Review Article

Avulsion Injuries of the Flexor Digitorum Profundus Tendon

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Abstract

Avulsions of the flexor digitorum profundus tendon may involve tendon retraction into the palm and fractures of the distal phalanx. Although various repair techniques have been described, none has emerged as superior to others. Review of the literature does provide evidence-based premises for treatment: multi-strand repairs perform better, gapping may be seen with pullout suture–dorsal button repairs, and failure because of bone pullout remains a concern with suture anchor methods. Clinical prognostic factors include the extent of proximal tendon retraction, chronicity of the avulsion, and the presence and size of associated osseous fragments. Patients must be counseled appropriately regarding anticipated outcomes, the importance of postoperative rehabilitation, and potential complications. Treatment alternatives for the chronic avulsion injury remain patient-specific and include nonsurgical management, distal interphalangeal joint arthrodesis, and staged reconstruction.

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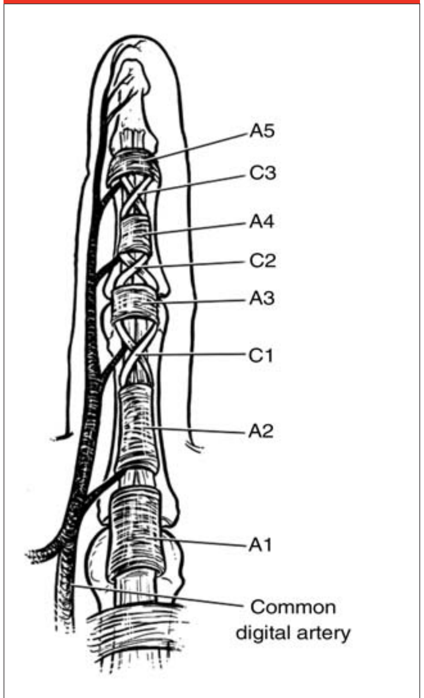
Avulsion-type injury involving the flexor digitorum profundus (FDP) tendon (ie, jersey finger injury) is relatively common and is seen in athletes and nonathletes. The mechanism of injury includes forced hyperextension of the distal interphalangeal (DIP) joint while the finger is actively flexing. The common term is derived from the classic scenario: as the athlete forcefully grabs the jersey of an opponent with the terminal aspect of the digit, the FDP tendon is avulsed from its insertion on the distal phalanx.[1] Avulsion injury of the FDP tendon most often occurs in the ring finger.[2] Classification is based on the proximal extent of retraction of the FDP tendon as well as on the presence or absence of a bony avulsion fracture fragment.[1] FDP tendon rupture can also occur from chronic attrition in systemic inflammatory conditions such as rheumatologic diseases,[3-5] and it has been reported in all age groups.[6] Treatment decisions are based on chronicity and injury pattern as well as patient-specific characteristics.

Anatomic Considerations and Injury Mechanism

The pathomechanics of avulsion injury of the FDP tendon include forced hyperextension of the DIP joint while the finger is actively flexing. Several anatomic observations highlight the increased susceptibility of the ring finger to this specific injury. First, the ring finger has the least independent motion of all the digits.[7] Second, the insertion of the ring finger FDP tendon is weaker than that of the long finger.[2] Additionally, the bipennate structure of the lumbrical muscle of the ring finger tethers the FDP tendon in the palm, thereby limiting its excursion and range of motion, thus predisposing it to rupture.[8] Finally, the ring fingertip extends approximately 5 mm beyond the terminal extent of the other digits during power grip, and it absorbs more force than does any other finger during pull-away testing.[9]

McMaster[10] demonstrated that rupture usually occurs at the bony insertion and less often at the musculotendinous junction because the tendon is the strongest link in the musculotendinous chain. When intratendinous rupture does occur, it is most often the result of traumatic distal phalanx avulsion-type amputation or underlying inflammatory changes in rheumatoid arthritis, osteoarthritis, tenosynovitis, or hook of hamate fracture (ie, attritional rupture).

