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Controversial management of avulsion in primary and immature permanent teeth: A review article

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Abstract
Compared with the abundant literature on the replantation of avulsed permanent teeth, and replantation of avulsed primary teeth is significantly more limited. A search of PubMed, using the terms: primary teeth, primary incisors, avulsion, exarticulation, replantation and reposition, and search in the reference list of the relevant articles. This article is a critical review of the arguments against replantation that have been presented in textbooks, review articles, and clinical guidelines.

Keywords: Avulsion, replantation, primary teeth, review

Introduction

As a clinician, understanding the complexities and implications of avulsion—whether of primary or permanent teeth—in pediatric patients is paramount. Avulsion is the complete displacement of a tooth from its socket due to trauma or injury. Avulsion management is the unique challenges and requires immediate and meticulous management to minimize long-term consequences on oral health and development.

When dealing with avulsion in pediatric patients, the management approach differs significantly depending on whether the affected tooth is primary or permanent. Primary teeth, although temporary, play crucial roles in maintaining space for permanent teeth and facilitating proper speech and chewing function. When a primary tooth is avulsed, the first step is to assess the extent of trauma and any associated injuries to the surrounding tissues. Immediate intervention focuses on controlling bleeding, managing pain, and stabilizing the affected area. Unlike permanent teeth, re-implantation of avulsed primary teeth is generally not recommended due to the potential risk of damaging the developing permanent tooth bud or causing several complications. Instead, the emphasis is on preserving the space and function of the primary dentition until the permanent successor is ready to erupt. Strategies such as monitoring eruption patterns and considering space maintainers may be employed to ensure optimal alignment and spacing for the incoming permanent teeth. Avulsion of primary teeth has been reported to comprise between 5.8% [1] and 19.4% [2] of all types of traumatic injuries to the primary dentition and 19.2% of luxation injuries only [3]. It occurs most often in 2–4-year-old children [4] and affects boys 1.2–1.5 times more than girls [5]. The maxillary primary central incisor is involved more than any other tooth [6] followed by maxillary lateral incisors and mandibular central incisors [7]. Tooth avulsion occurs most often in very young children as they learn to walk and run [8].

In contrast, avulsion of a permanent tooth in a pediatric patient requires a different approach due to the potential impact on long-term oral health and aesthetics. Permanent teeth serve a lifelong function and their premature loss can lead to significant complications, including malocclusion, bone loss, and psychological effects on the child. When a permanent tooth is avulsed, immediate action is essential to increase the chances of successful re-implantation. The tooth should be handled carefully by its crown (avoiding touching the root), rinsed gently with saline or milk to remove debris, and re-implanted into its socket as soon as possible. If immediate re-implantation is not feasible, the tooth should be transported in an appropriate storage medium such as saline or milk to maintain cell viability. Prompt referral to a dental specialist for re-implantation is crucial to maximize the likelihood of tooth survival and proper healing.

Post-re-implantation care involves monitoring the tooth closely for signs of infection, root resorption, or other complications. Antibiotics and anti-inflammatory medications may be prescribed to prevent infection and reduce inflammation. Radiographic assessment is necessary to evaluate the position and stability of the re-implanted tooth and monitor root development. Long-term follow-up is essential to assess the vitality, function, and aesthetics of the re-implanted tooth and address any emerging issues promptly.

Moreover, preventive measures play a critical role in reducing the incidence of dental trauma in pediatric patients. Educating parents and caregivers about safety practices, such as wearing mouthguards during sports activities and avoiding behaviours that may lead to dental injuries, can significantly lower the risk of avulsion events. Early identification of predisposing factors, such as malocclusion or overcrowding, and timely orthodontic intervention can also help mitigate the risk of traumatic dental injuries.

The managing avulsion of primary and permanent teeth in pediatric patients requires a comprehensive understanding of developmental stages, treatment options, and long-term consequences. By implementing evidence-based strategies, maintaining open communication with families, and prioritizing patient-centered care, a clinician shall strive to optimize oral health outcomes and enhance the quality of life for young patients.

