A brief review of extensor tendon injuries specific to the pediatric patient

C. Liam Dwyer · Rey N. Ramirez · John D. Lubahn

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Abstract Extensor tendon injuries in the pediatric population require careful evaluation and treatment. This article focuses on the differences in injury type and treatment of pediatric versus adult extensor tendon injuries. A detailed history and physical examination is crucial in the management of extensor tendon injuries of the young patient. Treatment of pediatric extensor tendon injuries depends largely on the site of injury. A majority of these injuries may be treated with splinting or primary repair. Treatment methods that require high compliance must be adjusted for the young child.

Keywords Extensor tendon · Hand laceration · Tendon repair · Pediatric

Introduction

A detailed history and physical examination is crucial in the management of extensor tendon injuries of the young patient. Due to their exposed superficial location, extensor tendons are injured more often than flexor tendons [1]. Common etiologies include sports, physical altercations, farm equipment, self-mutilation, crush injuries, and other trauma. In general, the treatment principles for pediatric extensor tendon injuries are similar to those for the adult. Pediatric treatment typically consists of splinting, direct repair under sedation, and cast

immobilization of 4 to 6 weeks. Children with extensor tendon injuries typically have excellent to good results with good functional outcomes [2]. An advantage is the ability of children to heal rapidly and to regain motion easily despite prolonged immobilization. This review focuses on extensor tendon injuries specific to the pediatric population and how they are treated differently in children than adults.

Diagnosis, Classification, and Treatment

Often, the history of the injury is obtained from the patient's parents as the child may be unwilling or unable to communicate the details with the examiner. Therefore, physical examination plays an even greater role in diagnosing extensor tendon injuries in the pediatric population. After carefully inspecting the extremity for lacerations, ecchymosis, or deformity, the child should be coaxed to demonstrate active movement of the tendons passing through the zone of injury. If the child is unwilling or unable to participate, the extremity should be evaluated for normal tenodesis and digital cascade. It is important to inspect for additional injuries associated with the extensor tendon injury including using radiographs to identify dislocations or fractures [3].

Just as in adults, extensor tendon lacerations in children may be classified by zone using the system described by Kleinert and Verdan (Fig. 1) [4, 5]. Eight zones of injury are described relative to the underlying bones and joints of the hand and wrist. An additional ninth zone at the musculotendinous junction was added by Doyle [6]. Each zone has characteristic tendon shape, bony anatomy, and tendon gliding properties that determine treatment (Table 1) [5, 7–9]. Figure 2 demonstrates a pediatric extensor pollicis longus (EPL) laceration in zone T-II treated with primary repair and splinting with excellent results including full active thumb IP joint extension.

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C. L. Dwyer · R. N. Ramirez · J. D. Lubahn (✉)
Department of Orthopaedics, UPMC Hamot, Erie, PA, USA
e-mail: jdlubahn@jdlubahn.com

R. N. Ramirez · J. D. Lubahn
Hand, Microsurgery, and Reconstructive Orthopaedics, LLP 300
State Street, Suite 205, Erie, PA 16507, USA

Fig 1 Pediatric extensor tendon zones [4]. Adapted from Griffin M, Hindocha S, Jordan D, Saleh M, Khan W. Management of extensor tendon injuries. *Open Orthop J.* 2012;6:36–42

Partial tendon injuries may be treated with simple wound care and splinting. Primary surgical repair is recommended for most complete injuries. Delayed treatment, two-stage procedures, tendon transfers, or tendon grafting may result in inferior results compared to early treatment, typically due to stiffness and loss of motion, although less dramatically than seen in adults [7].

Unique Injuries and Treatment

Extensor Injury Associated with Fracture

It is crucial to assess tendon integrity in the setting of skeletal trauma both before and after fixation. Extensor tendons are in close proximity to the long bones of the forearm, and therefore any forearm fracture or hardware placement may result in tendon laceration, entrapment, or attrition.

