0031-3955/00 $15.00 + .00

DIAGNOSIS AND MANAGEMENT OF DENTAL INJURIES IN CHILDREN

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Injuries to children's teeth can cause much emotional distress for patients and parents. The esthetic and functional implications of dental trauma can be long lasting, and the prognosis of injured teeth can be uncertain for years, even with appropriate treatment.[34, 42, 74] Lifetime dental rehabilitation will exceed an estimated $15,000 per tooth for loss of permanent teeth in children, which does not include the cost of time spent in the dental office and the potential psychological trauma to these children.[32]

Prompt and appropriate treatment significantly improves the prognosis of several dental injuries. This article reviews dental injuries in children, highlighting cases in which prompt referral is critical and describing emergency treatment that can be provided by pediatricians.

EPIDEMIOLOGY

The prevalence of dental trauma in children has been widely reported, and little agreement exists. Differences in study design and sampling criteria yield a broad range of findings relative to its incidence and prevalence. The most representative of the studies of the primary dentition indicate that approximately 30% of preschool children suffer dental injuries, with no significant difference among boys and girls.[7]

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Using an index developed by the National Institutes of Dental Research to track trauma to permanent incisors, Kaste et al[42] reported that 23% of males aged 6 to 20 years and 13.5% of females in this same age group had experienced permanent incisor trauma.[42] These data are consistent with others, reporting ranges from 12% to 33% in boys and 4% to 11% in girls in the permanent dentition.[2, 7, 24] Thus, among school-aged children, boys seem to suffer trauma almost twice as frequently as do girls. The prevalence and incidence of traumatic injuries seem to peak at 2 to 4 years of age and again at 8 to 10 years of age.[2, 27, 29, 70] These peaks probably are related to the activity levels and play characteristics of children at these ages.[2, 57]

Most of the figures reported are underestimates because children may have suffered apparently minor injuries that were not diagnosed, so one may assume that up to half of children sustain dental injuries.[6, 71]

ETIOLOGY

More agreement exists relative to the causes of dental injuries in children and the teeth most often involved. Falls are the most common cause of injuries in preschool and school-aged children, and most occur inside the home.[25, 29, 30, 49, 55, 60, 71] Sports-related accidents and altercations are the next most common cause of dental injuries among teenagers.[32, 57, 59, 60] A seasonal variation that is statistically significant for sports injuries has been reported.[25, 55, 71] Patients with mobility problems and physical disabilities, such as seizure disorders and cerebral palsy, are at greater risk for orodental injuries.[53, 57]

The maxillary central incisors are the most commonly injured teeth, followed by the maxillary lateral incisors and mandibular incisors.[29, 42, 57, 63, 68] The degree of prominence of the anterior teeth is an important predisposing factor to injury. The horizontal relationship of the child's maxillary incisors to mandibular incisors is termed *overjet*, and the normal value is 1 mm to 3 mm. Maxillary teeth protruding more than 4 mm are less protected by the upper lip, and these children are twofold to threefold more likely to sustain dental trauma[8, 25, 31, 38] (Fig. 1). Children with obviously protruding incisors should be referred to a pediatric dentist or orthodontist for assessment and possible treatment.

Dental trauma may be an important clinical marker for child abuse, because as many as 50% to 75% of cases of child abuse involve orofacial injury.[9, 21, 39] Signs include bruises in various stages of healing, indicating multiple traumatic incidents; torn upper labial frena; and bruising of the labial sulcus in young, pre-ambulatory patients or bruising on the soft tissues of the cheek. Accidental falls are more likely to cause bruises on skin overlying bony prominences, such as the forehead or chin, than is child abuse. Human hand marks and pinch marks on cheeks and ears and tooth trauma are also common findings.[69]

