

Avulsion of permanent teeth: theory to practice

REVIEW ARTICLE

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Abstract – This paper presents clinical protocols for the emergency, early and post treatment complications of the avulsed tooth. The biological basis for these protocols is presented so that the reader understands the clinical decisions that have been made. Most of the protocols described in this article, but not all, have been adopted in the official guidelines of the *International Association of Dental Traumatology*. Some experimental results are promising and they have therefore been included in the review to stimulate colleagues to further research.

Avulsion is a relatively uncommon type of traumatic injury to the permanent dentition (1–3). From a clinical perspective, since avulsions occur infrequently, the average practitioner will not instinctively know how best to treat each (rare) case that he/she encounters. Access to quick up to date information such as the IADT guidelines (<http://iadt-dentaltrauma.org>) or Andreasen's Dental Trauma Guide (<http://dentaltraumaguide.org>) is essential so as to offer optimal treatment to each patient in a timely manner.

It occurs most frequently between the ages of 7–14 years (3). The majority of these injuries occur in the maxillary central incisors (3). Since most avulsions occur before the patient's facial growth is complete it is critical to maintain the tooth and surrounding bone until facial growth is complete and a relatively uncomplicated 'permanent' restoration can be made. Therefore, while definitely the ultimate aim, success does not necessarily require that the tooth is healthy and functioning for the entire life of the patient. Therefore maintaining the tooth and surrounding bone for a few years can be considered a successful treatment in the growing patient.

Interestingly most of the injuries occur within a short distance from home, school or a sports venue (4, 5). Thus from a theoretical point of view if health providers in these locations were educated as to the best emergency treatment for these cases many more successful outcomes would result.

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 that leaves viable periodontal ligament cells on most of the root surface (Fig. 1). In addition, due to the crushing/scraping of the tooth against the socket, small-localized cemental damage also occurs (Fig. 2).

If the periodontal ligament left attached to the root surface does not dry out, the consequences of tooth

avulsion are usually minimal (6, 7). The hydrated periodontal ligament cells will maintain their viability, allowing healing with regenerated periodontal ligament cells when replanted without causing much destructive inflammation. In addition, since the crushing injury is contained within a 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. 3).

However, if excessive drying occurs before replantation, the damaged periodontal ligament cells will elicit an 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 that must be repaired by new tissue. The slower moving cementoblasts cannot cover the entire root surface in time and it is likely that, in certain areas, bone will attach itself directly onto the root surface. In time, through physiologic bone remodeling, the entire root will be replaced by bone; a process which has been termed osseous replacement or replacement resorption (Fig. 4) (8, 9).

Pulpal necrosis always occurs after an avulsion injury. While the necrotic pulp itself is of no consequence (other than the tooth will not continue its development), 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 microbes in the root canal and cemental damage on the external surface of the root results in an external inflammatory resorption that can be very aggressive. Resorption will continue as long as the microbes are not removed from the root canal and can lead to the rapid loss of the tooth (Fig. 5) (10).

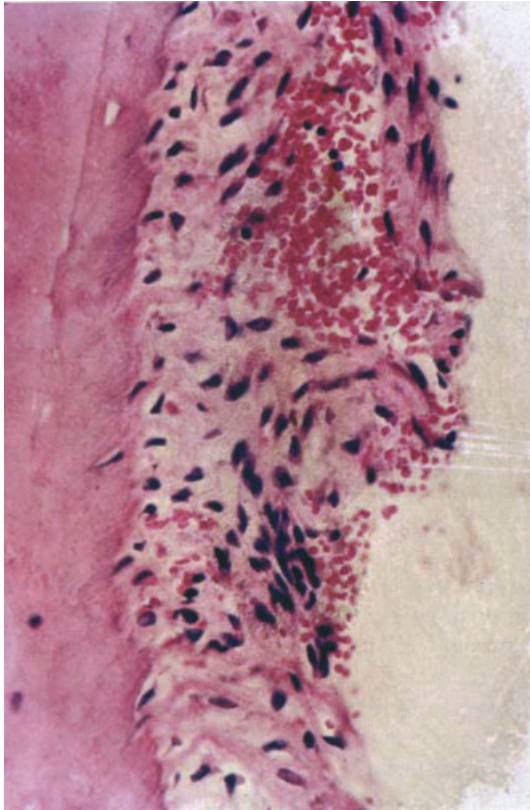


Fig. 1. Avulsed tooth. The periodontal ligament is torn leaving the root covered with periodontal ligament.

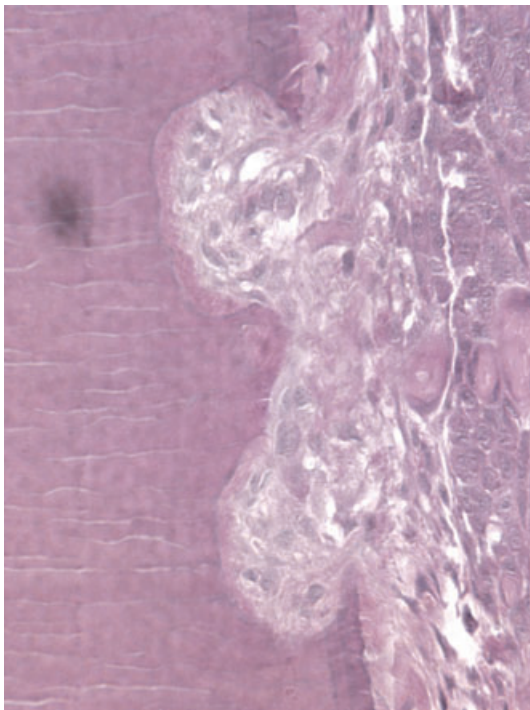


Fig. 2. Small root defect due to the crushing injury of the avulsion.