Review of the literature

The sixteen case reports published since 1925 document the replantation of a total of 31 primary incisors in 24 children. Patients' age at time of injury ranged between 9 months and 6 years (mean, 2-years 11 months); 17 teeth were maxillary central incisors, four maxillary laterals and 10 mandibular incisors. Five teeth were replanted within a few minutes of injury, 10 were replanted after a lapse of 30–60 min, five after 2–5 h and three teeth were 3–4 days out of their socket before being replanted. The roots of 13 incisors (five maxillary and eight mandibular) were dislodged out of the alveolar bone but still attached to the gingival tissue [9]. Twenty-one teeth were splinted and nine were subjected to root canal treatment. No data exists for the post replantation treatment of three teeth and two teeth neither received treatment nor a follow-up examination after replantation [10]. Follow-up periods ranged between 25 days and 5 years and 4 months. The replantation of 13 primary teeth was defined by the authors as successful and six as failures requiring early extraction; for 12 primary teeth, no data on outcomes were provided, or the data were irrelevant due to a very short follow-up period. Following replantation, six of the permanent teeth erupted normally, three had minimal white opacity in the enamel and two failed to erupt: one because of dilaceration of the root and the other because of a radicular cyst. No data were available regarding the 20 remaining permanent teeth. Incomplete reports, missing data and diversity of treatment modalities make it difficult to draw conclusions from the cases described. Based on current knowledge of supportive treatment for replanted permanent teeth it is not surprising that six of 19 articles that documented replantation of primary incisors and provided the outcome data reported on failures. This may be due to insufficient or lack of supportive treatment following tooth repositioning. Textbooks and articles that relate to the treatment of avulsed primary teeth have generally rejected the idea of replantation of these teeth [11].

Some authors have suggested using fixed or removable appliances to fill the gap created from early loss of maxillary primary incisors [12]. In recently issued updates of guidelines for the treatment of avulsed primary teeth, the American Academy of Pediatric Dentistry (AAPD) [13] and the International Association of Dental Traumatology (IADT) [14] recommended avoiding replantation of avulsed primary teeth because of potential damage to the developing permanent tooth germ.

Treatment plan for an avulsed primary tooth

The most commonly used treatment methods for an avulsed primary tooth are

- **No treatment:** the socket is cleaned with physiologic saline and left empty.
- **Replacement of avulsed teeth:** the avulsed tooth is replaced with fixed anterior prosthetic appliance or with all-porcelain resin-bonded retainers or with a removable prosthetic appliance. (However, children at an early age are not co-operative to deal with a removable appliance) [15].
- Replantation of the avulsed tooth.

While replanting the avulsed primary tooth, one must follow protocols similar to the one followed for permanent avulsed tooth. Following are some of the considerations to be kept in mind. First and foremost, should be the stage of root development, to ensure the strategic value of the tooth. If the avulsed primary tooth shows any clear sign of physiological root resorption, should not go ahead with replantation of such a tooth [16]. According to several authors, maximum extra-oral time recommended for the replantation of a primary tooth should be 30 minutes. Minimising the extra-oral time would help achieve the survival of the periodontal ligament and removal of the clot from the tooth socket, which is still fluid, by irrigation with sterile saline solution [17]. Authors have claimed that a major barrier to replantation could be the trapped clot in the socket which presents post trauma. The clot can also be pushed against the succedaneous permanent tooth bud; however, it may perhaps lead to morphological changes. Another important factor is the storage media for the tooth during its extra-oral time. The medium needs to maintain the viability of the root cells. HBSS (Hank's Balanced Salt Solution), physiologic saline solution or milk or child's own saliva or blood are some of the suggested and most accepted storage media [18]. Next important consideration is the degree of contamination. Both, the tooth and replantation area, should be kept as clean as possible to minimize the rate of infection and obtain a better prognosis [19]. The Dental Trauma Guide has recommended the cleaning of the root surface and apical foramen with a stream of normal saline and soaking the tooth in saline, thereby removing contamination and dead cells from the root surface also irrigation of the socket with saline is a must. Gingival lacerations should be sutured if necessary. Replantation should be performed with gradual, rhythmic movements, and the direction should always be apical to allow the dispersion of pressure through the Haversian system of the sockets alveolar bone. [20] Repositioning should be done by thumb and finger, as described by Andreasen. Avulsion injuries disrupt vascular nerve bundles, thereby restricting blood supply to the tooth. This can result in pulp necrosis, extending to external inflammatory root resorption. Furthermore, maintenance of inflammation could give rise to an abscess with or without fistula, thus further contributing to the failure of replantation. Completion of root canal treatment, extra-orally in the avulsed tooth, before replantation has also reported success [21]. Reports also proposed a successful outcome, with the resection of the root apex to about one fourth to one-fifth of the total root length followed by retrograde filling of the primary tooth root with calcium hydroxide.