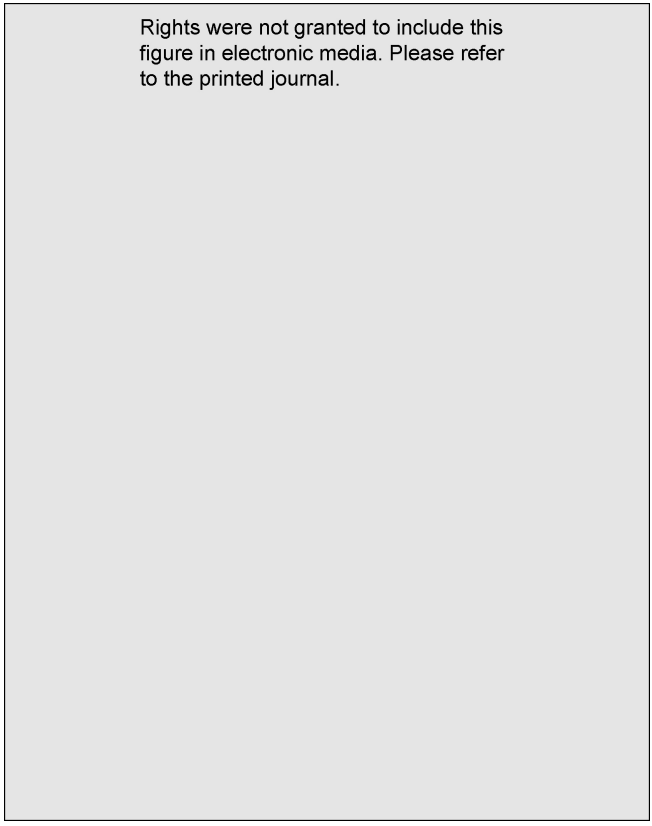

Figure 1. Patient with large horizontal overjet *(A)* and fractured central incisors *(B)*. (*From* McTigue D: Management of orofacial trauma in children. Pediatr Ann 14:125, 1985; with permission.)

MAXILLOFACIAL INJURIES

Early detection and management of facial fractures in children are important because they can heal rapidly and severely compromise facial development. A thorough discussion of their management is beyond the scope of this article, but a few general points can be made. Fractures of the mandibular condyles are the most common fractures, involving more than 50% of all facial fractures in children.[41, 45] The most common late complications observed with mandibular fractures are facial deformity, temporomandibular joint ankylosis and dysfunction, malocclusion, and chronic facial pain.[41, 45, 56]

Injuries to the chin can transmit forces through the mandible, fracturing its condyles. Bertolami and Kaban[12] reported a pattern of injuries associating chin trauma with fractures of the posterior teeth, mandibular condyles, and cervical spine. Thus, chin lacerations necessitate careful

evaluation of the cervical spine and mandibular condyles. Physical signs of condylar fracture include[45]:

Swelling in preauricular region
Pain in temporomandibular joint on movement
Anterior open bite of mandible
Malocclusion
Decreased range of mandibular motion

Mandibular fractures sometimes are detected by palpating the lower border of the mandible for steps or discontinuities and by having the child bite on a pencil to determine differences in occlusal forces.[41, 45, 56]

CLASSIFICATION OF DENTOALVEOLAR INJURIES

Traumatic injuries can result in fractures of the teeth or damage to the supporting alveolar bone and periodontium (Fig. 2). Anterior teeth have essentially no collateral circulation, and their neurovascular supply comes through the apex of the root. Tooth fractures can involve the enamel only or the dentin and enamel (i.e., uncomplicated fractures) or the neurovascular pulp (i.e., complicated fractures)[73] (Fig. 3). Pulpal injuries are the most complicated to treat. Fractures of the root also occur and may be oriented in a horizontal, vertical, or oblique direction.