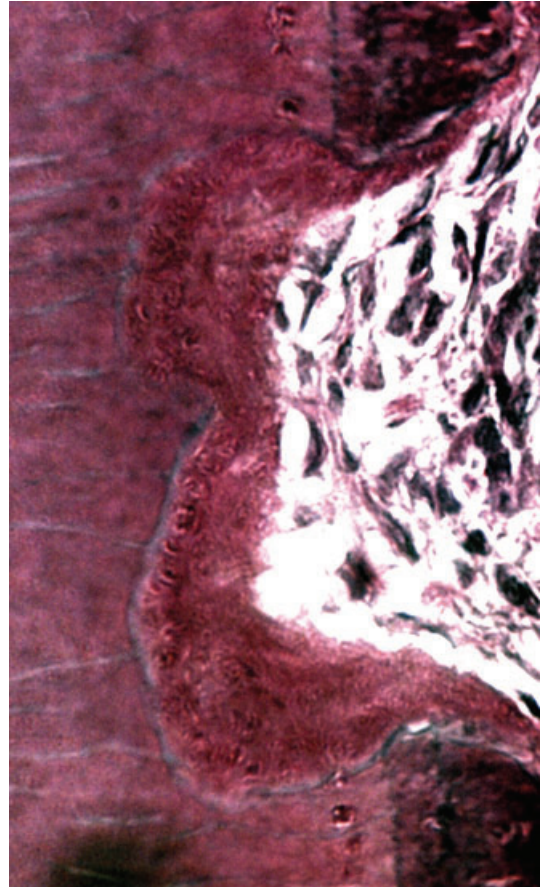


Fig. 3. Cemental/favorable healing. A previous resorptive defect is filled with new cementum and new periodontal ligament.

Thus, the effects experienced after tooth avulsion has occurred, appear directly related to the presence or absence of microbes in the root canal space and the severity and surface area of the inflammation on the root surface.

Treatment strategies should always be considered in the context of limiting root canal infection and limiting the extent of the peri-radicular inflammation, thus tipping the balance toward favorable (cemental) rather than unfavorable (osseous replacement or inflammatory resorption) healing.

Clinical management

As already stated the clinical strategies are aimed at limiting inflammation as a result of protective layer damage and infection as a result of pulp necrosis.

Emergency treatment at the accident site

Replant if possible or quickly place in an appropriate storage medium

The damage that occurred to the attachment apparatus during the initial injury is unavoidable but usually

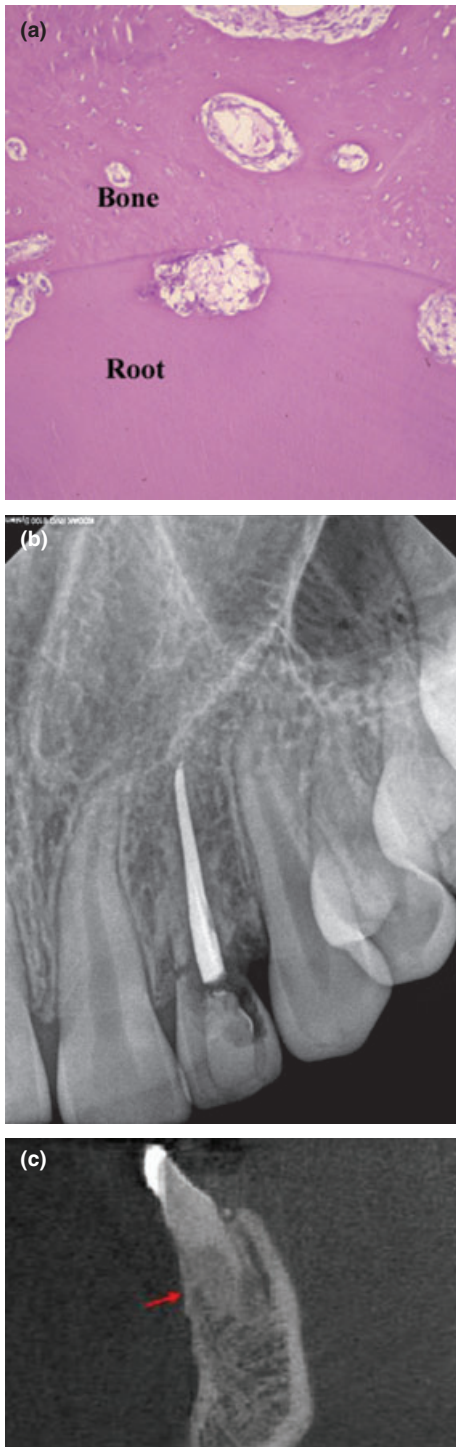


Fig. 4. Osseous replacement. (a) Histologic slide showing bone directly attached to the root and areas of both bone and root undergoing active resorption. Both areas will later be replaced with new bone; it is in this way that the entire root will eventually be replaced by bone. (b) Radiographic picture. The root is being replaced by bone. The lamina dura is lost around the root as it becomes incorporated in the bone (c) CBCT picture. The root is replaced by bone (red arrow) (CBCT courtesy of Dr. Marga Ree).



Fig. 5. 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 (c) CBCT picture. Lucency depicting loss resorption of the root (yellow arrows) (CBCT courtesy of Dr. Marga Ree).

minimal. However, all efforts are made to minimize periodontal ligament morphological changes of the remaining periodontal ligament while the tooth is out of the mouth. It appears that a cell that is morphologically intact will elicit a healing response with new replacement ligament cells while one that has lost its

morphological structure elicits a non-specific and destructive inflammatory response.