Figure 1



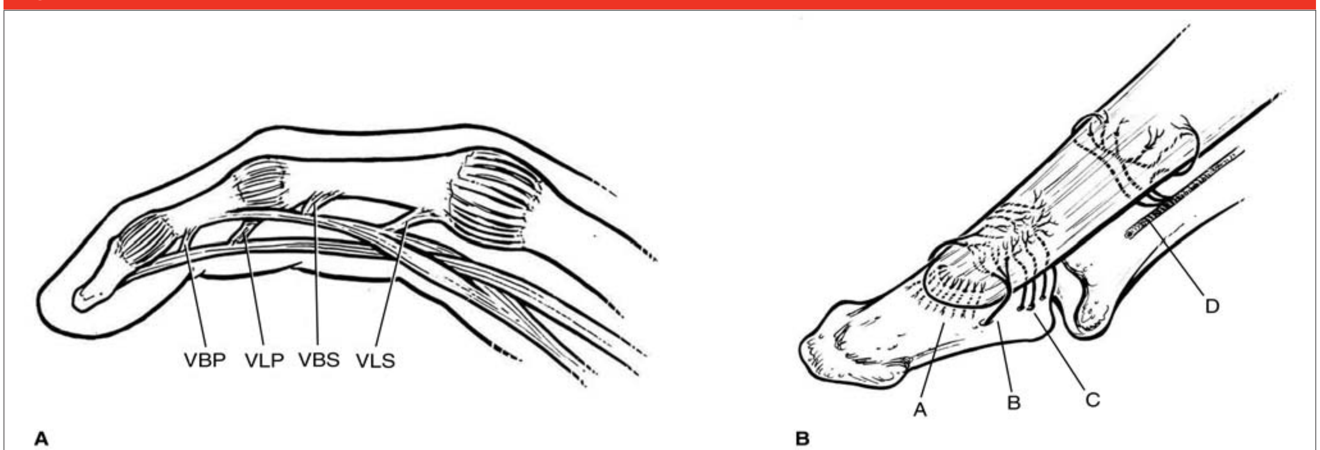
Fibro-osseous sheath anatomy. A = annular pulley, C = cruciate pulley

Regional Fibro-osseous Sheath and Vascular Anatomy: Clinical Implications

Avulsion injury of the FDP tendon represents a flexor tendon injury within zone 1 of the flexor tendon sheath, defined as distal to the insertion of the flexor digitorum superficialis tendon and includes the C3 and A5 pulleys.[1,11] The regional anatomy of the pulley and vincular systems (Figures 1 and 2) affects both the level of FDP tendon retraction and the ultimate prognosis following these avulsion injuries. For instance, in a Leddy type I lesion, the tendon retracts back into the palm, stripping the vincular blood supply and allowing for the collapse of the pulley system with the passage of time from injury.

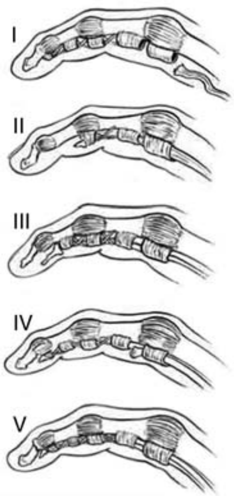
As described by Leversedge et al,[12] the FDP tendon insertion distal to the A5 pulley benefits from a dual vascular supply comprised of an intraosseous supply originating from the distal phalanx and an extraosseous system derived from the vinculum brevis profundus (VBP) (Figures 1 and 2). Intraosseous vessels arising from within the distal phalanx directly penetrate the FDP tendon at its insertion and are concentrated at the midpoint of the tendon insertion. Additionally, a longitudinally ori-

Figure 2



A, Vincular blood supply. **B,** Vascular supply of the flexor digitorum profundus tendon insertion. There is a well-defined hypovascular zone between C and D. A = intraosseous vessels arising from within the distal phalanx supplying the tendon at its osseous insertion, B = leash of vessels arising from bony ostia at the middle of the distal phalanx giving rise to longitudinally directed vessels at the volar aspect of the tendon, C = extraosseous leash of vessels that supply the dorsal aspect of the tendon <2 mm proximal to its insertion onto the distal phalanx, D = VBP-derived vascular network proximal to the tendinous insertion, VBP = vinculum brevis profundus, VBS = vinculum brevis superficialis, VLP = vinculum longus profundus, VLS = vinculum longus superficialis

