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Tooth Avulsion – Evidence Based Recommendation for Optimal Clinical Management

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Dr. Gopi Krishna

Most often, dental trauma occurs in toddlers as they are learning to ambulate. As they attempt to walk, they often stumble and have frequent falls which can injure their oral cavity. 30% of children experience trauma to their primary teeth, while 22% of children experience trauma to permanent teeth, prior to age 14. In the primary dentition, the peak incidence is between the ages of 2-4, whereas in the permanent dentition the peak is in the range of 8-10. The history, circumstances of the injury, pattern of trauma, and behaviour of the child and/or caregiver are important in distinguishing nonabusive injuries from abuse. Trauma to teeth may include fractures to the crown or root, displacements/luxations and avulsions. Luxations are more common in the primary dentition and fractures predominate in the permanent dentition. An avulsion is when a tooth is physically ejected from the bony socket. According to the World Health Organization (WHO) classification for traumatized teeth, avulsion, or exarticulation is the complete displacement of a tooth from its alveolar socket due to traumatic injury.

The main etiologic factors for avulsion in permanent dentition are fight and sports injuries. The most commonly avulsed teeth in children are the permanent maxillary central incisors, followed by the maxillary laterals and then the mandibular incisors, while lower jaw is seldom affected. Avulsion of teeth occurs most often in children from 7 to 9 years of age, when the permanent incisors are erupting. The reported incidence of complete avulsion ranges from 1%–16% of all traumatic injuries to the permanent dentition. Most frequently avulsion involves a single tooth; but multiple avulsions are occasionally encountered. Other types of injuries associated with avulsion are fracture of alveolar socket and injuries to the lips. Because of the complexity of this injury, the neurovascular supply is severely compromised and usually results in loss of pulp vitality. The level of the attachment apparatus of the avulsed tooth is essential when considering whether or not to reimplant the tooth.

Reimplantation of avulsed teeth is the treatment of choice. It is quite challenging for the dental professional since avulsed teeth recover optimal function and aesthetics after replantation under ideal conditions.

It has been shown that after avulsion, the number of viable cells on the root surface decreased with increased drying time and that after 2 hours it was not possible to demonstrate cell viability. PDL cells on the root surface will remain viable if they are hydrated. Vital PDL cells can reattach when replanted and viability is best maintained if the tooth is replanted within the first 15-20 minutes after avulsion. Therefore, the ideal treatment of choice at the time of avulsion is immediate replantation, thus re-establishing the natural nutrient supply to the periodontal ligament cells, thereby minimizing further damage and enhancing the healing process.

So, the avulsed tooth should be replanted immediately to prevent further injury to periodontal ligament (PDL) cells in the future. However, rapid replantation rarely occurs since factors such as the emotional stress of parents and lack of knowledge of appropriate first-aid measures to manage the problem at the location of the injury tend to delay definitive care. In these conditions the tooth should be maintained in a suitable storage medium until it is replanted by a dentist as soon as possible.

The ability of a storage/transport medium to support cell viability can be more important than the extraoral time to prevent ankylosis and replacement resorption. The American Association of Endodontics has recommended Hank's balanced salt solution (HBSS) as the storage medium of choice for avulsed teeth. Some authors suggested storing of an avulsed tooth in milk, HBSS, or saline (Buccal vestibule). Tissue transport medium, such as Viaspan and Hank's Balance Salt Solution (HBSS) have exceptional ability to keep cells alive and are considered to be superior storage media. Readily available storage media for an avulsed tooth, in order of preference, are milk, saliva and saline. Water is not recommended because the hypotonic environment damages the PDL cells. One study measured the average number of vital human lip fibroblasts remaining after 2-168 hours of storage in 3 media. This study showed that after 12 hours, Viaspan was effective at keeping 72.9% of cells vital while HBSS and milk maintained the vitality of 70.5% and 43.4% cells, respectively. In another study, HBSS, contact lens solutions, Gatorade, water and milk were compared at room temperature and on ice to determine which solution better maintained the viability of PDL cells after one hour of exposure. This study found that HBSS was superior to the other liquids and that water had the most

detrimental effect on PDL cells. Two percent milk followed by Gatorade preserved more viable cells than contact lens solution only if the liquids are kept on ice.