Pulpal sequelae are not a concern at the emergency visit and are dealt with at a later stage of the treatment.

The single most important factor to ensure a favorable outcome after replantation is that the tooth is replanted within as short time as possible (11, 12). Of utmost importance is the prevention of drying, which causes loss of normal physiologic metabolism and morphology of the periodontal ligament cells (7, 12). Complete healing can only be guaranteed if the tooth is replanted in the first 5 min (13). However from a practical point of view every effort should be made to replant the tooth within the first 15–20 min (14). This usually requires emergency personnel at the site of the injury with some knowledge of treatment protocol. Ideally home guardians, school nurses or sports coaches would have been instructed in the emergency handling of avulsed teeth. If required the dentist should communicate in a simple and clear manner with the person at the accident site. Communication must take into account that the person may be extremely nervous and have no experience dealing with the dentition and/or traumatic injuries. The aim is to replant a clean tooth with an undamaged root surface as gently as possible at the site of the injury after which the patient should be brought to the office as quickly as possible. The tooth should be gently washed and replanted as atraumatically as possible (15). 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 and availability are; milk, saliva (either in the vestibule of the mouth or in a container into which the patient spits), physiologic saline or water (16). Water is the least desirable storage medium because the hypotonic environment causes rapid cell lysis and increased inflammation on replantation (17).

Cell culture media such as Hank's Balanced Salt Solution (HBSS) in specialized transport containers; have shown superior ability in maintaining the viability of the periodontal ligament fibers for extended periods (18). However, they are presently considered to be impractical as they are, except for a few areas of the world (19) not generally available at the accident sites where injury is likely to occur. When these media have been used they have shown extremely good results (19) If we consider that more than 60% of avulsion injuries occur close to the home or school (20), it should be beneficial to have these media available in emergency kits at these two sites.

Management in the dental office

Emergency visit

It is essential to recognize that the dental injury might be secondary to a more serious injury. If, on examination, a serious injury is suspected, immediate referral to the appropriate expert is the first priority.

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 or delay the loss of the tooth (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 while the history and clinical evaluation is taken. Hank's Balanced Salt Solution is presently considered the best medium for this purpose. Milk or physiologic saline is also appropriate for storage purposes.

The medical and accident history is taken and a clinical examination is 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 and, when clear of the clot and debris, its walls are examined directly for the presence, absence, or collapse of the 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 (together) is suggestive of an alveolar fracture. The socket and surrounding areas, including the soft tissues, should be radiographed. CBCT radiographs are particularly helpful in these cases (Fig. 6). Three vertical angulations are required for diagnosis of the presence of a horizontal root fracture in adjacent teeth (11). 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 or more is considered the point where survival of root periodontal ligament cells is not possible.

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 (15).

If the tooth has a closed apex, revitalization of the pulp space is not possible (21) 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.