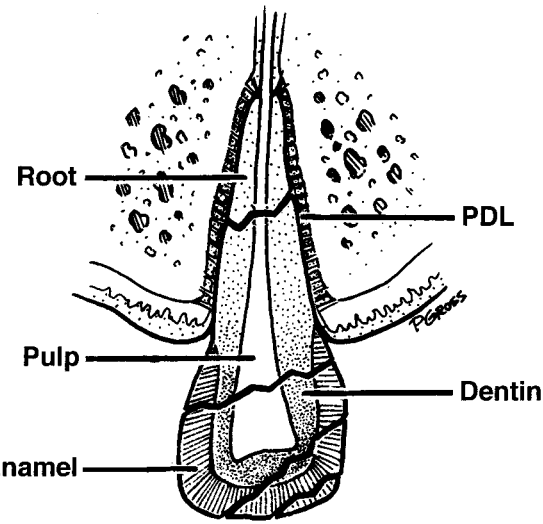

Figure 2. Classification of tooth injuries. Tooth fractures may involve enamel, dentin, or pulp and may occur in the crown or the root. (*From* McTigue D: Introduction to dental trauma: Managing traumatic injuries in the primary dentition. *In* Pediatric Dentistry: Infancy Through Adolescence, ed 3. Philadelphia, W.B. Saunders Co., 1999, p 214.)

Figure 3. Complicated crown fracture exposing the dental pulp. (*From* McTigue D: Managing traumatic injuries in the young permanent dentition. *In* Pediatric Dentistry: Infancy Through Adolescence, ed 3. Philadelphia, W.B. Saunders Co., 1999, p 534.)

Luxation injuries refer to damage to the supporting structures of the teeth, which include the periodontal ligament and alveolar bone. The periodontal ligament (PDL) is the physiologic "hammock" of connective tissue that supports the tooth in its socket (see Fig. 2). Maintaining its vitality is the primary treatment objective of all luxation injuries.

Luxation injuries are defined as follows[2]:

Concussion. The tooth is not mobile and has not been displaced. The periodontal ligament may be inflamed, and the tooth may be tender to biting pressure.

Subluxation. The tooth is loosened but not displaced from its socket. Some periodontal ligament fibers are damaged and inflamed.

Intrusion. The tooth is driven into the socket, which compresses the periodontal ligament and causes a crushing fracture of the alveolar socket.

Extrusion. A central dislocation of the tooth from its socket is present. The periodontal ligament is lacerated and inflamed (Fig. 4*A*).

Lateral luxation. The tooth is displaced in a facial, lingual, or lateral direction. The periodontal ligament is lacerated, and fracture of the supporting bone occurs (Fig. 4*B*).

Avulsion. The tooth is completely displaced from the alveolar. The periodontal ligament is severed, and fracture of the alveolus may occur.

PATHOLOGIC SEQUELAE OF TRAUMATIZED TEETH

Traumatized teeth are at substantial risk for devitalization because the thin strand of pulp tissue can be severed easily at the root apex by

