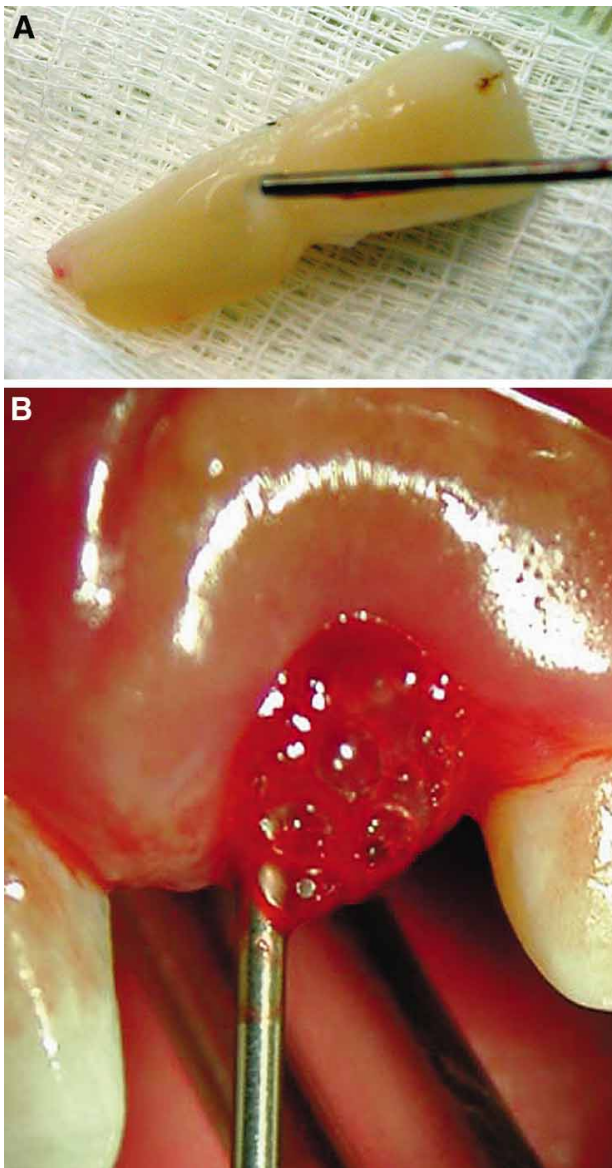


Fig. 7. Emdogain® placed A. on the root surface and B. into the socket before the tooth is replanted.

Current and Future strategies for treating avulsed teeth

surgeon at this stage. If these lacerations are sutured, care must be taken to clean the wound thoroughly beforehand as dirt, or even minute tooth fragments, left in the wound affect healing and the esthetic result.

Adjunctive therapy

Systemic antibiotics given at the time of replantation and prior to endodontic treatment are effective in preventing bacterial invasion of the necrotic pulp and, therefore, subsequent inflammatory resorption (27). Tetracycline has the additional benefit of decreasing root resorption by affecting the motility of the osteoclasts and reducing the effectiveness of collagenase (28). The administration of system antibiotics for patients not susceptible to tetracycline staining is Doxycycline 2× per day for 7 days at appropriate dose for patient age and weight (28, 29) or Penicillin V 1000 mg and 500 mg 4× per day for 7 days, beginning at the emergency visit and continuing until the splint is removed after 7–10 days (27). The bacterial content of the sulcus should also be controlled during the healing phase. In addition to stressing the need for adequate oral hygiene to the patient, the use of chlorhexidine rinses for 7–10 days may also be useful.

In a recent study by our group (as yet unpublished), great benefits were seen when the pulp contents were removed at the emergency visit and Ledermix® was placed into the root canal. This product contains a tetracycline corticosteroid combination that has been shown to move through the dentinal tubules. Apparently the use of the medicament was able to shut down the inflammatory response after replantation to allow for more favorable healing in comparison to those teeth that did not possess the medicament. We are confident that the immediate use of this medicament will become standard practice in the not too distant future.