Outcomes of avulsion

The speed with which the avulsed tooth is replanted is the most important factor for success. There are several possible effects on the root surface and attachment apparatus of an avulsed tooth.

Normal PDL healing: complete regeneration of the PDL. Damage cannot be clinically or radiographically detected.

Surface resorption: the crushing injury is restricted, inflammatory response is limited and repair can occur with replacement cementum. Clinically, the tooth presents asymptomatic, with normal mobility and percussion sounds. Radiographically, there are no periradicular radiolucencies and no loss of lamina dura.

Ankylosis and replacement resorption: occurs when excessive drying damages the PDL cells and evokes an inflammatory response that results in the replacement of the cells with alveolar bone. Dentoalveolar ankylosis is the term used when precursor bone cells populate the damaged root resulting in a direct bone-root contact void of an attachment apparatus. Replacement resorption occurs when osteoclasts in contact with the root resorb dentin that is eventually replaced with new bone by osteoblasts. Clinically, the tooth will be immobile and have a high-pitched sound when percussed. Radiographically, there is absence of the lamina dura. With replacement resorption, the root surface appears moth-eaten. In young patients, infraocclusion or submergence results when replacement resorption interferes with the tooth's ability to move with the normal downward growth of the alveolar process.

External inflammatory root resorption: the result of a combination of severely damaged attachment and bacterial contamination of a necrotic pulp. It may rapidly progress. Clinically, it presents as radiolucencies in the root and adjacent bone.

The Requirements for a Storage Medium for Avulsed Teeth

The prognosis for reimplantation of avulsed teeth has increased in the last fifteen years. Two factors that have a profound effect on the prognosis of replanted avulsed teeth are extraoral time of the avulsed tooth and the medium used to preserve the tooth before replantation. In these situations, a storage medium is necessary. Thus in order to optimize the chances for reimplantation success, the avulsed teeth should be placed in a good storage medium. There have been many storage media recommended and each will be discussed.

Dry storage leads to cell necrosis and compromised healing. Teeth prevented from drying will heal with normal ligament. The fundamental philosophy for the storage of avulsed teeth is that the teeth should be stored in an environment that most closely replicates the oral environment from which the teeth came. The normal metabolic, morphologic and physiologic conditions of the teeth should be paralleled as closely as possible.

Additionally, some storage media require refrigeration, for instance milk must kept cold in order for it to function at an optimum level. This can become a problem if the child is rushed to a hospital emergency room where they may have to wait for hours before being seen, during this time, the teeth should be kept cold.

Another factor to consider is length of time the medium is effective. Only a few storage media have been tested for the length of time for which they remain effective. It has been determined by research that milk drastically loses its effectiveness after two hours of storage. Once again in the hospital scenario, milk will not be effective if the child waits for a long time. Some storage media, like HBSS and ViaSpan maintain their effectiveness for at least twenty-four hours.

Discussion of Storage Media

There have been many different storage media postulated for storage of avulsed teeth during transport to a dentist or emergency room. In order to provide the best opportunity for success following reimplantation, the best medium should be used.

Recent studies by Gopikrishna et al establish the potential benefits of **coconut water** on PDL cells of avulsed teeth. In this study it's concluded that coconut water statistically showed better viability of cells than propolis, HBSS, and milk. This might be due to the nutrients present in coconut water such as proteins, amino acids, vitamins, and minerals, which help in nourishing the cells and maintaining their viability. The primary sugars present in coconut water are glucose and fructose, which are responsible for the high osmolarity of coconut water. It is also rich in many essential amino acids including lysine, cystine, phenylalanine, histidine, and tryptophan. Coconut (Cocos nucifera L.), popularly known as "Tree of Life," is a natural drink produced biologically and hermetically packed inside the coconut in a hygienic way without any contamination. The electrolyte composition of coconut water resembles intracellular fluid more closely than extracellular plasma. The predominant cations are potassium, calcium, and magnesium. Sodium, chloride, and phosphate are found in much lower concentrations. It is a hypotonic solution that is more acidic than plasma, and has a specific gravity of approximately 1.020, comparable with blood plasma.