International Association of Dental Traumatology advice to place a flexible type of splint. This allows the physiological movement of the tooth, thus favouring reattachment of the periodontal ligament, thereby avoiding the risk of aspiration. Antibiotics should be prescribed depending upon the degree of contamination. A soft diet should be advised for a minimum of one week. The follow-up period inclusive of clinical and radiographic evaluations, is essential. This ensures the success rate of replantation and allows the early detection of any signs of failure.

Avulsion (treatment guidelines for primary teeth IADT 2020)

Clinical findings: The tooth is completely out of the socket.

- The location of the missing tooth should be explored during the trauma history and

- Examination, especially when the accident was not witnessed by an adult or there was a loss of consciousness.
- While avulsed teeth are most often lost out of the mouth, there is a risk that they can be embedded in soft tissues of the lip, cheek, or tongue, pushed into the nose, ingested or aspirated.
- If the avulsed tooth is not found, the child should be referred for medical evaluation to an emergency room for further examination, especially where there are respiratory symptoms.

Radiographic recommendations and findings

- A periapical (size 0 sensor/ film, paralleling technique) or occlusal radiograph (size 2 sensor/film) is essential where the primary tooth is not brought into the clinic to ensure that the missing tooth has not been intruded.
- The radiograph will also provide a baseline for assessment of the developing permanent tooth and to determine whether it has been displaced.

Treatment

Avulsed primary teeth should not be replanted

- Parent/patient education: Exercise care when eating not to further traumatize the injured soft tissues. To encourage gingival healing and prevent plaque accumulation, parents should clean the affected area with a soft brush or cotton swab combined with an alcohol-free 0.1%-0.2% chlorhexidine gluconate mouth rinse applied topically twice a day for 1 wk.

Follow up

- Clinical examination after: - 6-8 wk further follow up at 6 yr of age is indicated to monitor eruption of the permanent tooth radiographic follow up only indicated where clinical findings are suggestive of pathosis (eg an unfavorable outcome)
- Parents should be informed to watch for any unfavorable outcomes and the need to return to the clinic as soon as possible. Where unfavorable outcomes are identified, treatment is often required.
- The follow-up treatment, which frequently requires the expertise of a child-oriented team, is outside the scope of these guidelines.

Arguments against replantation mentioned in the literature

Children have no esthetic demands

Moss stated that: 'children do not become aware of the loss of a primary incisor prior to age five or six. [22]. It is relevant that a number of articles have described techniques aimed to restore the esthetic appearance of the anterior maxillary segment in preschool children who have suffered from discolored, severely decayed or missing teeth. These include bleaching of dark discolored incisors following trauma reconstruction of severely decayed teeth using post and crown and fixed or removable appliances [23].

Financial costs, time consumption, and lack of children's cooperation

Hill and Kenny *et al*. have suggested that treatment costs, as well as the time required for dental visits, are factors to be considered before reaching a decision on replantation of avulsed primary teeth. Wilson and Kupietzky's comments about poor patient cooperation are surprising, because both suggest a prosthetic replacement for the missing primary incisors, a procedure that requires a very high level of child cooperation [24].