Figure 3



Type	Classification: Level of Retraction	Vincular System Disrupted
I	Palm (lumbrical origin)	VLP and VBP
II	PIP ± small volar cortical avulsion (VLP preserved)	VBP
III	A4 (entrapped large osseous avulsion fragment)	None
IV	Bony avulsion + tendon avulsion with retraction	Variable
V	Bony avulsion + comminuted P3 fracture	Variable

Classification of flexor digitorum profundus tendon avulsion injuries and associated vincular disruption. A = annular pulley, P = phalanx, PIP = proximal interphalangeal, VBP = vinculum brevis profundis, VLP = vinculum longus profundus

ented leash of vessels arising from bony ostia densely arborizes over the volar surface of the distal tendon, and a nonostial, transversely oriented anastomotic leash originating from intraosseous vessels at the distal phalanx base supplies the dorsal surface of the FDP tendon within 2 mm of its insertion.

The VBP-derived network (Figure 2) supplies the dorsal and lateral surfaces of the tendon. This network extends proximally to the level of the flexor digitorum superficialis (FDS) muscle bifurcation and distally to the DIP joint. A well-defined dorsal zone of hypovascularity is created between these two spatially distinct vascular networks; the dorsal zone lies subjacent to the volar plate of the DIP joint and within 1 cm of the tendinous insertion.[12] This hypovascular region is the anatomic point of failure and is the reason why a small remnant of tendon is left on the distal phalanx. During the surgical repair, this remnant is split longitudinally to gain access to the distal phalanx. This region is located between the distal extent of the VBP network and the dorsal vascular leash that arises from the intraosseous vessels; it is approximately 3.4 mm in length and is 70% the thickness of the tendon.[12]

Classification

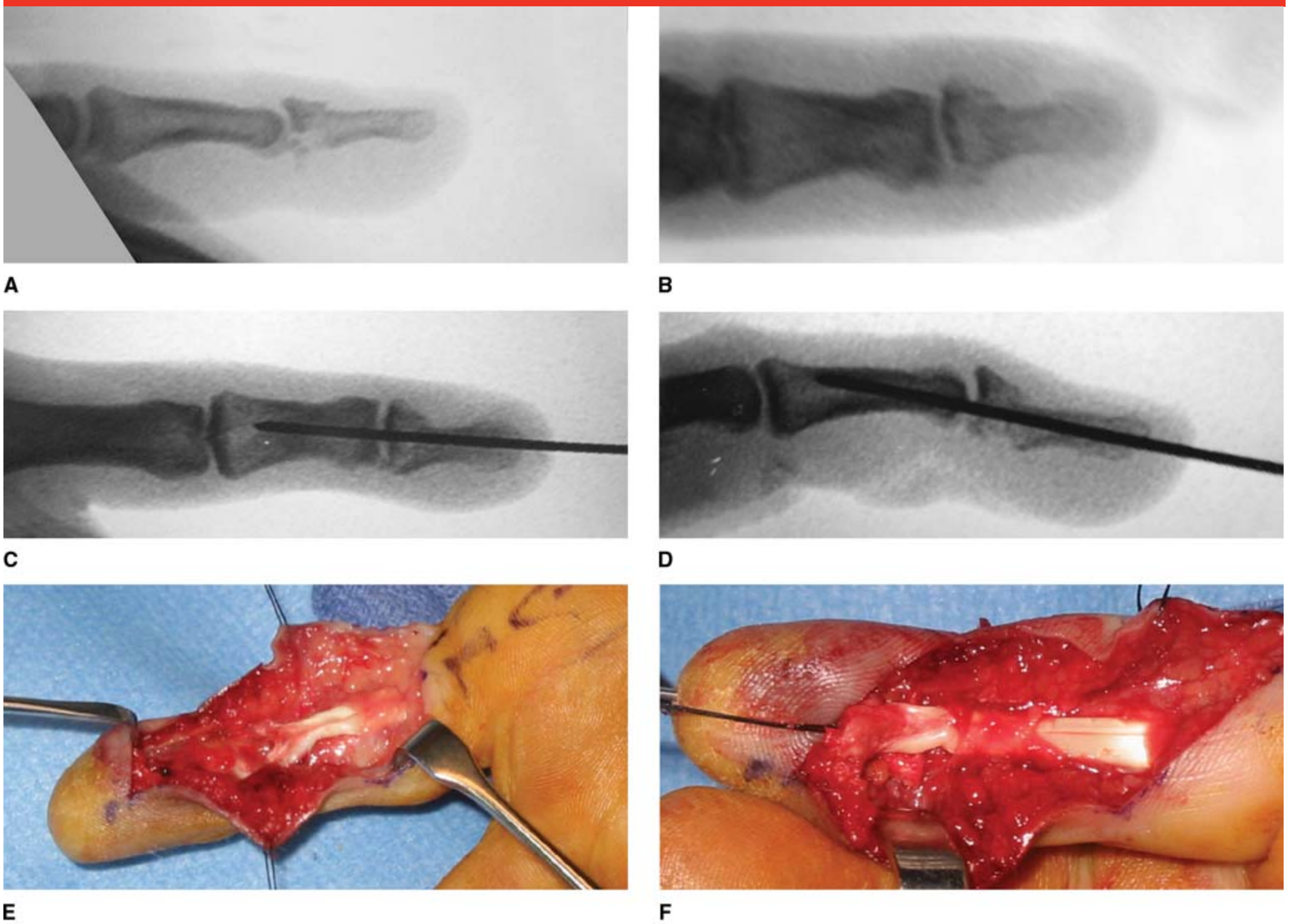
Leddy and Packer[1] described a classification system of FDP tendon avulsion injuries that is still widely used today (Figure 3). In a series of 36 patients, they devised a schema based on the level to which the avulsed FDP tendon retracted, and they incorporated subtypes based on the presence and size of a bony avulsion fragment as assessed on injury radiographs (types I through III).