HBSS has unquestionably been the most tested solution. It stores and preserves avulsed teeth for at least 24 hours, needs no refrigeration, has ADA Seal of Acceptance FDA Approval. But it's only available in Save-A Tooth systems.

Eagle's Medium stores and preserves teeth for 2 weeks, but it must be refrigerated and is not available except in research labs.

ViaSpan. Best preservation of all solutions, up to 72 hours Must be refrigerated. Very expensive. Not available in small containers.

0.9% normal sterile saline has a compatible osmolality with the PDL cells, but does not contain any nutrients to help maintain cell vitality. Therefore, sterile saline is only good as a short-term storage medium for avulsed teeth and should not be used if the tooth cannot be reimplanted within 1 hour.

Milk has a compatible osmolality with the PDL cells of an avulsed tooth and has been tested as effective to store teeth for no more than 2-3 hours. Milk does not contain the necessary nutrients to maintain the

PDL cells for any longer periods of time. Additionally, there are issues related to the practicality of using milk that severely impact its efficacy. Milk sounds, like an easy, inexpensive method for storage, however, using milk is not as effective as other media available and is logistically more difficult than other, more effective options. For example, if a child avulses a tooth on a remote sports playing field no milk will be readily available. Additionally, the milk needs to be kept refrigerated during transport for the best prognosis.

Propolis, a substance made by the honeybee, is a potent antimicrobial, antioxidant, and anti-inflammatory agent. The main chemical classes present in propolis are flavonoids, phenolics, and various aromatic compounds. Flavonoids are well known plant compounds that have antioxidant, antibacterial, antifungal, antiviral, and anti-inflammatory properties. It has also been found that propolis is a superior transport medium to HBSS or milk in terms of maintaining PDL cell viability after avulsion and storage.

There is another commercially available product marketed for the storage of avulsed teeth called **EMT Tooth Saver**, which contains antibiotic-free protective medium. EMT Tooth Saver has not been tested for efficacy and does not have FDA approval or the ADA Seal of Acceptance. The compatibility of EMT ToothSaver cannot be known without research testing and therefore, this media cannot be recommended.

Water, Gatorade, and **contact lens solution** have all been tested as possible storage media for avulsed teeth. None of these possible media are compatible with the PDL cells and are therefore not recommended as a possible storage media. These media can actually harm the PDL cells that need to be protected.

Like water, saliva is not compatible with the PDL cells. In addition to the damage the saliva can cause to the cells, saliva also contains bacteria that can cause the PDL cells to become infected. Therefore, it is not recommended to store teeth in either a cup with saliva or in the mouth of the victim or another person.

Despite the fact that ViaSpan and Eagle's Medium provide the best storage environment, these media are not practical options. These media are not readily available to school nurses and are not packaged for individual uses. Despite the time advantages, these media may be cost prohibitive when compared to other options available, for example, ViaSpan is $600 a gallon.

Coconut water obtained from the fruit of coconut palm is grown in more than 93 countries around the world, with a very high growth density in South Asian countries (India and Sri Lanka), South East Asian countries (Vietnam, Thailand, Indonesia, Malaysia, Philippines), and Pacific nations (Western Samoa, Vanuatu, Fiji). It also has a significant presence in Jamaica and Mexico. Thus, in an Indian Scenario coconut water, which is natural, hygienic, and easily available in these geographical locations, can be advocated as a superior transport medium for avulsed teeth.