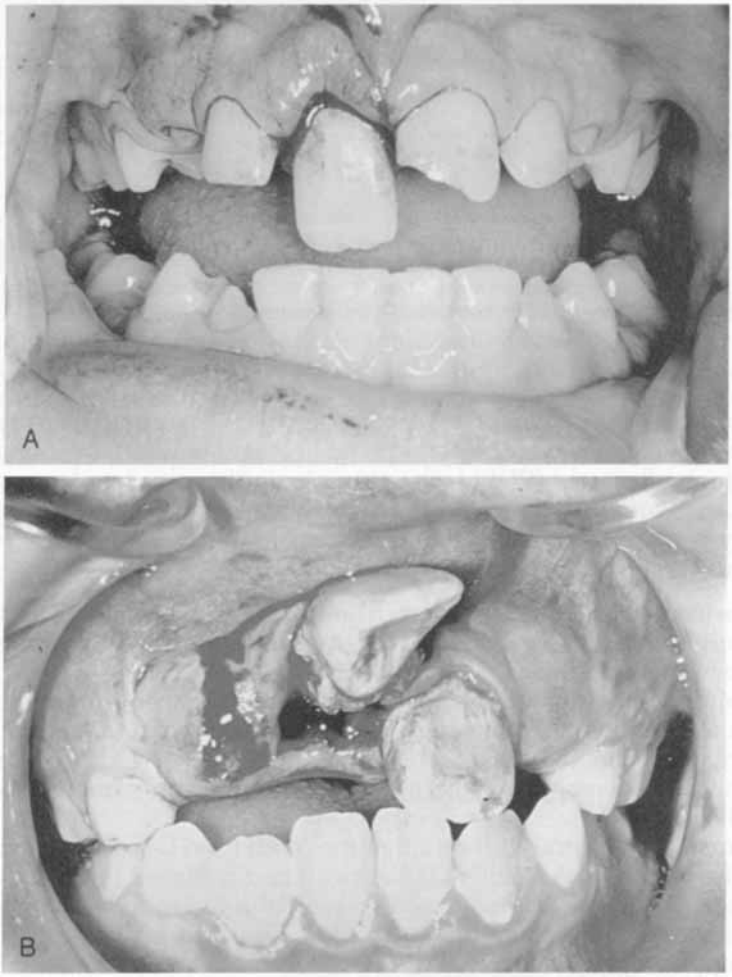

Figure 4. *A,* Extrusion injury of maxillary right central incisor and crown fracture of maxillary left central incisor. *B,* Laterally luxated tooth. (*From* McTigue D: Managing traumatic injuries in the young permanent dentition. *In* Pediatric Dentistry: Infancy Through Adolescence, ed 3. Philadelphia, W.B. Saunders Co., 1999, p 542.)

relatively minor blows. Disruption of the neurovascular supply to the tooth results in ischemic necrosis of the pulp and can manifest externally by color change in the tooth crown (Fig. 5). This discoloration can be pink, yellow, gray, or black, depending on the pathologic process occurring.[37, 61, 62] Discoloration is a clear indication for prompt referral to a pediatric dentist for evaluation and treatment. Left untreated, these teeth may abscess or undergo inflammatory resorption of the roots.[2, 14]

Another common dental injury that can lead to pulp necrosis is fracture of the tooth crown, which exposes pulp tissue (see Fig. 3). The vitality of this tissue can be preserved in most cases if treated appropriately, and the fracture can be esthetically restored with composite resin materials.[19, 28]

Uncomplicated fractures that include only dentin and enamel are significant because they can cause sensitivity to thermal change and mastication. The exposed dentinal tubules also provide a convenient pathway for bacteria and thermal or chemical irritants that could produce pulpal inflammation.[2]

Luxation injuries to the periodontal ligament, left untreated, herald a poorer prognosis for tooth survival than does pulp necrosis alone.

Figure 5. Examples of discoloration of teeth secondary to injury. *A*, Primary right central incisor. *B*, Permanent left central incisor.

Necrotic, infected pulp tissue in the root canal can drive an inflammatory resorptive process that can destroy the root within weeks.[3, 65]

INITIAL ASSESSMENT

The history of the traumatic incident is important in assessing the severity of injury. Clinicians should determine when, where, and how the injury occurred. The time elapsed since an injury occurred has a critical role in determining future treatment, and, in most cases, the prognosis worsens with a delay in treatment.[2, 5, 6] Where and how the injury occurred provide important information regarding its severity. Because dental injuries are a subset of head trauma, a thorough neurologic evaluation to rule out severe head injury is indicated.[40, 64] The potential of child abuse should be ruled out with careful history taking.[9, 21, 39, 69]

The child's tetanus immunization status should be determined because tetanus prophylaxis may be indicated when dirty wounds occur.[1] Tetanus precautions should be considered for children suffering avulsed teeth, deep lacerations, or intrusion injuries.

The value of systemic antibiotic therapy is questionable.[2, 3] Under experimental conditions using animal models, antibiotics decrease the extent of root resorption, but no effect on pulpal or periodontal ligament healing has been demonstrated.[3, 4, 20, 33, 58] Antibiotics may be indicated for managing secondary infections in affected soft tissue.

Clinicians can gain important information by determining the following:

- History of spontaneous pain in any of the child's teeth secondary to the injury; indicative of pulpal exposure or inflammation
- Tenderness of the teeth to touch or the pressure of eating; indicative of periodontal ligament damage or displacement
- Sensitivity of teeth to hot or cold; indicative of pulp exposure or inflammation
- Change in the child's bite or occlusion; indicative of displaced teeth or facial fractures

Positive findings here indicate prompt referral to a dentist for treatment.