Extensor tendon entrapment in pediatric forearm fractures is well reported [10, 11]. It is especially important to suspect interposition of soft tissue when multiple reductions are required. Interposition of soft tissue may result in a rubbery “feel” to the reduction to be noted by the surgeon. If soft tissue interposition is suspected, a limited open reduction maneuver should be considered to remove the obstruction. In the case report by Gould, several closed reduction attempts were done for a pediatric Galeazzi-type fracture of the radius. It was eventually determined by performing a limited incision that the EPL, extensor indicis proprius EIP, extensor digitorum communis (EDC), and extensor digiti minimi (EDM) were entrapped within the fracture site.

Delayed Extensor Tendon Rupture

Though less commonly reported than in adults, children may develop attritional ruptures of the extensor tendons. Recent case reports have described EPL ruptures in children after both-bone forearm fractures previously treated with closed reduction [10], closed reduction and percutaneous pinning [12, 13], as well as with intramedullary nailing of forearm fractures [14–17]. These injuries were treated with hardware removal, when present, and EIP tendon transfer or PL tendon interposition graft. Another recent case report described a zone VII rupture of the EDC to the index after closed treatment of a pediatric distal radius fracture. This case was treated by a takedown of the bony prominence and an EIP tendon transfer [18].

Although rare, attritional pediatric tendon ruptures may occur after fractures whether treated closed or with hardware placement. Attritional pediatric extensor tendon ruptures are not typically directly repairable and reconstruction options include tendon graft or tendon transfer.

Neonatal Extensor Tendon Injury

A less common pediatric extensor tendon injury is that of the neonate. Fuller and Raphael [19] described the excellent clinical outcome of repair of two extensor tendon lacerations in the neonate as a result of iatrogenic injury during an emergency cesarean section. The two zone-III injuries in the 30-week gestational age newborn were both treated using 7–0 Chromic suture. The index finger was treated with single-layer full-thickness closure through skin and extensor (dermatotenodesis) and the long finger with a layered closure of the extensor and skin because the cut ends of the extensor mechanism were easily visualized and re-approximated. The patient was splinted in full extension for 3 weeks and had full active motion at 8 weeks without further complication. Similarly, Rinker [20] describes the successful outcome of the repair of an EPL laceration in zone II on the thumb resulting from an emergency cesarean section. This repair involved two 6–0 polypropylene horizontal mattress and splinting for 5 weeks. At 5 months, the patient demonstrated full active extension and had no other complications.

Neonatal extensor tendon injuries are generally by iatrogenic sharp lacerations during delivery. We recommend direct repair of most neonatal extensor tendon injuries. The small diameter of neonatal tendons makes core suture techniques challenging. Therefore, mattress or figure-of-8 suture patterns may be used. Absorbable sutures are appropriate given the rapid healing that is expected.

Table 1 Pediatric extensor tendon zones [5, 7]. Adapted from Kleinert HE, Verdan C. Report of the Committee on Tendon Injuries (International Federation of Societies for Surgery of the Hand). *J Hand Surg Am.* 1983;8:794–8 and Armstrong MB, Adegun O. Tendon injuries in the pediatric hand. *J Craniofac Surg.* 2009;20:1005–10