A type I injury is a tendon retraction into the palm in which the tendon is tethered by the lumbrical origin. At this level, both the vinculum longus profundus (VLP) and VBP are ruptured. As a result, there is a substantial loss of both the intrinsic and extrinsic vascular supply to the tendon. In type II injuries, the FDP tendon retracts to the level of the proximal interphalangeal joint, and the avulsion may occur in association with a small volar cortical avulsion. In this scenario, the VBP is disrupted, but the VLP remains preserved as it arises at the level of the proximal interphalangeal (PIP) volar plate. In type III injuries, retraction to the level of the A4 pulley of the middle phalanx is seen; these injuries are defined by the associated large bony fragment incarcerated within this crucial pulley. In direct contrast with type I injuries, both vincula are usually intact in type III injury patterns because the VBP originates at the distal portion of the middle phalanx.

The Leddy and Packer classification has been extended to include and better classify distinct injury patterns.[13-16] Type IV injuries are rare and unique in that they include a large avulsion fragment incarcerated at the A4 pulley, followed by superimposed rupture of the FDP tendon insertion off this osseous fragment, with secondary tendon retraction into the finger or palm.[7,13-16] Type V injuries are complex and defined by the presence of concomitant osseous distal phalanx avulsion and distal phalanx fracture (Figure 4). The status of the vincula in type IV and V injuries varies depending on whether the tendon stump lies far from the bone fragment or remains on the side of the osseous fragment, within the fibro-osseous sheath system.

Al-Qattan[17] subclassified type V injuries to differentiate associated extra-articular (type Va) and intra-articular (type Vb) distal phalanx fractures, because these fractures

Figure 4



Type V avulsion injury of the flexor digitorum profundus (FDP) tendon defined by concomitant osseous distal phalanx avulsion and comminuted distal phalanx fracture. Preoperative fluoroscopic AP (**A**) and lateral (**B**) views demonstrating a comminuted intra-articular distal phalanx fracture. Intraoperative fluoroscopic AP (**C**) and lateral (**D**) views following Kirschner wire fixation of the dorsal fracture fragment of the distal phalanx base to the shaft. **E,** Intraoperative photograph of a Bruner approach, exposing incarceration of the FDP tendon under the A4 pulley. **F,** Advancement of the FDP tendon through the pulley system. **G,** The completed repair of the FDP tendon using a pullout suture–dorsal button technique.

mandated distinct methods of management.