During clinical examination, the oral cavity should be examined for:

- Injuries to soft tissues, such as lips, frena, tongue, buccal mucosa, and palate; tooth fragments can become embedded in soft tissues, leading to chronic infection and fibrosis[2, 17]
- Fractured anterior teeth; with attention to exposure of the vascular pulp tissue at the fracture sites
- Fractured posterior teeth; occurs secondary to blows to the chin and may accompany fractures of the mandibular condyles and cervical spine[12]
- Loose, displaced, or missing teeth

Children presenting with any of these signs should be referred to a dentist for treatment.

MANAGEMENT OF TRAUMATIZED TEETH

Primary Teeth

The most common injuries to primary teeth are luxation injuries, in which the teeth are loosened, displaced, or completely avulsed.[26, 29, 70] The main concern in managing injuries to primary incisors is prevention of damage to the succeeding permanent incisors. Anatomically, the permanent anterior teeth develop in close proximity to the apices of primary incisors (Fig. 6); thus, periapical infection caused by necrotic pulp tissue or intrusion injuries can irreversibly damage the permanent tooth.[11, 15, 68] If this injury occurs during the calcification of the permanent tooth crown (birth to age 4 y), enamel hypoplasia (Fig. 7) may occur. These injuries also can alter the path of the developing permanent tooth,[18] so heroic efforts to save severely luxated primary incisors are not recommended.

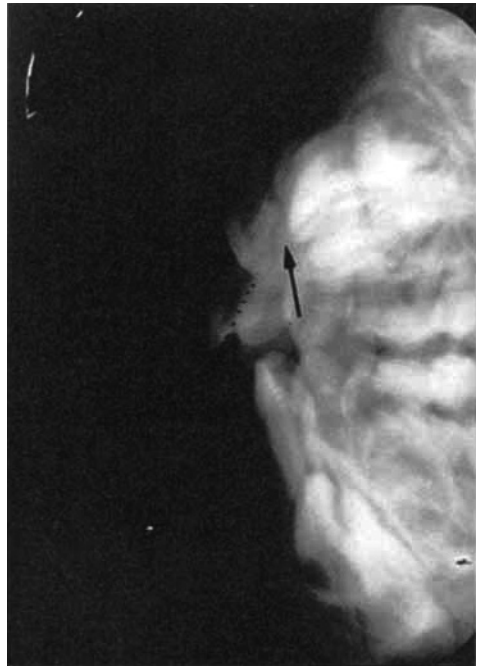

Figure 6. Lateral anterior radiograph showing proximity of developing permanent central incisor crown to intruded primary central incisor *(arrow)*.

Figure 7. Hypoplasia of the patient's maxillary left permanent central incisor as a result of intrusion of a primary incisor. (*From* McTigue D: Introduction to dental trauma: Managing traumatic injuries in the primary dentition. *In* Pediatric Dentistry: Infancy Through Adolescence, ed 3. Philadelphia, W.B. Saunders Co., 1999, p 222.)

Children presenting to the pediatrician with badly displaced or loose primary anterior teeth should be referred to a dentist for immediate care (Fig. 8). If a dental referral is not immediately available and the clinician is concerned that the injured primary teeth might be aspirated, these teeth can be removed.[27, 70] Early loss of primary anterior teeth has no irreversible effect on speech or space availability for permanent incisors.[15, 50] If parents object to the esthetics of missing anterior teeth, fixed or removable prostheses can be fabricated.[70]

Figure 8. Extruded primary central incisors.

MANAGEMENT OF PERMANENT TOOTH INJURIES

Tooth Fractures

No effective "first aid" measures to manage fractures of a tooth exist. In most cases, however, even complicated fractures with pulp exposures can be treated successfully hours after the injury, so immediate treatment is not necessary.[19, 28] To achieve optimum patient comfort and esthetics, patients should be referred for definitive care as soon as possible.

Some patients present with crown fractures and have retrieved the fractured fragments. The literature is replete with anecdotal reports of successful reattachment of these fragments, and long-term, multicenter studies have confirmed their success.[51, 67] Patients presenting with crown fractures and tooth fragments should keep the fragments hydrated and be referred to a dentist as soon as is practical for reattachment.