The need for analgesics should be assessed on an individual case basis. The use of pain medication stronger than a non-prescription, non-steroidal, anti-inflammatory drug is unusual. The patient should be sent to a physician for consultation regarding a tetanus booster within 48 h of the initial visit.

Second Visit

This visit should take place 7–10 days after the emergency visit. At the emergency visit, emphasis was placed on the preservation and healing of the attachment apparatus. The focus of this visit is the prevention or elimination of potential irritants from the root canal space. These irritants, if present, provide the stimulus for the progression of the inflammatory response and bone and root resorption. Also, at this visit, the course of systemic antibiotics is completed,



Fig. 8. Examples of splints. A. TTS splint. This splint allows space for adequate cleaning therefore minimizing infection due to plaque and food debris. It is flexible in a horizontal and vertical direction. B. Resin splint that is too thick, making it impossible for the patient to keep it clean.

acceptable splint, with a new titanium trauma splint recently been shown to be particularly effective and easy to use (26). After the splint is in place, a radiograph should be taken to verify the positioning of the tooth and as a preoperative reference for further treatment and follow-up. When the tooth is in the best possible position, it is important to adjust the bite to ensure that it has not been splinted in a position that will cause traumatic occlusion. One week is sufficient to create periodontal support to maintain the avulsed tooth in position (6). Therefore, the splint should be removed after 7–10 days. The only exception to this is when avulsion occurs in conjunction with alveolar fractures, in which case it is suggested that the tooth should be splinted for a suggested period of 4–8 weeks (6).

Management of the soft tissues

Soft tissue lacerations of the socket gingiva should be tightly sutured. Lacerations of the lip are fairly common with these types of injuries. The dentist should approach lip lacerations with some caution and it might be prudent to consult with a plastic

Trope

the chlorhexidine rinses can be stopped, and the splint is removed.

Endodontic Treatment

Extra – oral time < 60 min

Closed Apex

Initiate endodontic treatment at 7 to 10 days. In cases where endodontic treatment is delayed or signs of resorption are present, treat with 'long-term' calcium hydroxide treatment before obturation.

No chance exists for the revascularization of these teeth, and endodontic treatment should be initiated at the second visit at 7–10 days (6, 13). If therapy is initiated at this optimum time, the pulp should be necrotic without infection or, at most, only minimal infection (30–32). Therefore, endodontic therapy with an effective interappointment antibacterial agent (33) over a relatively short period of time (7–10 days) is sufficient to ensure effective disinfection of the canal (34). If the dentist is confident of complete patient cooperation, long-term therapy with calcium hydroxide remains an excellent treatment method (5, 32). The advantage of its use is that it allows the dentist to have a temporary obturating material in place until an intact periodontal ligament space is confirmed. Long-term calcium hydroxide treatment should always be used when the injury occurred more than 2 weeks before the start of endodontic treatment or if radiographic evidence of resorption is present (32).

The root canal is thoroughly instrumented and irrigated, then filled with a thick, powdery mix of calcium hydroxide and sterile saline (anesthetic solution is also an acceptable vehicle). The calcium hydroxide is changed every 3 months within a range of 6–24 months. The canal is obturated when a radiographi-

cally intact periodontal membrane can be demonstrated around the root. Calcium hydroxide is an effective antibacterial agent (33, 34), and favorably influences the local environment at the resorption site, theoretically promoting healing (35). It also changes the environment in the dentin to a more alkaline pH, which may slow the action of the resorptive cells and promote hard tissue formation (35). However, the changing of the calcium hydroxide should be kept to a minimum (not more than every 3 months) because it has a necrotizing effect on the cells that are attempting to repopulate the damaged root surface (36).

While calcium hydroxide is considered the drug of choice in the prevention and treatment of inflammatory root resorption, it is not the only medicament recommended in these cases. Some attempts have been made to not only remove the stimulus for the resorbing cells but also to affect them directly. The antibiotic-corticosteroid paste, Ledermix, is effective in treating inflammatory root resorption by inhibiting the spread of dentinoclasts (37, 38) without damaging the periodontal ligament. Its ability to diffuse through human tooth roots has been demonstrated (39), whilst its release and diffusion is further enhanced when used in combination with calcium hydroxide paste (40). Calcitonin, a hormone that inhibits osteoclastic bone resorption, is also an effective medication in the treatment of inflammatory root resorption (41).