The relative incidences of pure FDP tendon avulsions, and those sustained in association with distal phalanx osseous avulsion fracture, remain difficult to quantify; there are no large studies dedicated to the clinical spectrum of FDP tendon injury patterns. Based on our review of available case series limited by relatively small cohorts, Leddy and Packer[1] type I, II, and III injuries are the most common. Types IV and V are seen with less frequency. Approximately 50% of FDP tendon avulsions are associated with an osseous fragment.

Clinical and Radiographic Examination

Physical examination of the patient with a suspected FDP tendon avulsion injury is relatively straightforward. The pathognomonic finding is inability to actively flex the DIP joint.[18] The cascade of the fingers is disrupted, and the involved digit rests in a more extended position. Acute pain can obscure the diagnosis by inhibiting active flexion of the entire finger, including at the PIP joint. A local digital anesthetic block is useful in eliminating pain so as to obtain a better assessment of the active motion of the finger. To avoid a delay in diagnosis, isolation of DIP and PIP active joint motion is essential.

The course of the fibro-osseous sheath and flexor tendon of the involved digit should be palpated. Identification of the point of maximal tenderness may represent the subcutaneous location of the avulsed tendon stump.[19] Local pain, swelling, and ecchymosis are associated findings. Localizing the extent of stump retraction is a critical component of the preoperative assessment because the level of retraction plays an important role in dictating the approach to management.

Radiographs of the involved digit are obtained to assess for underlying fractures or bony avulsion fragments. When the physical examination is unrevealing or equivocal, the use of ultrasonography as a modality for distal tendon stump localization has been described, but it is operator dependent.[20] MRI also may be used. In general, these advanced imaging modalities may be more helpful in the chronic setting rather than with acute injury, when surgical exploration and repair are recommended regardless of the level of tendon retraction.

Prognostic Factors

In regard to clinical outcome, several prognostic factors have been identified. The level of proximal tendon retraction is directly related to the magnitude of disruption of the vincular system. The preserved vascular supply to the profundus tendon may include both the VLP and sheath synovial fluid via diffusion. The chronicity of the avulsion injury is also an important preoperative consideration and affects treatment options. The presence and size of associated osseous fragments and distal phalanx fracture have ramifications on the reconstructive strategy selected.

Management

Management options are based on the time elapsed since injury (acute, 10 to 14 days; subacute, 14 days to 4 to 6 weeks; and chronic, >6 weeks), extent of proximal FDP tendon retraction and vincular system disruption, bone fragment size, and Leddy and Packer avulsion type.[1] Expeditious management is recommended in all cases because the tendon may retract more proximally than the associated fracture pattern suggests.[21]

In cases of subacute rupture, myostatic contracture may prevent full advancement of the FDP tendon to its insertion site. Following exposure, a suture is positioned in the distal aspect of the tendon, and steady traction is placed on the myotendinous junction for several minutes. A direct repair is performed when the pulley system can be dilated and the FDP tendon brought to its insertion site without tightening the cascade more than 1 cm of tip-to-palm distance compared with the adjacent digits. In these cases, it is imperative to splint the proximal interphalangeal joint in neutral to prevent a flexion contracture.

If the tendon cannot be passed under the collapsed pulleys, or if the repair will shorten the tendon >1 to 1.5 cm, then management options include the following: (1) wound closure, observation, and possible later DIP joint fusion if unstable (the patient should have 5/5 PIP joint flexion strength preoperatively); (2) immediate DIP joint fusion (the patient should have 5/5 PIP joint flexion strength preoperatively); (3) primary tendon graft (if the pulleys are adequate, but myostatic contracture prevents advancement of the tendon stump to its insertion); or (4) two-stage tendon reconstruction with placement of a silicone rod if pulleys are collapsed at the time of the primary exploration. A thorough preoperative discussion with the patient regarding intraoperative concerns and the approach to treatment is essential.