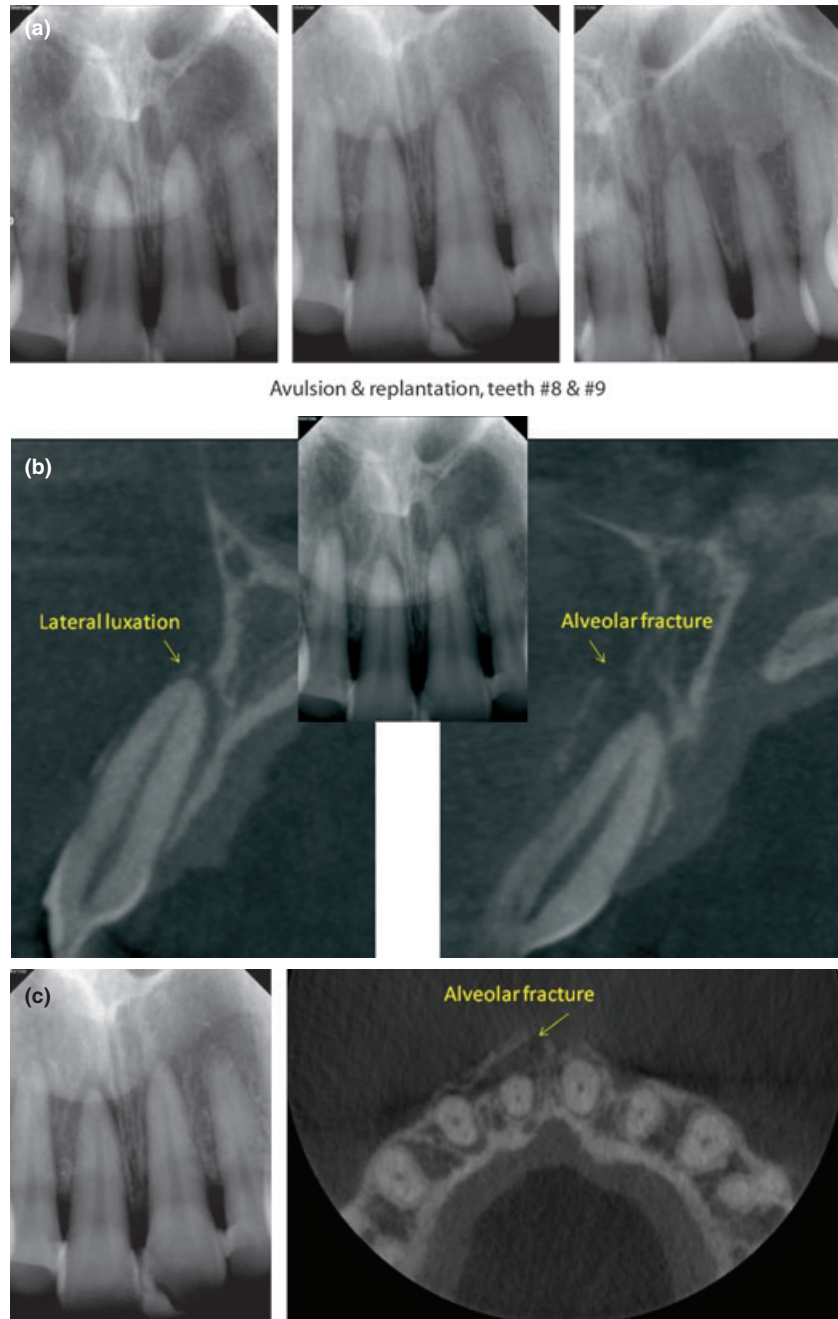


Fig. 6. Radiographic examination after avulsion of maxillary left and right upper central incisors. (a) Three views taken at different angles with periapical radiographs. (b) Sagittal view taken with a CBCT shows that the right central incisor is associated with an alveolar fracture while the left central incisor is not in its original position and is still laterally luxated. (c) Cross sectional view showing the alveolar fracture associated with the right central incisor (courtesy of Dr. Fred Barnett).

A dry time of less than 5 min is ideal while 15–20 min is considered acceptable where periodontal healing would be expected (6, 7, 14).

A continuing challenge is the treatment of the tooth that has been dry for more than 20 min (periodontal cell survival is possible) but less than 60 min (periodontal survival not possible). 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.

Soaking the tooth before replantation (usually done while a history is taken) would wash off dead cells from the root surface. In addition, if possible, treatment

protocols that would block the inflammatory response and/or speed up the replacement of the damaged root surface with new cementum would be ideal.

Recent studies have evaluated the effectiveness of the placement of tetracycline/corticosteroids or corticosteroid alone inside the root canal (acting as a reservoir) in order to block the surrounding inflammation (22–25). Results have been extremely positive even when the roots have been dry for over 60 min (22–25) emphasizing again the importance of the destructive inflammation in the resultant unfavorable healing with osseous replacement. It appears that the tetracycline is not critical for the positive effects of the medicament and corticosteroids

alone will have the same effect (as the combination) (23–25). It is important to stress that the corticosteroids need to be placed as soon as possible after the initial injury while the initial destructive inflammation is taking place. Practically this means that in the emergency visit the root canal would have to be cleaned and the intracanal corticosteroid placed with a lentulo-spiral filler. This protocol would require that the dentist open into the pulp space in the first visit – a change in strategy where root canal ‘issues’ were previously left for the second visit.

Emdogain (enamel matrix protein) has been shown to stimulate the formation of periodontal ligament from bone marrow progenitor cells (26, 27). Emdogain has been evaluated in experimental environments where the tooth has been dry for over 60 min. While not considered useful enough in those extreme situations it would be interesting to evaluate this medicament in the 20–60 min dry time range.

Open apex

In an open apex tooth, revitalization of the pulp as well as continued root development is possible (Fig. 7). Cvek et al. (21) found in monkeys that soaking the tooth in doxycycline (1 mg in approximately 20 ml of physiological saline) for 5 min before replantation significantly

enhanced revascularization. This positive effect of doxycycline was confirmed in dogs by Yanpiset et al. (28). More recently Ritter et al. (29) found additional benefit in dogs if the roots were covered with minocycline before replantation. 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

When the root has been dry for 60 min or more, the periodontal ligament cells are not expected to survive (6, 7). 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 or sodium hypochlorite for 5 min to remove all remaining periodontal ligament and thus remove the tissue that will initiate the destructive inflammatory response on replantation. The root surface should not be scaled so as to leave as much cementum as possible so as to further slowdown the osseous replace-