Open Apex

Avoid endodontic treatment and look for signs of revascularization. At first sign of an infected pulp initiate apexification procedure. Teeth with open apices have the potential to revascularize and continue root development and initial treatment is directed toward the re-establishment of the blood supply (13, 14) (Fig. 3). The initiation of

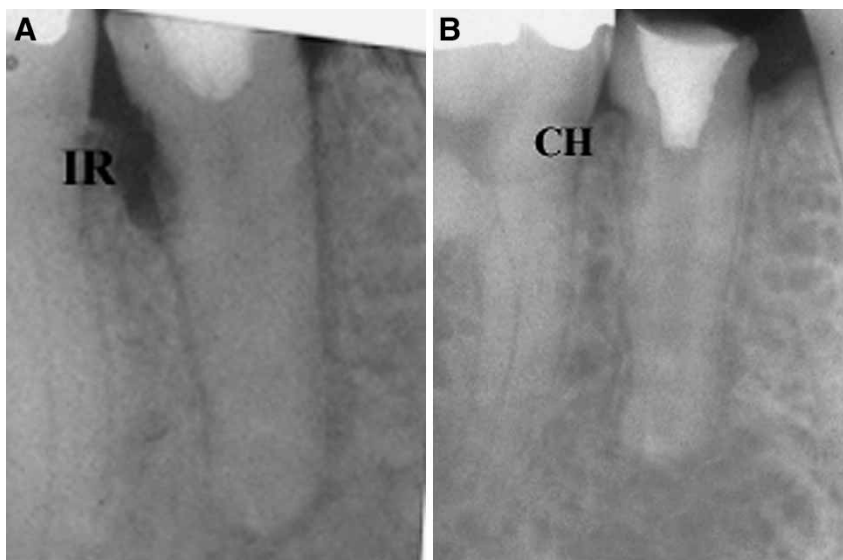


Fig. 9. A. Active resorption can be seen soon after the tooth was replanted. B. After long-term Ca (OH)₂ treatment, the resorptive defects have healed, and an intact lamina dura can be traced around the root. The tooth is ready for obturation.

Current and Future strategies for treating avulsed teeth

endodontic treatment is avoided if at all possible unless definite signs of pulp necrosis, such as peri-radicular inflammation, are present. The diagnosis of pulp vitality is extremely challenging in these cases. After trauma, diagnosis of a necrotic pulp is particularly desirable because, due to cemental damage accompanying the traumatic injury, infection in these teeth is potentially more harmful. External inflammatory root resorption can be extremely rapid in these young teeth because the tubules are wide and allow the irritants to move freely to the external surface of the root (13, 14) (Fig. 9).

Patients are recalled every 3–4 weeks for sensitivity testing. Recent reports indicate that thermal tests with carbon dioxide snow (-78°C) or difluordichlormethane (-50°C) placed at the incisal edge or pulp horn are the best methods for testing sensitivity, particularly in young permanent teeth (42, 43, 46) (Fig. 10). One of these two tests must be included in the sensitivity testing of these traumatized teeth. The laser Doppler flowmeter has been shown to be a superior tool in the diagnosis of revascularization of an immature tooth after trauma (44). In a recent study in dogs, Yanpiset et al. (45) showed that the presence of revascularization can be detected as early as 4 weeks after an avulsion by this method. Radiographic (apical breakdown and/or signs of lateral root resorption) and clinical (pain to percussion and palpation) signs of pathosis are carefully assessed. At the first sign of pathosis, endodontic treatment should be initiated and, after disinfection of the root canal space, an apexification procedure should be carried out.



Fig. 10. Modern cold testing methods, placed on the incisal edge of the incisors.