Luxated and Avulsed Teeth

Luxation injuries of permanent teeth constitute legitimate dental emergencies and should be managed immediately for the best possible outcome. The prognosis for avulsed permanent teeth worsens in direct proportion to the extraoral period.[2] The primary therapeutic concern is to maintain the vitality of the periodontal ligament. Such teeth that are reimplanted within 5 minutes have an 85% to 97% likelihood of healing, whereas those reimplanted after 1 hour rarely survive.[2–4]

In a study of the clonogenic capacity of periodontal ligament cells, Lekic et al[46] found that an extra-alveolar duration of only 15 minutes caused a significant decrease in the number of periodontal ligament progenitor cells. This decreased capacity to reproduce cells may explain the impaired healing associated with the delayed replantation of avulsed teeth.[44] Avulsed permanent teeth must therefore be immediately reimplanted by the first capable person, whether that be the injured child or a parent, teacher, coach, or pediatrician. Often, parents call the office before bringing their children in for care, and parents must be instructed to attempt to reimplant the tooth immediately. The procedure for reimplantation is as follows (Fig. 9):

1. The tooth should be carefully held by the crown to prevent damage to the periodontal ligament.
2. It should be rinsed gently with saline or tap water to remove debris. No attempt should be made to scrub or sterilize the tooth.
3. The tooth should be manually reimplanted in the socket.
4. The child should keep the tooth in place with finger pressure or by biting on a gauze pad and be referred to a pediatric dentist for immediate treatment.

For a variety of reasons, it is sometimes impossible to reimplant a tooth immediately. Several in vitro studies have demonstrated the