Zone	Finger	Thumb ^a	Subtype	Treatment	Notes
I	DIP joint	IP joint	Type I: closed injury, with or without an avulsion fracture Type II: open laceration injury Type III: open abrasion injury involving skin Type IV: (a) transepiphyseal plate fracture, (b) fracture of 20–50% of the articular surface, (c) fracture of >50% of the articular surface [6]	Closed injury: 6 weeks of continuous DIP extension splinting followed by 2 weeks of night splinting. Young children require casting to prevent removal of splint. Open injury: suturing of tendon substance extremely difficult. Consider dermatotomodesis, incorporating the skin and tendon into single repair [9]. Open injury with soft tissue loss: require skin coverage procedures along with primary or delayed tendon grafting. Fracture: as these involve the physis, anatomic reduction and Kirschner wire fixation are recommended.	“Mallet Finger” injuries are unable to actively extend their DIP joint. If allowed to persist, these injuries may lose passive dorsiflexion of the DIP joint and go on to develop compensatory swan-neck deformities. Commonly occur via closed tendon ruptures or bony avulsions of the distal phalanx rather than open lacerations.
II	Middle phalanx	Proximal phalanx	<50% width laceration	Routine wound care and splinting for 3 to 4 weeks.	Commonly occur via laceration or crush injury.
III	Apex PIP joint	MCP joint	>50% width laceration Closed	Primary repair with at least 4 weeks of splinting. Since the tendon ends do not retract in this region, treat with PIP extension splinting for 6 weeks allowing adjacent joints to remain mobile. Younger children unable to be maintained in an extension splint alone require a cast to cover and secure the splint.	“Boutonnière Deformity” of a flexed PIP joint and hyperextended DIP joint may develop 1 to 2 weeks after injury if not treated due to central slip disruption and subsequent volar migration of the lateral bands. The central slip may rupture or avulse with a bony fragment.
IV	Proximal phalanx	Metacarpal	Failed non-operative treatment, displaced avulsion fracture, PIP instability with loss of motion	Re-approximation of the central slip to the middle phalanx using a suture anchor with PIP immobilization for 3 to 4 weeks. A supplemental k-wire may be used for PIP immobilization in younger children. PIP extension splinting for 3–4 weeks.	Typically, only partial injuries involving the broad extensor hood.
V	Apex MCP joint	–	–	Irrigation and debridement followed by repair of the capsule and extensor mechanism separately.	Human “fight bite” injuries where the extensor mechanism retracts due to flexed position at time of injury.
VI	Dorsal hand	–	–	Primary repair followed by splinting of the wrist and fingers in the intrinsic-plus position for 4–6 weeks.	Juncturae tendinae may complicate exam.
VII	Dorsal retinaculum	Dorsal retinaculum	–	Dynamic splinting or supervised occupational therapy of tendon gliding to limit the risk of adhesions within the extensor retinaculum.	Extensor retinaculum may complicate repair.
VIII	Distal forearm	Distal forearm	–	Repair followed by 4–6 weeks of wrist extension splinting.	Multiple tendons may be involved.
IX	Mid and Proximal forearm	Mid and Proximal forearm	–	Primary repair followed by long arm immobilization for 4–6 weeks.	Tendon transfer may be required.

^a Open injuries necessitate primary repair of the capsule and tendons separately with splinting for 6 weeks. Closed injuries may be treated with thumb and wrist extension splinting for 3 to 4 weeks

Fig 2 Pediatric EPL laceration in zone T-II. **a** Pre-op image demonstrating extensor lag at the IP joint; **b** intra-op image demonstrating primary repair with re-approximation of tendon ends; **c** post-op image demonstrating excellent outcome with full active extension of the thumb IP joint

Postoperative Protocol

Although early active motion may be encouraged after extensor tendon repair, children should be statically immobilized with a splint or cast. The advantage of static immobilization, a method shown to be effective even in adults [21], is that it does not rely on the patients' cooperation as does dynamic splinting or early active motion protocols. The potential benefit of early postoperative motion is to limit adhesions and contractures. However, Fitoussi et al. [2] found that most complications in the management of pediatric extensor tendon ruptures were associated with motion at the repair site, including ruptures of the repair or callus lengthening. They also found no complications associated with immobility of the

repair site, including tendon adhesion and joint contracture. Complications including adhesions, joint contracture, bowstringing (zone VII), tenodesis, and re-rupture are more common in adults than the pediatric population.

The rapid recovery of pediatric patients [22] enables them to tolerate static immobilization. However, immobilization using splinting and casting alone can be difficult in children due to their small-sized digits. Two techniques that may be used to augment this are k-wire joint immobilization [2] or by incorporating an alumifoam splint into the cast. An alumifoam splint placed directly on the skin allows precise control of joint alignment although necessitates close monitoring for skin breakdown. However, it is recommended to place a long arm cast to further protect the splint and repair.

Conclusions

Extensor tendon injuries in the pediatric patient require careful evaluation and treatment. Although the management of these injuries is relatively similar to that of the adult patient, there are key differences, principally in the rehabilitation and recovery stages. Studies have demonstrated that pediatric patients are able to achieve excellent results with limited complications using strict immobilization rather than early active motion protocols. Surgeons should remain cognizant of extensor tendon injury during the management of forearm long bone fractures. The pediatric patient is resilient, and with appropriate treatment practices, excellent results with good functional outcomes are to be expected.

Conflict of interest C. Liam Dwyer declares that he has no conflict of interest.

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