Extra-oral time > 60 min

Closed Apex

As with < 60 dry time. These teeth are treated endodontically in the same way as those teeth that had an extra-oral time of < 60 min

Open Apex (if replanted)

If endodontic treatment was not performed out of the mouth, initiate apexification procedure. In these teeth the chance of revascularization is extremely poor (4, 32). Therefore, no attempt is made to revitalize these teeth. An apexification procedure is initiated at the second visit if root canal treatment was not performed at the emergency visit. If endodontics was performed at the emergency visit, the second visit is a recall visit to assess initial healing only.

Temporary Restoration. Effectively sealing the coronal access is essential to prevent infection of the canal between visits. Recommended temporary restorations are reinforced zinc-oxide-eugenol cement, acid-etch composite resin, or glass-ionomer cement. The depth of the temporary restoration is critical to its sealability. A depth of at least 4 mm is recommended so that a cotton pellet cannot be placed; the temporary restoration is placed directly onto the calcium hydroxide in the access cavity. Calcium hydroxide should first be removed from the walls of the access cavity due to the fact that it is soluble and will wash out when it comes into contact with saliva, leaving a defective temporary restoration.

After initiation of the root canal treatment, the splint is removed. If time does not permit complete removal of the splint at this visit, the resin tacks are smoothed so that the soft tissues are not irritated and the residual resin is removed at a later appointment.

At this appointment, healing is usually sufficient to perform a detailed clinical examination on the teeth surrounding the avulsed tooth. The sensitivity tests, reaction to percussion and palpation, and periodontal probing measurements should be carefully recorded for reference at follow-up visits.

Obturation visit

At practitioners convenience or, in cases of long-term calcium hydroxide therapy, when an intact lamina dura is traced. If the endodontic treatment was initiated 7–10 days after the avulsion and clinical and radiographic examinations do not indicate pathosis, obturation of the root canal at this visit is acceptable, although the use of long-term calcium hydroxide is a proven option for use in these cases. On the other hand, if endodontic treatment was initiated more than 7–10 days after the avulsion or active resorption is visible, the pulp space

Trope

must first be disinfected before obturation. Traditionally, the re-establishment of a lamina dura (Fig. 9) is a radiographic sign that the canal bacteria have been controlled. When an intact lamina dura can be traced, obturation can take place.

The canal is re-instrumented and irrigated under strict asepsis. After completion of the instrumentation, the canal can be obturated by any acceptable technique with special attention to an aseptic technique and the best possible seal of the obturating material.

Permanent Restoration

Much evidence exists that coronal leakage caused by defective temporary and permanent restorations results in a clinically relevant amount of bacterial contamination of the root canal after obturation. Therefore, the tooth should be permanently restored either at or soon after the time of obturation of the root canal. As with the temporary restoration, the depth of restoration is important for its seal and therefore the deepest restoration possible should be made. A post-obturation restoration should be avoided whenever possible. Because most avulsions occur in the anterior region of the mouth where esthetics is important, composite resins with the addition of dentin bonding agents are usually recommended in these cases. They have the additional advantage of internally strengthening the tooth against fracture if another trauma should occur.

Follow-Up Care

Follow-up evaluations should take place at 3 months, 6 months and yearly for at least 5 years. If osseous replacement is identified, timely revision of the long-term treatment plan is indicated. In the case of inflammatory root resorption, a new attempt at disinfection of the root canal space by standard re-treatment can reverse the process. Teeth adjacent to and surrounding the avulsed tooth or teeth may show pathologic changes long after the initial accident. Therefore, these teeth should be tested at recall and the results compared to those collected soon after the accident.

References

1. Andreasen JO. The effect of extra-alveolar period and storage media upon periodontal and pulpal healing after replantation of mature permanent incisors in monkeys. *Int J Oral Surg* 1981;10:43–51.
2. Soder PO, Otteskog P, Andreasen JO, Modeer T. Effect of drying on viability of periodontal membrane. *Scand J Dent Res* 1977;85:167–172.
3. Andreasen JO, Hjorting-Hansen E. Replantation of teeth, I: Radiographic and clinical study of 110 human teeth replanted after accidental loss. *Acta Odontol Scand* 1966;24:263–269.