Chronic injuries secondary to delayed patient presentation or diagnosis are managed on a case-by-case basis after careful consideration of patient-specific factors. Staged graft reconstruction is reserved for a select, small group of patients and is undertaken only after full disclosure of the possible risk of decreased proximal interphalangeal joint motion with this approach. In our experience, most patients have functional PIP joint motion and may be treated nonsurgically or, if symptomatic, with DIP joint arthrodesis.

Type I and II Injuries

The ideal surgical repair should sustain functional loads to facilitate early postoperative mobilization and therapy. Surgical options include a dorsal button (pullout versus nonpullout suture), direct tie around bone, suture anchor, or a combination of button-anchor techniques. An attempt is made to localize the level of retraction preoperatively based on examination and supplemental imaging modalities. The proximal tendon is identified using a Bruner approach[22] or midaxial incisions and advanced through the fibro-osseous flexor tendon system to the distal phalanx. Often, it is necessary to dilate the pulley system to advance the

Figure 5

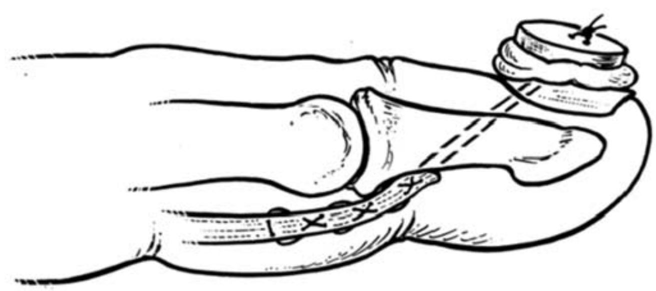


Illustration of a completed flexor digitorum profundus tendon repair achieved using a dorsal button technique.

avulsed tendon. It is paramount that the FDP tendon be passed through the Camper chiasma anatomically. Although the cruciate pulleys may be incised, great care is taken to preserve the competence of the A2 and A4 pulleys. Independent of the repair technique used, the FDP tendon should not be advanced more than 1 to 1.5 cm to avoid creating quadriga syndrome (ie, flexion lag in the adjacent digits when the injured FDP is improperly tensioned—"over-advanced"—because the remaining fingers share a common muscle belly). Intraoperatively, restoration of the digital cascade with progressive digital flexion from radial to ulnar must be confirmed.

Dorsal Button Technique

The original repair method described by Bunnell[23] included a pullout suture–dorsal button combination. Since then, there have been many modifications.

In the dorsal button technique, once the tendon is advanced, the FDP tendon remnant may be split in the midline, to be used for reinforcement at the end of the repair. The distal phalanx just distal to the volar plate insertion is identified and sharply cleared of any remaining soft tissue to allow for direct tendon-to-bone healing. An unlocked core stitch (eg, Bunnell or Kessler stitch) using a 2-0 monofilament with two or four strands is placed in the FDP tendon terminal end. For example, a 2-0 monofilament can be used to pass two different Bunnell sutures with three passes each, one pair dorsally and one pair volarly. To avoid the germinal matrix, a Keith needle is drilled from proximal volar to distal dorsal, out the nail bed and nail plate, several millimeters distal to the lunula. The paired sutures composing this four-strand repair are tied over a button. Nonabsorbable 3-0 or 4-0 braided suture on a tapered needle may be used to suture the FDP tendon remnant on the distal phalanx to the FDP tendon as reinforcement (Figure 5).