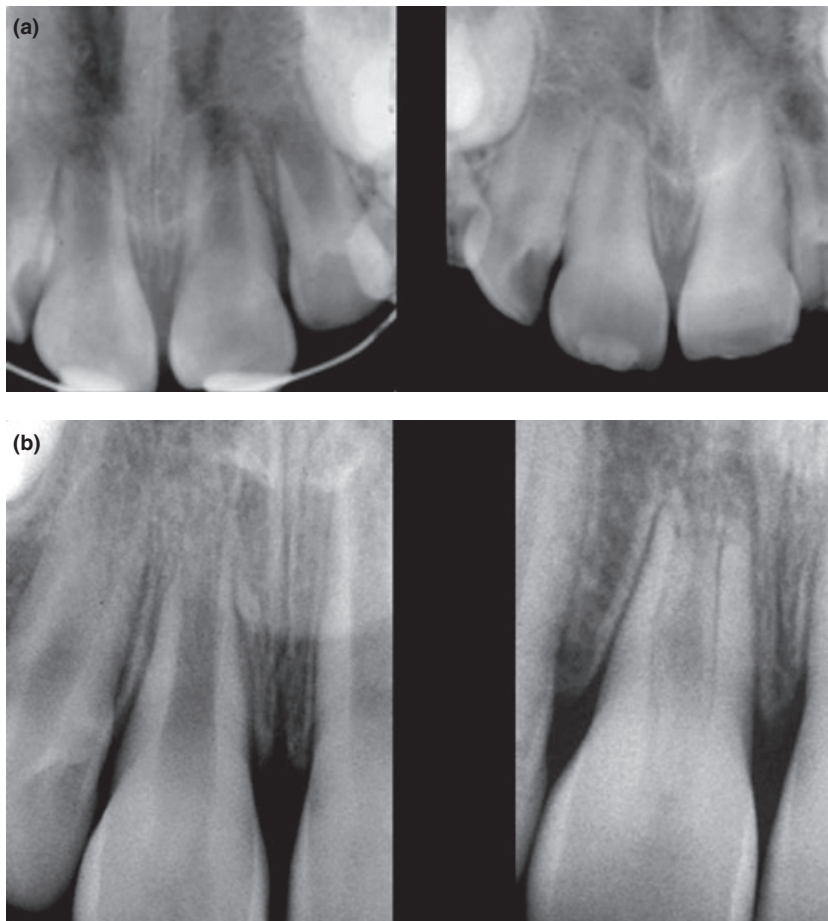


Fig. 7. (a) Revitalization of immature avulsed upper central incisor. The tooth was quickly replanted and revitalization took place. The dentinal walls are thickened and the apex is closed (courtesy of Dr. Joe Camp). (b) Similar clinical situation as in (a). In this case the vital tissue in the pulp space appears to be periodontal ligament. A lamina dura can be traced inside the root canal.

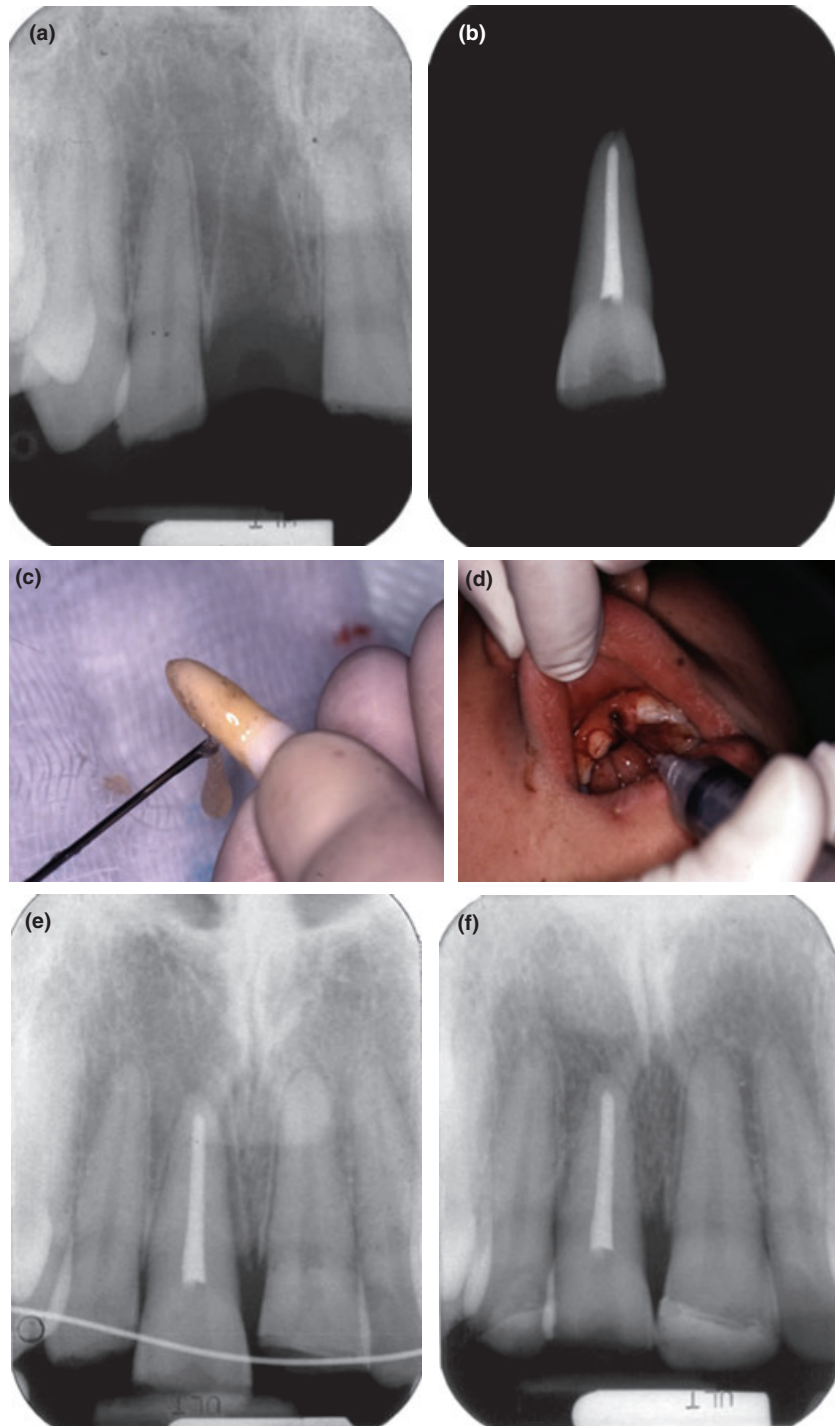


Fig. 8. Treatment of avulsed tooth with Emdogain™ after 12 h dry time. (a) Radiograph of the empty socket of avulsed tooth (b) root canal treatment completed outside the mouth since time was not a factor (c) the periodontal ligament was removed with acid and the Emdogain™ placed on the root and (d) into the socket (e) radiographic picture immediately after reimplantation and (f) the 12 months follow up showing reasonable healing for a tooth that had a dry time of 12 h.

ment. The tooth should then be soaked in 2% stannous fluoride for 5 min and replanted (30, 31). Aledronate was found to have similar resorption slowing effects as fluoride when used topically (32) but further studies need to be carried out to evaluate whether its effectiveness is superior to fluoride and whether this justifies its added cost. Emdogain® (enamel matrix protein) may be 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 (26, 33) (Fig. 8). Corticosteroids in the root canal in these cases will limit the inflammatory response and thus indirectly slow the loss of the tooth to osseous replacement (22–25).