4. Trope M. Root resorption of dental and traumatic origin. Classification based on etiology. *J Pract Periodont Aesthet Dent* 1998;10:515–522.
5. Tronstad L. Root resorption etiology, terminology and clinical manifestations. *Endod Dent Traumatol* 1988;4:241.
6. Andreasen JO, Andreasen FM. *Textbook and Color Atlas of Traumatic Injuries to the Teeth*, 3rd edn. Copenhagen and St. Louis, Munksgaard and CV Mosby, 1994.
7. Andreasen JO, Kristersson L. The effect of limited drying or removal of the periodontal ligament: Periodontal healing after replantation of mature permanent incisors in monkeys. *Acta Odontol Scand* 1981;39:1.
8. Barrett EJ, Kenny DJ. Avulsed permanent teeth: a review of the literature and treatment guidelines. *Endod Dent Traumatol* 1997;13:153–163.
9. Hiltz J, Trope M. Vitality of human lip fibroblasts in milk, Hanks Balanced Salt Solution and Viaspan storage media. *Endod Dent Traumatol* 1991;7:69.
10. Blomlof L. Milk and saliva as possible storage media for traumatically exarticulated teeth prior to replantation. *Swed Dent J Suppl* 1981;8:1.
11. Trope M, Friedman S. Periodontal healing of replanted dog teeth stored in Viaspan, milk and Hanks Balanced Salt Solution. *Endod Dent Traumatol* 1992;8:183–188.
12. Hedegard B, Stalhøne I. A study of traumatized permanent teeth in children aged 7–15 years. Part I. *Swed Dent J* 1973;66:431–438.
13. Cvek M et al. Effect of topical application of doxycycline on pulp revascularization and periodontal healing in replanted monkey incisors. *Endod Dent Traumatol* 1990;6:170–177.
14. Yanpiset K, Trope M. Pulp revascularization of replanted immature dog teeth after different treatment methods. *Endod Dent Traumatol* 2000;16:211–217.
15. Bjorvatn K, Selvig KA, Klinge B. Effect of tetracycline and SnF₂ on root resorption in replanted incisors in dogs. *Scand J Dent Res* 1989;97:477–482.
16. Selvig KA, Zander HA. Chemical analysis and microradiography of cementum and dentin from periodontally diseased human teeth. *J Periodontol* 1962;33:303–310.
17. Levin L, Bryson EC, Caplan D, Trope M. Effect of topical alendronate on root resorption of dried replanted dog teeth. *Dent Traumatol* 2001;17:120–126.
18. Iqbal MK, Bamaas N. Effect of enamel matrix derivative (EMDOGAIN®) upon periodontal healing after replantation of permanent incisors in Beagle dogs. *Dent Traumatol* 2001;17:36–46.
19. Filippi A, Pohl Y, von Arx T. Treatment of replacement resorption with Emdogain® – preliminary results after 10 months. *Dent Traumatol* 2001;17:3–10.
20. Flores MT, Andreasen JO, Bakland LK, Feiglin B, Gutman JL, Oikarinen K, Pitt Ford TR, Sigurdsson A, Trope M, Vann WF JR. Guidelines for the management of traumatic dental injuries. *Dent Traumatol* 2001;5:193–198.
21. Andersson L, Malmgren B. The problem of dentoalveolar ankylosis and subsequent replacement resorption in the growing patient. *Austr Endod J* 1999;25:57–61.
22. Filippi A, Pohl Y, von Arx T. Decoronation of an ankylosed tooth for preservation of alveolar bone prior to implant placement. *Dent Traumatol* 2001;2:93–95.
23. Hammarstrom L, Lindskog S. General morphologic aspects of resorption of teeth and alveolar bone. *Int Endod J* 1985;18:93–99.
24. Andreasen JO. Etiology and pathogenesis of traumatic dental injuries. *Scand J Dent Res* 1970;78:329–337.
25. Andersson L, Friskopp J, Blomlof L. Fiber-glass splinting of traumatized teeth. *ASDC J Dent Child* 1983;3:21.
26. Von Arx T, Filippi A, Buser D. Splinting of traumatized teeth with a new device. TTS (Titanium Trauma Splint). *Dent Traumatol* 2001;17:180–184.