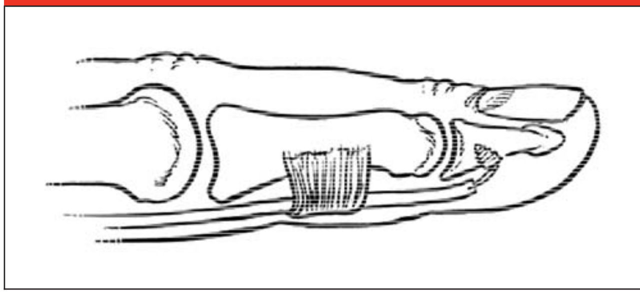
Alternatives to tying over a button are to pass the suture material directly around the distal phalanx or through the nail plate, via two separate holes, and then tie it directly over the nail plate.[24,25] Recently, a buttonless fixation technique via a drill hole was described by Teo et al[26] in a series of 18 patients. They used a modified Kessler suture tied internally through drill holes, providing transosseous internal fixation, and showed favorable outcomes. Biomechanical analyses by Silva et al[27] demonstrated similar tensile loads to failure for three common pullout suture configurations (Bunnell and Kleinert, 39 N, respectively; Kessler, 30 N), which surpass the tensile load of 20 N created with unresisted, active digital flexion.

Generally, the disadvantage of pullout suture techniques is that the fixation point of the tendon-to-bone and the suture knot is a relatively large distance, leading to excessive tendon-to-bone gapping, especially with use of monofilament suture material.[28,29] Complications of this technique include possible nail plate deformity and/or possible nail fold necrosis, reliance on direct tendon-to-bone healing within 6 weeks, and the need to protect the pullout suture configuration. In our experience, when care is taken to avoid pressure to the eponychium, button complications are rare. Technical pearls include exiting well distal to the lunula, placing the button with the convex side onto the nail plate over two-ply cotton padding, and trimming the circumference of the button so that there is no impingement on the surrounding skin.

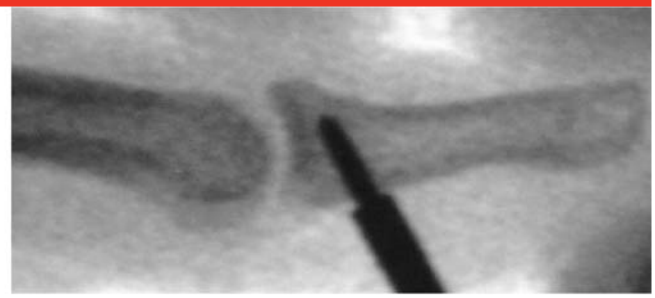
Suture Anchor Technique

The suture anchor technique (Figure 6) for FDP tendon avulsion repairs follows the principles of this fixation method when it is used in other anatomic locations for musculotendinous repairs or reconstructions. Different anchor sizes are available (eg, Micro and Mini suture anchors [DePuy Mitek, Raynham, MA]); selection is based on the dimensions of the distal phalanx. Pilot holes are typically drilled at a 45° angle from distal-volar to proximal-dorsal, in accordance with the deadman angle theory of suture anchors, to increase the resistance to pullout of the implant.[30] Furthermore, more bone is available at the proximal-dorsal cor-

Figure 6



A



B

A, Schematic drawing of the suture anchor technique illustrating the deadman angle. **B,** Intraoperative fluoroscopic image demonstrating retrograde insertion of the anchor without violation of the articular surface.

ner to avoid any possibility of dorsal perforation by the anchor.

Schreuder et al[30] simulated type I FDP tendon avulsions in 18 fresh-frozen fingers and performed repairs with dual Micro suture anchors) with 3-0 Ethibond (Ethicon, Somerville, NJ) and a modified Bunnell unlocked core suture. Biomechanical testing demonstrated that gap formation was lowest in the 45° retrograde insertion group, but load to failure was similar in all three groups (~30 N). In a comparative study of suture anchors to pullout button techniques, Brustein et al[31] reported that the mean load to failure of the pullout button group (43.3 ± 4.8 N) and of the single 1.8-mm Mini anchor (44.6 ± 12.7 N) were inferior ($P < 0.001$) to that of a dual 1.3-mm Micro suture anchor technique (69.6 ± 10.8 N). All failures in the pullout button group occurred by suture rupture at the knot tied over the button. In contrast, failures in the anchor groups occurred by either suture rupture at anchor attachment or anchor pullout of bone. In an in vivo cyclical testing protocol simulating passive digital mobilization, Latendresse et al[32] concluded that both the pullout button and Micro suture anchor fixation techniques are inadequate to support postoperative active digital motion.