Risk of pulp necrosis and external root resorption

Andreasen and Andreasen claimed that replantation of primary teeth is not justified due to the risk of pulp necrosis. Obviously, the pulp of an avulsed tooth is expected to become necrotic, due to detachment from its original blood supply: revascularization of the pulp can be expected only in young permanent teeth with an open apex. Harrison concluded that replantation of primary teeth can hardly be justified based on the observation of rapid external resorption of the root. In primary as in permanent teeth, if the pulp is not removed after replantation, external inflammatory root resorption is an obvious complication [25].

Replantation may inflict damage to the permanent successor

According to Andreasen & Andreasen damage to the developing permanent successor may result from a coagulum that is forced into the area of the follicle during insertion of the avulsed primary incisor back into its socket.

Further, the same authors who warned against defects inflicted to the permanent tooth when the root of the primary tooth is pushed back into the socket, the repositioning of an orally luxated primary incisor: the root of the primary incisor that was dislodged from its socket in a labial direction is pushed back into the socket and toward the bud of the permanent tooth. It is not clear how replantation increases the risk to permanent successors more than does repositioning of labially luxated teeth minor hypocalcified area in the enamel of the permanent successors is seen [26]. Removing the blood clot by rinsing the alveolar socket with physiological saline before replantation reduces the risk of damage to the permanent tooth [27].

Severe damage to permanent incisors (impaction because of a radicular cyst) and impaction and dilacerations following replantation of primary predecessors [28].

Ankylosis

According to Levine ankylosis of replanted primary teeth occurs when the root has been stripped of its periodontal membrane, allowing the joining of the cementum and the bone. Fried attributed the development of ankylosis to the splint used to immobilize the replanted tooth.

Ankylosis of a replanted primary tooth has been considered to interfere with eruption of the permanent tooth and to cause delayed or ectopic eruption of the permanent successor [29].

In fact, extraction and replantation of primary teeth has been performed to intentionally induce ankylosis such as in the application of this procedure in primary canines to obtain abutments for anteriorly directed orthodontic forces aimed to protract the maxilla.

Risk of aspiration

Killian criticized Kawashima & Pineda for not splinting replanted teeth, and thus exposing a child to the danger of aspiration.

In any case, in which dental trauma affects supporting tissues by causing teeth to become loose, the teeth must be

splinted to adjacent unaffected teeth. As ankylosis does not seem to be a problem, long-term splinting time can eliminate the risk of aspiration [30].

Avulsion injuries in the permanent dentition

Avulsion injuries to permanent teeth are among the most serious TDIs, damaging the periodontal ligament (PDL), pulp, and sometimes even the alveolar bone. Complications from compromised healing of PDL and pulp in replanted avulsed permanent teeth include repair-related surface resorption, infection-related inflammatory resorption, and ankylosis-related replacement resorption. Repair-related resorption is self-limiting, while infection-related resorption can be successfully prevented or treated with endodontic treatment [31]. However, replacement resorption cannot be treated and is currently considered the most relevant risk factor in determining long-term prognosis of replanted avulsed teeth. While the root development stage and the post-injury storage medium can influence ankylosis of the replanted avulsed tooth, extra-oral dry time is the most important etiologic factor for ankylosis [32].