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 extra-orally (34). 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 either revitalization or a long-term apexification procedure. In these cases, completing the root canal treatment extra-orally, where a seal in the blunderbuss apex is easier to achieve, may be advantageous. When endodontic treatment is performed extra-orally, it must be performed aseptically with the utmost care to achieve a root canal system that is free of bacteria.

Open apex

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 not be replanted. 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 (35, 36), the height and, more importantly, the width of the alveolar bone will be maintained (Fig. 9), allowing for easier permanent restoration at the appropriate time when the facial development of the child is complete (37). Presently the recommendation is that if maintenance of a submerged root will be beneficial until the patient's facial growth is complete replantation of the tooth should be strongly considered.



Fig. 9. Ankylosed tooth that was previously submerged. Note the bone growth in a coronal direction above the root maintaining the correct height of the socket. In addition the width of the socket is maintained as long as the root is present in the bone (courtesy of Dr. Trudeau).

Preparation of the socket

The socket should be left undisturbed before replantation (11). Emphasis is placed on the removal of obstacles within the socket to facilitate the replacement of the tooth into the socket (38). It should be lightly aspirated if a blood clot is present. If the alveolar bone has collapsed, a factor that 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 (11, 38–40). Semi-rigid (physiologic) fixation for 7–10 days has been recommended (11, 38). 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. Many splints satisfy the requirements of an acceptable splint, with a new titanium trauma splint recently been shown to be particularly effective and easy to use (Fig. 10) (40). 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 (11). Therefore, the splint should be removed within two weeks (37). The only exception to this is when avulsion occurs in conjunction with alveolar fractures or horizontal root fracture, in which case it is suggested that the tooth should be splinted for a suggested period of 4–8 weeks (11).

Management of the soft tissues

Soft tissue lacerations of the socket gingiva should be tightly sutured. Lacerations of the lip are fairly common



Fig. 10. Titanium trauma splint (TTS) is particularly effective and easy to use.

with these types of injuries. The dentist should approach lip lacerations with some caution and it might be prudent to consult with a plastic 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 aesthetic 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 (41). Tetracycline has the additional benefit of decreasing root resorption by affecting the motility of the osteoclasts and reducing the effectiveness of collagenase (42). The administration of systemic antibiotics for patients not susceptible to tetracycline staining is doxycycline two times per day for 7 days at appropriate dose for patient age and weight (42, 43) or Penicillin V 1000 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 (41). 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.

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

Extra-oral time <60 min

Closed apex

Root canal anti-bacterial strategies are initiated at 7–10 days.

If therapy is initiated at this optimum time, the pulp space should be free of infection or, at most, only minimal infection (44, 45). Therefore, root canal therapy with an effective inter-appointment antibacterial agent over a relatively short period of time (7–10 days) is sufficient to ensure effective disinfection of the canal (44). If corticosteroid is in the root canal space it is removed and replaced with a creamy mix of calcium hydroxide. If the dentist is confident of complete patient

cooperation, long-term therapy with calcium hydroxide remains an excellent treatment method (10, 44). The advantage of its use is that it allows the dentist to have a temporary root filling material in place until an intact periodontal ligament space is confirmed.

Long-term calcium hydroxide treatment has been recommended when the injury occurred more than 2 weeks before the start of endodontic treatment or if radiographic evidence of resorption is present (44).

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 root filled when a radiographically intact periodontal membrane can be demonstrated around the root. Calcium hydroxide's main effect is that it is an effective antibacterial agent (46, 47). In addition it favorably influences the local environment at the resorption site, theoretically promoting healing (48). 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 (48, 49). 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 (50).

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 (51) without damaging the periodontal ligament. Its ability to diffuse through human tooth roots has been demonstrated (52), whilst its release and diffusion is further enhanced when used in combination with calcium hydroxide paste (53). Calcitonin, a hormone that inhibits osteoclastic bone resorption, is also an effective medication in the treatment of inflammatory root resorption (54). Recently a tri-antibiotic paste has been introduced as the disinfectant of choice when revitalization is attempted (56). It has been shown to be a potent antibacterial medicament with the advantage (over calcium hydroxide) in that it only needs to be in place for 2–4 weeks (55). There have been recent cases showing remarkable healing of resorptive defects after its use (Fig. 11). An important added advantage in cases with open apices and thin dentinal walls is that if revitalization is successful the root wall will thicken internally thus strengthening it (Fig. 11). This strengthening effect cannot happen even in successful calcium hydroxide cases.