Instructions for the accident victim or parent

1. If the tooth is one of the four front baby teeth (deciduous teeth), there is no need to reimplant it (do not replace it in the socket). Front baby teeth do not hold space for the adult teeth that will begin to erupt at age six, and the early loss of one of these teeth rarely causes harm to the adult dentition.
2. If the root of an adult tooth is broken, (especially if part of the root remains in the socket) reimplantation is not possible. Any attempt will fail. This means that the trip to the dentist, though necessary, may be put off until it is convenient. The only things a dentist can do under such circumstances is to prescribe antibiotics, and to place artificial bone in the socket for possible implant placement at a later date
3. Any avulsed tooth must be reimplanted in the socket within 60 minutes if the reimplantation is to have a reasonable chance of working.

This may be done at the site of the accident by any adult including the patient himself provided the tooth is fairly clean and provided it slips back into the socket easily with light finger pressure. If the tooth goes back into its proper position so that the patient may bite down without pushing the tooth out of its normal alignment, then the process has been successful.

- If the tooth is dirty, simply have the patient remove all dirt with their own saliva. Have the patient suck fairly hard on the tooth. Be sure that the patient spits out blood and debris after each sucking action. This removes dirt and will hopefully dislodge any clot that may have formed in the socket making it easier to reimplant the tooth.
- You still must take the patient to a dentist, but the major emergency has been averted and there is less urgency associated with the emergency.
- If the tooth cannot be replaced in the socket (for any reason), then the tooth should be transported to the dental office in a suitable storage medium as early as possible.

Instructions for the dentist

1. If the tooth has been properly replaced in the socket at the site of the accident:

- Do not extract the tooth to treat the root.
- Clean the affected area with water spray, or chlorhexidine mouth rinse.
- Verify proper alignment of the tooth by the following methods:
  - Have the patient bite down and verify that the tooth is not in traumatic occlusion and remains in acceptable alignment with neighboring teeth.
  - Take a periapical x-ray if the tooth is in traumatic occlusion, remove the tooth from the socket and proceed to step 2 below.
- Suture gingival lacerations
- Splint the tooth with (preferably) a flexible splint. Have the patient bite into occlusion to eliminate traumatic bite prior to splinting. The splint will be kept on the tooth for 7 to 10 days.
- Prescribe a suitable antibiotic (doxycycline is ideal).
- Refer to physician for evaluation of tetanus immunization.
- If the tooth has an open apex (blunderbuss) avoid doing a root canal unless an abscess develops or there is radiographic evidence of pulpal necrosis.

- Proceed to the Post-emergency procedures.

2. If the tooth has not been replaced in the socket, or if it must be removed due to traumatic occlusion or misalignment:

If the tooth has an open apex (not fully formed root)

- **If the tooth has been out of its socket for much more than an hour, or especially, if the tooth has dried out during transportation,** the reimplantation procedure is unlikely to be successful, and the patient or parents should be so informed. It is still permissible to attempt reimplantation since survival is always possible, even if unlikely. It is however unlikely that the root will continue to form its apex and apexification will be necessary. There is also a very substantial chance that the root will experience external resorption or become ankylosed. The most reasonable course of action is to warn the parents of this outcome and to avoid the procedure altogether.
- **If the tooth has been out of its socket for an hour or less, and has been properly transported to the dental office,** then the procedure has a better chance of working. This implies that the blunderbuss root will continue to form an apex and the tooth will continue to erupt normally after the reimplantation procedure.
- Clean the affected tooth with water spray or saline.
- Place the tooth in a solution of doxycycline if available (Low concentration, about 1mgm per 20 cc of saline. Can be made on premises using 1/2 of a 100 mg tablet finely crushed and added to about a liter of saline. In most situations, this step is not especially practical and may be omitted if it is not possible. At minimum, clean the tooth with copious saline solution. Do not use antiseptic solutions on tooth.
- Irrigate the socket with saline and remove all coagulum.
- Inspect the socket. If bone is displaced into the socket, move it back into position with a suitable instrument in order to allow proper insertion of the tooth.
- Replace the tooth in the socket with minimal digital pressure.
- Suture gingival lacerations.
- Take a periapical x-ray to check root alignment.
- Splint tooth in position with (preferably) a flexible splint. Have patient bite into occlusion to be certain that the position is correct before applying the splint. The splint will be kept in place for about one week.
- Prescribe a suitable antibiotic (doxycycline is ideal).
- Refer to physician for evaluation of tetanus immunization.
- Do not perform a root canal procedure unless a post op x-ray shows serious periapical involvement. The idea here is to allow the root apex to form normally. If the pulp dies at any point during treatment, then a root canal procedure with apexification will be necessary.