Current and Future strategies for treating avulsed teeth

27. Hammarstrom L, Pierce A, Blomlof L, Feiglin B, Lindskog S. Tooth avulsion and replantation: a review. *Endod Dent Traumatol* 1986;2:1-9.
28. Sae-Lim V, Wang C-Y, Choi G-W, Trope M. The effect of systemic tetracycline on resorption of dried replanted dogs' teeth. *Endod Dent Traumatol* 1998;14:127.
29. Sae-Lim V, Wang C-Y, Trope M. Effect of systemic tetracycline and amoxicillin on inflammatory root resorption of replanted dogs' teeth. *Endod Dent Traumatol* 1998;14:216-228.
30. Lundin S-A, Noren JG, Warfvinge J. Marginal bacterial leakage and pulp reactions in Class II composite resin restorations in vivo. *Swed Dent J* 1990;14:185-191.
31. Fuks A, Chosak A, Eidelman E. Partial pulpotomy as an alternative treatment for exposed pulps in crown-fractured permanent incisors. *Endod Dent Traumatol* 1987;3:100-102.
32. Trope M et al. Short versus long term Ca(OH)₂ treatment of established inflammatory root resorption in replanted dog teeth. *Endod Dent Traumatol* 1995;11:124-129.
33. Bystrom A, Claesson R, Sundqvist G. The antibacterial effect of camphorated paramonochlorphenol, camphorated phenol and calcium hydroxide in the treatment of infected root canals. *Endod Dent Traumatol* 1985;1:170-177.
34. Sjogren U, Figdor D, Spangberg L, Sundqvist G. The antimicrobial effect of calcium hydroxide as a short term intracanal dressing. *Int Endod J* 1991;24:119-125.
35. Tronstad L et al. pH changes in dental tissues following root canal filling with calcium hydroxide. *J Endod* 1981;7:17-22.
36. Lenghedden A, Blomlof L, Lindskog S. Effect of delayed calcium hydroxide treatment on periodontal healing in contaminated replanted teeth. *Scand J Dent Res* 1991;99:147-153.
37. Pierce A, Lindskog S. The effect of an antibiotic corticosteroid combination on inflammatory root resorption. *J Endod* 1988;14:459-464.
38. Pierce A, Berg JO, Lindskog S. Calcitonin as an alternative therapy in the treatment of root resorption. *J Endod* 1988;14:459-462.
39. Abbott PV, Heithersay GS, Hume WR. Release and diffusion through human tooth roots in vitro of corticosteroid and tetracycline trace molecules from Ledermix paste. *Endod Dent Traumatol* 1988;4:55-62.
40. Abbott PV, Hume WR, Heithersay GS. Effects of combining Ledermix and calcium hydroxide pastes on the diffusion of corticosteroid and tetracycline through human roots in vitro. *Endod Dent Traumatol* 1989;5:188-192.
41. Pierce A, Berg JO, Lindskog S. Calcitonin as an alternative therapy in the treatment of root resorption. *J Endod* 1988;14:459-465.
42. Fuss Z et al. Assessment of reliability of electrical and thermal pulp testing agents. *J Endod* 1986;12:301-309.
43. Fulling HJ, Andreasen JO. Influence of maturation status and tooth type of permanent teeth upon electrometric and thermal pulp testing procedures. *Scand J Dent Res* 1976;84:266-272.
44. Mesaros S, Trope M. Revascularization of traumatized teeth assessed by laser Doppler flowmetry: case report. *Endod Dent Traumatol* 1997;13:24-30.
45. Yanpiset K, Vongsavan N, Sigurdsson A, Trope M. Efficacy of laser Doppler flowmetry for the diagnosis of reimplanted immature dog teeth. *Dent Traumatol* 2001;17:63-70.
46. Ohman A. Healing and sensitivity to pain in young replanted human teeth. An experimental and histologic study. *Odontol Tidskr* 1965;73:166-172.