Open apex; <60 min dry

Teeth with open apices have the potential to revitalize and continue root development and initial treatment is directed toward the re-establishment of the blood supply (21, 28, 29) (Fig. 7). The initiation of endodontic

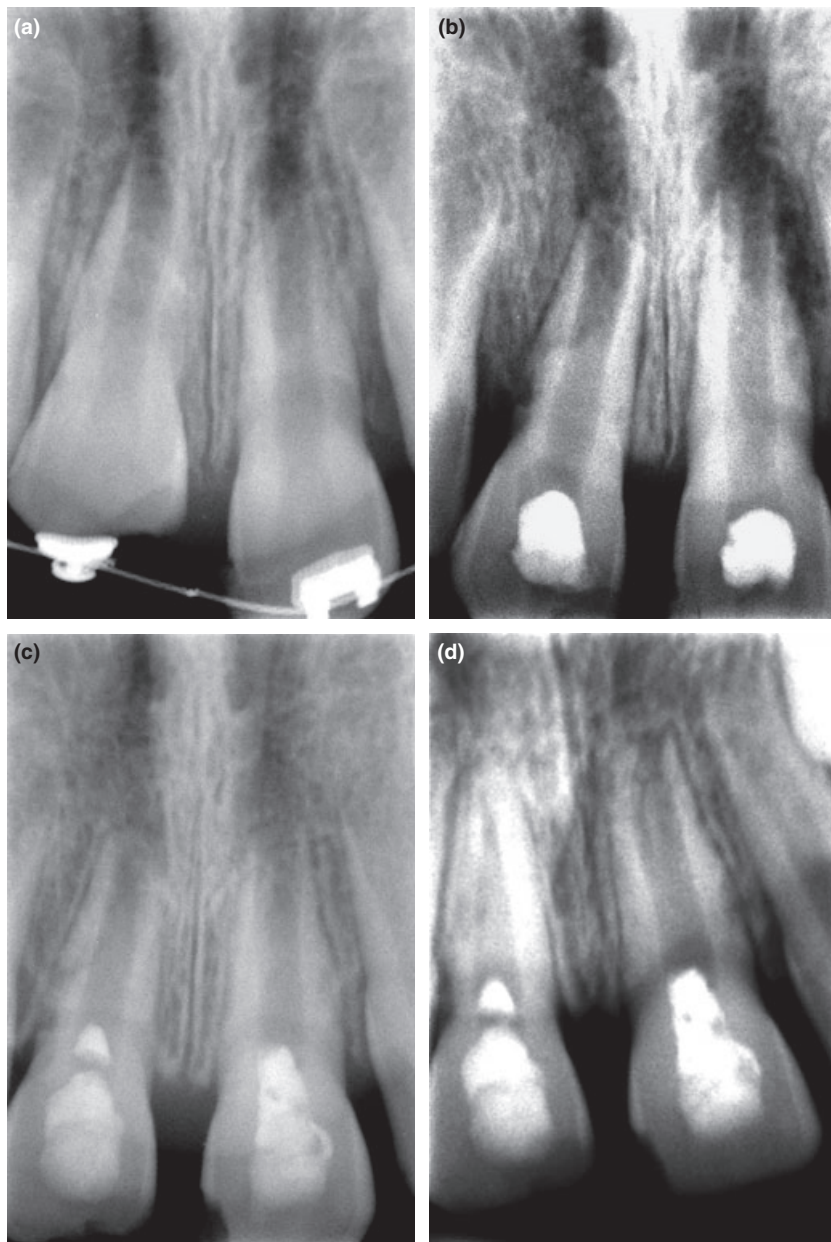


Fig. 11. Avulsed immature tooth with external root resorption treated with tri-antibiotic paste and a blood clot. The resorptive defects healed and the root thickened and the apex closed. (a) radiograph of central incisors immediately after re-implantation and splinting (b) radiograph 2 months later showing active external inflammatory root resorption and apical periodontitis. (c) 6 months follow up after revitalization procedure. The external and apical root resorption are healing and (d) at 12 months follow up the apices have closed and the root walls thickened (courtesy of Dr. Linda Levin).

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, accurate diagnosis of a necrotic pulp is particularly important 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 (21, 28, 44) (Fig. 5).

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 (56–58). 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 (59, 60). In a study in dogs, Yanpiset et al. (60) 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, a disinfection procedure with a tri-antibiotic paste should be initiated and a 'non-vital' revitalization procedure attempted (61) (Fig. 11). If this procedure fails the more traditional apexification procedure can be initiated with long-term calcium hydroxide or an apical plug with MTA (62, 63).

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)

In these teeth the chance of initial revitalization is extremely poor and the tri- antibiotic paste revascularization is not considered worthwhile since these teeth will be lost in a relatively short time to osseous replacement (9, 44). 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 (64). The depth of the temporary restoration is critical to its sealability. A depth of at least 4 mm is recommended so if there is not enough space for a cotton pellet to 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.

Root filling visit

If the disinfection protocol was initiated 7–10 days after the avulsion and clinical and radiographic examinations do not indicate pathosis, filling 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 must first be disinfected before root filling. Traditionally, the re-establishment of a lamina dura (Fig. 12) is a radiographic sign that the canal bacteria have been controlled. When an intact lamina dura can be traced, root filling can take place.

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

Permanent restoration

Much evidence exist that coronal leakage caused by defective temporary and permanent restorations result in a clinically relevant amount of bacterial contamination of the root canal after root filling (65–67). Therefore, the tooth should be permanently restored either at or soon after the time of filling 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. Because most avulsions occur in the anterior region of the mouth where esthetics is important, composite resins with the addition of dentin