If the tooth has a fully formed root (apex)

If the tooth has been out of its socket for an hour or less, and it has been properly handled (as stated above in instructions for patients), the reimplantation procedure is the same as that shown above with the exception of the use of doxycycline rinse. The instructions are repeated below for clarity and completeness:

- Clean the affected tooth with water spray or saline.
- Clean the tooth with copious saline solution. Do not use antiseptic solutions on tooth.
- Irrigate the socket with saline and remove all coagulum.
- Inspect the socket. If bone is displaced into the socket, move it back into position with a suitable instrument in order to allow proper insertion of the tooth.
- Replace the tooth in the socket with minimal digital pressure.
- Suture gingival lacerations.
- Take a periapical x-ray to check root alignment.
- Splint tooth in position with (preferably) a flexible splint. Have patient bite into occlusion to be certain that the position is correct before applying the splint. The splint will be kept in place for about one week.
- Prescribe a suitable antibiotic (doxycycline is ideal).
- Refer to physician for evaluation for tetanus immunization.
- Proceed to post-emergency procedures.

If the tooth has been out of the socket for well over an hour, or if the tooth has been allowed to dry out during transport, the treatment differs from that above mostly because of changes that have taken place on the surface of the root. The following procedure is designed to minimize external root resorption during post operative healing.

- Rinse off all debris from the tooth with copious water or saline.
- Gently and quickly root plane the root of the tooth to remove necrotic periodontal ligament and any foreign debris that has dried onto the surface.
- Immerse the tooth in a 2.4% Sodium Fluoride solution acidulated to pH 5.5 for 5 minutes. This item is rarely found in dental offices today. It has been replaced with various neutralized rinses, gels and foams of lesser concentration. In the absence of the stronger solution, a lesser concentration of fluoride may be used instead. The idea is to convert surface hydroxyapatite into fluoroapatite to reduce external resorption during healing. Keep the tooth in the fluoride solution for a minimum of five minutes; 20 minutes if possible. Wash off the fluoride solution afterwards with copious saline.
- Irrigate the socket with saline and remove all coagulum.
- Inspect the socket. If bone is displaced into the socket, move it back into position with a suitable instrument in order to allow proper insertion of the tooth.
- If available, apply Emdogain to the inside of the socket. This is a specialty item and is not likely to be found in the offices of most general dentists. It has been found to be helpful in experimental situations but no human studies have been carried out to prove its usefulness in reimplantation of avulsed teeth. If available, it may be useful, but certainly not essential.
- Replace the tooth in the socket with minimal digital pressure.
- Suture gingival lacerations.
- Take a periapical x-ray to check root alignment.
- Splint tooth in position with (preferably) a flexible splint. Have patient bite into occlusion to be certain that the position is correct

before applying the splint. The splint will be kept in place for about one week.

- Prescribe a suitable antibiotic (doxycycline is ideal).
- Refer to physician for evaluation of tetanus immunization.
- Proceed to post-emergency procedures.

3. Adjunctive treatment and follow-up.

Soft tissue management: Gingival tissue should be tightly secured in the cervical area of the replanted tooth to help prevent the ingress of bacteria. Lip lacerations must be thoroughly cleaned and approximated tension-free before suturing. It is best to consult an oral or plastic surgeon if the laceration extends through the vermilion border into the skin.