The IADT Guidelines for management of avulsed permanent teeth were traditionally based on two broad considerations: root development stage (mature vs. immature teeth) and extra-oral time (<60 min vs. >60 min). The 2020 IADT Guidelines continues to follow the same format, but now has an important change in that irrespective of whether the extra oral time was less or more than 60 min, the initial treatment steps while replanting the avulsed tooth remain the same. For instance, the 2012 IADT Guidelines for avulsed teeth with extra oral time >60 min recommended removal of all attached soft tissues from the root surface with gauze prior to replantation. his recommendation was based on experimental and human clinical studies showing that extended post-avulsion extra-oral time will result in a necrotic PDL that will hinder healing and cause gradual osseous replacement of the root [33]. Thus, preparing the root by removing nonviable PDL was considered an important step for avulsed teeth undergoing delayed replantation, with the intention of possibly slowing down osseous replacement and ankylosis. However, the 2020 IADT Guidelines for avulsed teeth with extra-oral time >60 min no longer recommend removal of PDL, and instead suggest only removal of gross foreign debris prior to replantation. This changed recommendation was likely based on evidence from a recent study that reevaluated clinical follow-up data from the Copenhagen cohort of 400 replanted avulsed human teeth. This landmark retrospective study showed that not all replanted teeth with extended dry storage time >60 min developed ankylosis. Indeed, around 15% of such teeth remained non-ankylotic even though no attempts were made to remove PDL from such teeth. Another recent experimental animal study also concluded that removal of PDL with gauze prior to delayed replantation of an avulsed tooth neither protects the tooth from ankylosis and osseous replacement nor does it influence the rate of replacement resorption [34]. Adhering to the current IADT recommendation of not removing the PDL prior to delayed replantation of avulsed teeth retains the potential of healing without ankylosis in at least a small percentage of such teeth, which would not be possible if blanket removal of PDL is carried out in all avulsed teeth with extended extra-oral time.

Another change in the 2020 IADT Guidelines for avulsion injuries in permanent teeth is that there is no longer a recommendation for topical application of antibiotics on the root surface of immature teeth (where extra-oral time is <60 min) prior to replantation. The 2012 IADT Guidelines had included this recommendation[4] based on experimental animal studies that demonstrated topical doxycycline or minocycline treatment of avulsed immature teeth enhanced pulp revascularization and significantly decreased frequency of infection-related and ankylosis-related resorption [35]. However, after the 2012 IADT Guidelines were published, a human clinical study demonstrated that topical doxycycline treatment of avulsed teeth did not show improved treatment outcomes for pulp survival and periodontal healing compared to teeth soaked only in saline, regardless of the root development stage, storage medium, or extra-oral time. Evidence from this study prompted the changed recommendation in the current guidelines and negated the need for topical antibiotic treatment prior to replanting immature avulsed teeth [36].

With the omission of the above two pre-replantation treatment steps from the 2020 IADT Guidelines (i.e., removal of PDL in avulsed teeth with >60 min extra-oral time; and topical antibiotic treatment for avulsed immature teeth with <60 min extra-oral time), there is now near uniformity in the initial emergency management steps of avulsed teeth, irrespective of whether the avulsed tooth was mature or immature, or the extra-oral time was > or <60 min. The treatment steps for avulsed teeth now differ only in their later endodontic management–with replanted mature teeth recommended to undergo root canal treatment 2 weeks post-replantation; while for replanted immature teeth, pulp revascularization and continued root development is the stated endodontic goal. Although the emergency management steps for avulsed teeth across all situations are now very similar, the obvious caveat is that their long-term prognosis remains dependent on factors like the extra-oral dry time, root development stage, and the type of storage media used.

There are several other differences between the 2012 and 2020 IADT Guidelines for the management of avulsed permanent teeth. The new guidelines provide more clear and practical guidance such as specifying the type of flexible splint to be used (0.4 mm diameter wire or 0.13–0.25 mm nylon fishing line); postponing endodontic management to coincide with the splint removal appointment (2 weeks post-replantation) rather than starting root canal treatment extra-orally or 7–10 days post-replantation; and administering local anesthetic without a vasoconstrictor to avoid any delay in the healing of traumatized tissues. The changes made to the 2020 IADT avulsion guidelines are highly commendable, providing precise evidence-based and pragmatic instructions to the clinician on how best to manage avulsion injuries in the permanent dentition [37].