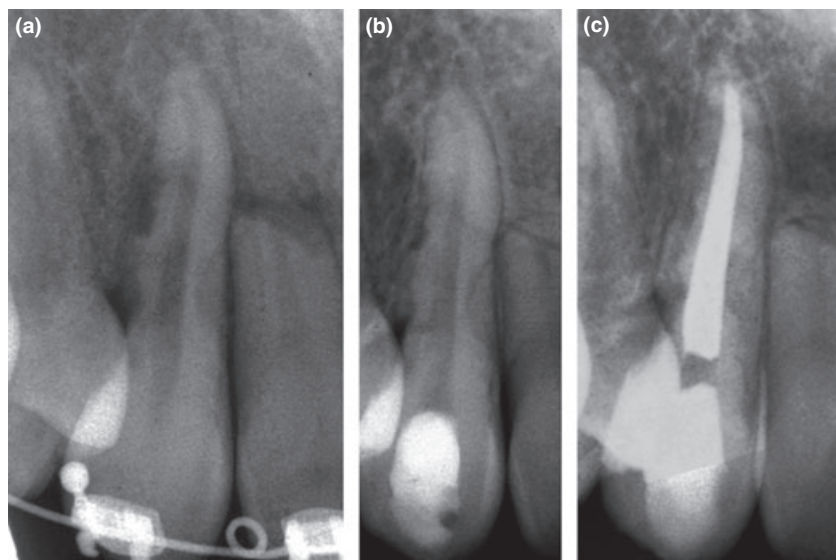


Fig. 12. Tooth with external inflammatory resorption treated with long term calcium hydroxide treatment. A tooth with active external inflammatory resorption. B after long term calcium hydroxide treatment an intact lamina dura has been reestablished and C the root is permanently filled.

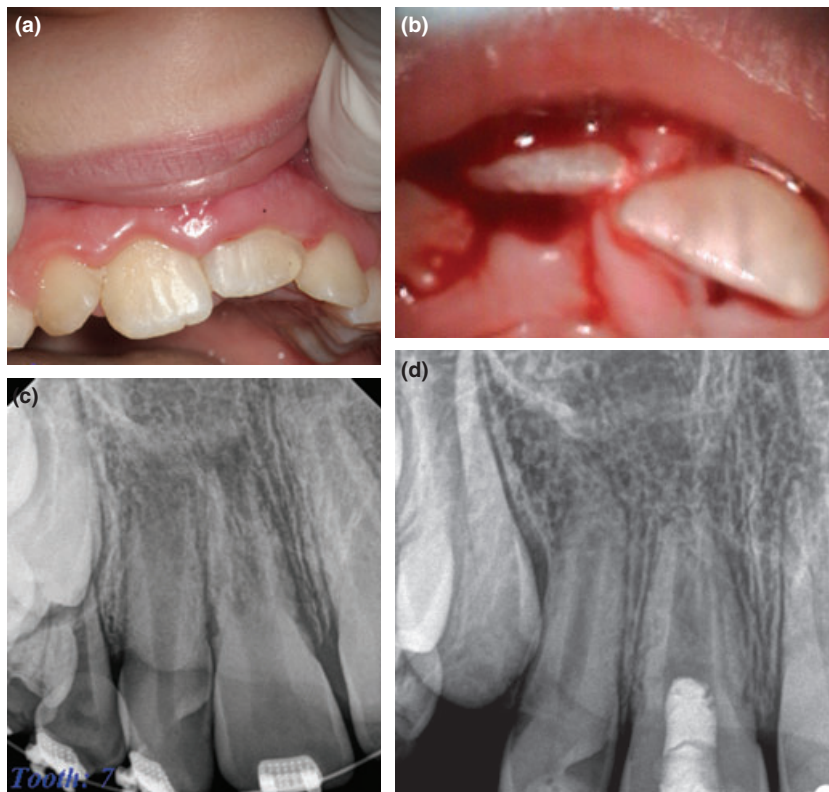


Fig. 13. Treatment of early ankylosis. A Three weeks after the trauma the tooth has stopped erupting and is ankylosed B the tooth is carefully removed and replanted in its correct position after covering it with Emdogain™ C radiographic picture at the start of the revitalization protocol and D at 18 months follow up the tooth does not show signs of ankylosis and the roots appear to be thickening (courtesy of Dr. Bentkover).

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.

Management of complications

Follow-up evaluations should take place at 3 months, 6 months and yearly for at least 5 years (11).

External inflammatory root resorption, both of pulpal infective origin and sub-epithelial (cervical) origin, are considered reversible in most cases (9).

Traditionally osseous replacement has been considered irreversible and the long-term treatment plan should include loss of the tooth.

Recently attempts have been made to reverse early osseous replacement (33). At the first sign of ankylosis (high metallic sound on percussion or lack of mobility) the tooth is dislodged with an elevator and replanted after covering with Emdogain™. Filippi et al. have shown promising results with this procedure (33). In addition isolated cases have been reported with good results (Fig. 13). However there is a need for more experimental studies and long term follow up studies before this can be recommended as a routine clinical procedure. In a growing patient the tooth that is undergoing ankylosis and osseous replacement will become infra-occluded relative to the adjacent teeth. This is undesirable since the cervical bone will stop advancing in a coronal direction leaving a large bone defect when the tooth is lost causing major aesthetic challenges when the final replacement is made. When the tooth is infra-occluded for about 2 mm the crown should

be removed and the root below the CEJ submerged (35, 37). This procedure leaves the root to be slowly replaced by bone stopping the collapse of the socket. In addition if the crown has been removed to below the CEJ the bone will now grow above the submerged root to the level of the CEJ's of the adjacent teeth. In this way the correct height of the socket is maintained to its original height before infra-occlusion occurred. With this submergence procedure many of these young patients will be ready for the permanent restoration when the socket is a good height and width thus avoiding the difficult procedures involved in growing bone in a collapsed socket before an acceptable esthetic restoration can be made.

Conclusion

In this review of the literature of avulsion and replantation of permanent teeth, the author has described the biological basis of treatment protocol based on experimental and clinical studies. Although some protocols have not yet been adopted in the international guidelines, experimental results are promising and they have therefore been included in the review to stimulate colleagues to further research.

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