Splinting the tooth: The ideal splint for avulsed teeth is a flexible splint. These are typically made using Gortex or other synthetic cloth or metallic mesh strips made for this purpose. Other types of flexible splint may involve bonded orthodontic brackets and thin orthodontic wire. Ideally, the splint should encompass several teeth on either side of the avulsed tooth. There are quite a few options depending on the comfort level of the practitioner. The recommendation for flexibility involves theoretical considerations in the formation of the new periodontal ligament. However, since the splint is kept in place for no more than 7 to 10 days, the flexibility factor may be of little practical significance.
The simplest type of splint involves nothing more than a fairly thick strip of light cured composite running across three teeth with the avulsed tooth in the middle. The procedure for upper incisors (the most commonly avulsed teeth) involves having the patient bite into occlusion and keeping his teeth in this position for the entire procedure. This stabilizes the tooth and guarantees that the tooth will not be in traumatic occlusion. The three teeth are pumiced and acid etched. Bond is applied and light cured. Finally a fairly thick layer of composite is layered over the buccal surfaces of three teeth. Use a color that contrasts with the teeth in order to make removal easier. In the case of lower incisors, place the splint on the buccal surface if the occlusion permits. Otherwise, place it lingually. The splint is removed in about a week (10 days tops) and assessed for mobility. If the mobility is excessive, then reapply the splint for another several weeks. Otherwise, allow the tooth to function normally

Systemic antibiotics: If the patient is not susceptible to tetracycline staining, the antibiotic of choice is doxycycline at an appropriate dose for patient age and weight. Penicillin V can be substituted for doxycycline. Adult dosage of doxycycline is 100mg b.i.d. x 7 days. Adult dosage of Penicillin V is 1-2g stat, then 500mg q.i.d. x 7 days. Fractures of the alveolus may have their own indications for antibiotic coverage.

Tetanus: Refer the patient to a physician within 48 hours for a tetanus booster if the avulsed tooth contacted soil or if the status of the tetanus coverage is uncertain.

Analgesics: Prescribe if needed. Typically, an over the counter non-steroidal anti-inflammatory drug suffices.

Diet: Post-operative instructions should include a soft diet for 2 weeks.

Oral hygiene: Instruct the patient to brush with a soft toothbrush after every meal and prescribe a 0.1% chlorhexidine mouth rinse 2x per day for 7 days.

Follow-up appointments: Include splint removal and initiation of endodontic treatment, if required, at one week. Clinical and radiographic exams should be scheduled at 2-3 weeks, 3-4 weeks, 6-8 weeks, 6 months, 1 year and annually for 5 years.

4. Post-emergency procedures (managing the tooth after reimplantation):

Root canal procedure should be initiated in 7-10 days unless the avulsed tooth has an open apex and the tooth was reimplanted under optimal conditions.

The splint should be removed in 7 to 10 days unless the radiograph shows serious bony involvement along the lateral edges of the root.

If the tooth has a closed apex, or if a tooth with an open apex has obviously abscessed or shown radiographic evidence of pulpal necrosis, begin the root canal procedure prior to removing the splint. At this time, instrument the canal completely and place calcium hydroxide paste in the canal. Allow the paste to remain in the canal for approximately a month prior to obturation of the canal. The root canal procedure may be completed when an intact lamina dura can be traced all the way around the root. In most cases this will happen within a month. If the lamina dura has not begun to form, or if external resorption is apparent on the radiograph, then the calcium hydroxide should remain in the canal. The status of the lamina dura should be checked one month post op and at three month intervals after that. At the time of the exam, the calcium hydroxide paste should be washed out and replaced with fresh paste.

5. Additional Considerations

A. Avulsed primary teeth should not be replanted.
B. Avulsed permanent teeth require follow-up evaluations for a minimum of 2-3 years to determine the outcome of therapy.
C. Inflammatory resorption, replacement resorption, ankylosis and tooth submergence are potential complications when avulsed teeth are replanted.