Discussion

Injuries to the primary dentition Johnson recommended that: ‘Avulsed primary teeth should be given to the tooth fairy!’ [38]. The general attitude of the dental literature toward the treatment of traumatized primary teeth was summarized by Moss and Maccaro in the sentence: ‘Heroic methods designed to maintain the primary incisors following trauma should be discouraged [39].

the treatment protocol for avulsed permanent teeth can be modified and adapted to fit the specific needs of primary teeth [40].

Modification is needed due to several differences and factors to be considered: (i) patient ages and children's capability to cooperate and follow instructions at a young age, (ii) parents' compliance with postoperative instructions, (iii) the temporary nature of the primary dentition with the inborn tendency of the root of primary teeth to resorb and (iv) the proximity of avulsed primary teeth to the developing permanent successors.

When children lose permanent incisors, they are generally old enough to accept treatment (the 'Tell- Show-Do' behavior management technique is usually sufficient), to follow postoperative instructions, and to clean their teeth and avoid swallowing when rinsing their mouth with an antiseptic solution. In younger age groups, however, pharmacological means may be necessary to achieve children's cooperation during treatment, and adults' compliance is needed as well. Parents should be provided with detailed instructions for oral hygiene and for the application of chlorhexidine gluconate to the gingival margins surrounding the replanted teeth.

Due to the proximity of the developing permanent tooth bud to the socket of the primary incisor, special attention should be paid when manipulating instruments into the socket to assure that the permanent tooth is at no risk of damage during replantation, the root apex of the primary tooth should be resected as described by Filippi *et al* [41].

It seems that before replantation of primary teeth can be recommended in the complicated case, as delineated below, replantation of primary teeth should be performed under ideal conditions.

Replantation should be avoided in the following cases:

1. When the crown of the permanent successor is not yet completely developed.
2. Children with systemic diseases that may aggravate the treatment or decrease its success rate.
3. Children with behavior disorders whose compliance with postoperative instructions is expected to be problematic.
4. Multiple avulsions (no adjacent abutment teeth for splinting).
5. Avulsion of the coronal fragment of a tooth with root fracture.
6. Severe fracture of the alveolar bone.
7. Tooth close to natural shedding.
8. Root resorption due to previous trauma.
9. Severely decayed teeth.
10. Teeth that had infected PDL prior to avulsion.

To replant an avulsed primary tooth while the PDL is still vital, the tooth must be repositioned within 15 min [42]. This can be achieved only if the avulsed tooth is replanted at the site of injury. Awareness of the public to the recommendation to reposition avulsed permanent teeth as soon as possible may lead to immediate replantation of avulsed primary teeth by parents or by another layperson who may later seek the aid of a dentist. In such cases, if the preliminary conditions contraindicate replantation as mentioned above – remove the replanted tooth. If they do not contraindicate replantation, the replanted teeth should not be removed. Such teeth should receive optimal supportive treatment (i.e., endodontic treatment, splinting, etc.) and follow up to increase the chances of the teeth's survival, and to decrease the risk of damage to the permanent successor.

Conversely, if the tooth is not replanted immediately at the site of injury, the PDL should not be expected to maintain its vitality. The total time interval from injury to the moment the avulsed tooth is ready to be replanted, or even until the tooth is immersed in Hank's Balanced Salt Solution, may be too long. Too many steps are needed during this period of time: It must be realized that the child lost a tooth; the tooth must be looked for and found; the child must get to the dental office and the dentist must be available to provide emergency treatment; medical history should be obtained and clinical examination and radiograph taken; parents need be informed about the possible risks, benefits and alternatives to the procedure; the child's cooperation need be achieved using sedative drugs; and local anesthesia must be obtained at the site of treatment and the socket prepared for replantation.

After such a long extra-oral time, the PDL and the pulp can be considered as necrotic. It should be noted that replantation of primary teeth is not riskless. Lack of child cooperation requires the use of sedation.

Conclusion

Presently, replantation of avulsed primary incisors is not 'evidence-based care' and therefore cannot be formally recommended. However, a general attitude of 'look for the evidence' should be adopted, rather than negation based on anecdotal evidence from statements made in published works.

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