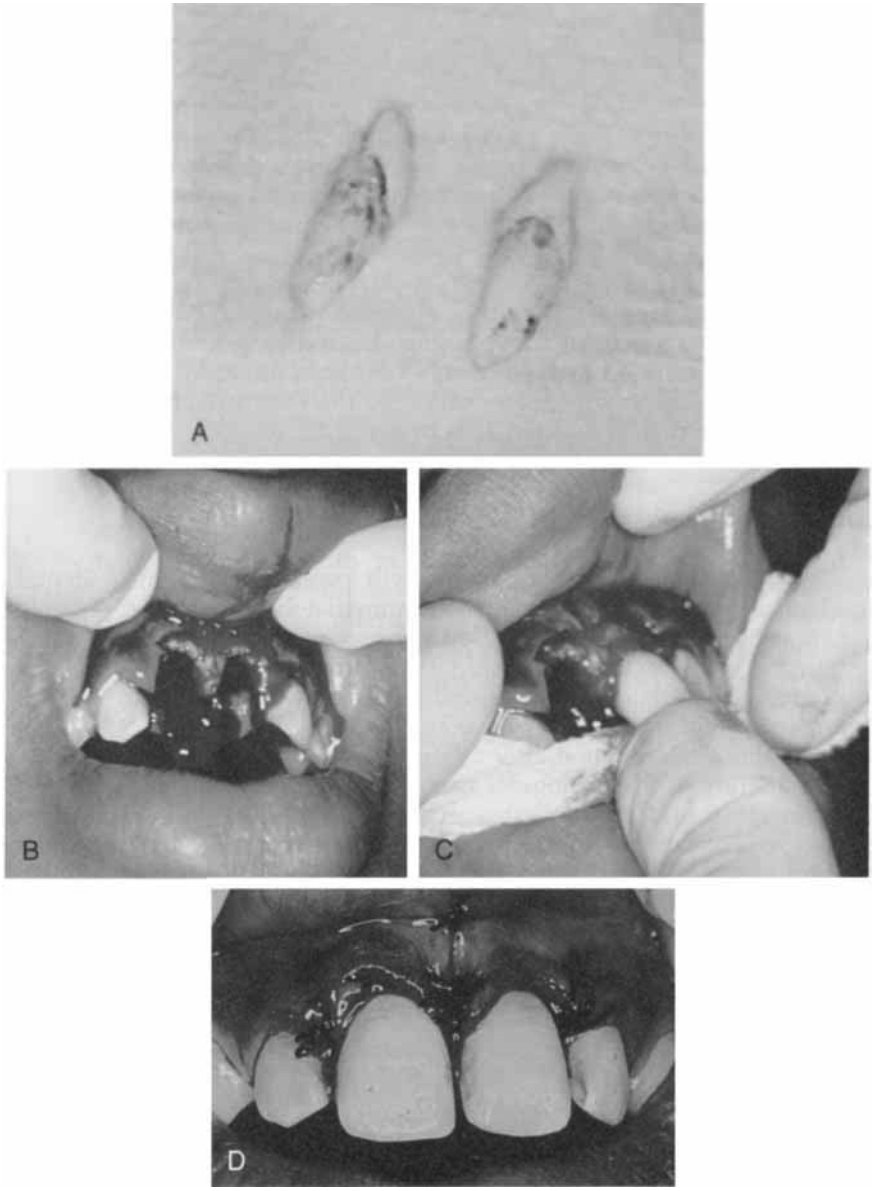

Figure 9. Immediate reimplantation is the best treatment for avulsed permanent teeth. *A,* Both maxillary permanent central incisors avulsed. *B,* Sockets of avulsed teeth. *C,* Reimplanting avulsed teeth with finger pressure. *D,* Avulsed teeth reimplanted. (*Adapted from* McTigue D: Managing traumatic injuries in the young permanent dentition. *In* Pediatric Dentistry: Infancy Through Adolescence, ed 3. Philadelphia, W.B. Saunders Co., 1999, p 543.)

effectiveness of cell culture media, such as Viaspan or Hank's Balanced Salt Solution (HBSS), in preserving the vitality of periodontal ligament cells when used as interim storage solutions.[66] Viaspan is not readily available for clinical use, but HBSS is available in an avulsed tooth-preserving system called Save-A-Tooth (Smart Practice, Phoenix, AZ). The use of such a system increases the likelihood of periodontal ligament survival for several hours.[43]

The best alternative storage medium for avulsed teeth if cell culture media is unavailable is milk,[13, 44] which is readily available and relatively aseptic, and its osmolality is more favorable to maintaining the vitality of periodontal ligament cells than is saline solution or tap water. Evidence shows that extraoral storage of avulsed teeth is improved with chilled storage media.[13, 46] Storage in liquid media that is packed in ice is the standard procedure for organ transplant, and packing an avulsed tooth in milk and ice maintains the desired low temperature without diluting the milk and decreasing its osmolality.[44]

Water is an unfavorable transplant medium because of its low osmolality, which causes cells to swell and rupture within minutes.[13, 44] If milk or other cell cultural media are not immediately available, storing the tooth in the child's saliva prevents dessication and produces less cell damage than does water or dry storage.[13, 44]

PREVENTION OF DENTAL INJURIES

Falls are the most common cause of dental injuries in preschool and preteen-aged children, whereas sports accidents account for most dental injuries in teenagers. Strong evidence shows that mouthguards prevent oral injuries when used in sports. Flanders and Bhat[23] reported that only 0.07% of injuries suffered in high school football, in which mouthguards are required, involved the teeth or oral structures. In basketball, in which mouthguards are not regularly worn, 34% of all injuries involved the teeth or oral structures. Responding to a survey of high school basketball players in Florida, 30.9% of the athletes reported an orofacial injury during the previous season. Only 4.2% reported using mouthguards, and only 0.6% of orofacial injuries occurred among athletes wearing mouthguards. Based on these data, the researchers estimated that injuries increased sixfold to eightfold when mouth protectors were not used.[47] These findings concur with those in a study of orofacial injuries in female basketball players.[72] Mouthguards also reduce the prevalence of concussion and jaw fracture by cushioning the force of chin-hit concussion.[22, 35]

Despite their proven effectiveness in preventing oral injuries, the use of mouthguards in sports other than football is uncommon. A recent National Institutes of Dental Research report decried the lack of rules mandating protective equipment in other sports and called for more public education regarding their benefit.[52]

Three types of mouthguards are readily available: (1) stock, (2) self-

adapted, and (3) custom made (Fig. 10). Stock mouthguards fit loosely over the maxillary teeth and cannot be altered. This loose fit means that the wearer must keep the teeth in contact to protect the guard from being displaced. These have been reported to impede speech and respiration.[2] Self-adapted, or "boil-and-bite," thermoplastic mouthguards are available in a preformed shape that can be altered by boiling it in water and biting into the warmed plastic for a customized fit. Custom-made mouthguards are fabricated from a stone model made from an impression taken by a dentist. Although any of these types provide protection from mouth injury, in vitro studies indicate that the custom-made mod-

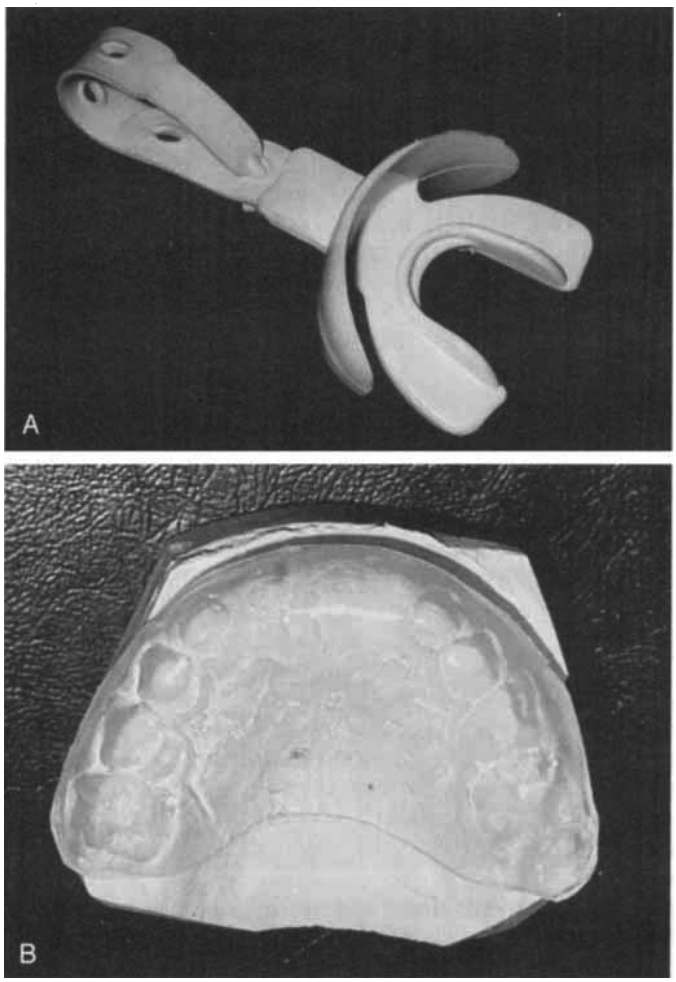

Figure 10. *A*, Stock mouthguard. *B*, Custom-made mouthguard on stone cast of patient's maxillary arch.

els afford better protection against projectile impact at the incisal and marginal edges.[16, 36, 54] Several studies report improved comfort and retention of custom-made mouthguards.[22, 36, 48] The cost involved in fabricating custom-made mouthguards prevents some athletes from securing them, but all children engaged in contact sports should be encouraged to wear some sort of mouthguard.[52, 72]

SUMMARY

Approximately half of children sustain some type of dental injury. Management of injuries to the anterior teeth of preschool children is directed toward minimizing potential damage to the developing permanent teeth; therefore, heroic measures to save primary teeth are not indicated. Crown fractures in the permanent dentition, even those exposing the dental pulp, can be successfully treated hours after an injury. Prompt referral for dental treatment is advisable. Displacement injuries to permanent teeth constitute genuine dental emergencies in which the prognosis is directly related to the timeliness of treatment. Avulsed permanent teeth should be immediately reimplanted by any capable person. If that is impossible, the teeth should be placed in cold milk and the child referred for immediate treatment by a dentist. Mouthguards prevent dental injuries but are not widely used outside of a few organized sports. Efforts should continue to promote mouthguard use in all contact sports.

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