Intraoperative fluoroscopy (Figure 6) is used to ensure that there has not been penetration of the dorsal cortex or DIP joint. The terminal edge of the FDP tendon must be flush with the underlying bone to allow for direct tendon-bone healing.

Advantages of using the suture anchor technique include complete internalization of the suture and avoidance of potential nail plate deformity and a dorsal incision. Additionally, suture anchors allow for the use of locked suture repair techniques and permanent tendon-to-bone fixation. This technique may be suboptimal in osteoporotic bone or contraindicated in an avulsion injury with an associated distal phalanx fracture.[29] Use of anchors typically requires some advancement of the FDP tendon, which may increase the risk of a DIP joint contracture. Surface repair has also been found to cause a reduction in bone density by 40% in a canine model; this phenomenon theoretically increases the risk of clinical failure.[33-35]

Despite these potential limitations to the suture anchor technique, McCallister et al[25] reported similar clinical outcomes at 1 year postoperatively in a consecutive, nonrandomized, retrospective cohort of 26 patients following either modified pullout button or dual suture anchor zone 1 FDP tendon avulsion repairs. No significant differences in sensibility, active digital arc of motion, DIP joint flexion contracture, or grip strength were seen between the two cohorts. Furthermore, there were no failures or revision surgeries in either group following identical postoperative rehabilitation protocols. However, suture anchor repair did yield a significantly more rapid return to work ($P < 0.05$).[25]

Evidence-based Premises for Management

Because of variable biomechanical testing protocols, along with multiple suture materials, core suture configurations, and the anchor types (eg, variable anchor number, size, configurations) that can be used, universal recommendations cannot be made on either button or anchor repair as the optimal repair for these injuries.[27,28,30,31,33,36] However, assessment of the literature does provide premises for evidence-based treatment: multi-strand repairs perform better;[37] locking suture configurations are biomechanically superior;[26] nonabsorbable braided suture material, in particular FiberWire (Arthrex, Naples, FL), is preferred;[29] gapping continues to be seen with pullout suture–dorsal button repairs; two Micro anchors are better than one anchor;[27,32] and failure via bone pull-out remains a concern with suture anchor methods.

Type III Through V Injury

A variety of osseous fixation constructs may be considered in the management of type III, IV, and V injuries to address the large avulsion fragment and/or the associated distal phalanx fracture. Mini Fragment screws[38] (Synthes, Paoli, PA), interosseous wires,[39] and Kirschner wires have yielded satisfactory outcomes. When the fragment is sufficiently large in type III injuries, Mini Fragment plate (Synthes) fixation may be considered.[40] In select cases, fragment excision followed by a direct tendon-to-bone repair technique may be performed. In contrast with type I and II FDP tendon avulsion injuries, the preservation of the vincula system may make type III injuries amenable to late primary repair.

Postoperative Protocol

Intraoperatively, a dorsal block splint is made so that the end of the splint extends 2 to 3 cm beyond the fingertips. The wrist is positioned at zero degrees of extension, the metacarpophalangeal joints are maximally flexed (70° to 90°), and the interphalangeal joints are placed in neutral. Care is taken to avoid any pressure or any firm restriction on the volar aspect of the fingers. Even the most compliant patient may actively flex the fingers during sleep; therefore, there should be nothing volar to the fingertip that would provide resistance in case of accidental finger flexion. At the initial postoperative visit (ie, 4 to 7 days), a substantial improvement in the postoperative edema is often noted.[41]

The postoperative motion protocol instituted depends on multiple factors. These include the qualities of the tendon and that of the repair itself, the stability of fixation of any associated fractures, and patient-specific factors. If a strong repair is achieved, early gentle motion may be initiated in a compliant patient. To help meet this goal, we now use a suture anchor and dorsal button combination to create a four-strand locking repair with braided nonabsorbable suture. In our experience, controlled active motion with wrist tenodesis can be started postoperatively with this technique in a reliable patient. Place-and-hold exercises with blocking is started at approximately 4 weeks postoperatively. This exercise entails passively flexing the interphalangeal joints and asking the patient to actively hold the flexed position. Blocking is performed by using a contralateral finger to isolate the joint and facilitate differential gliding between the FDS muscle and FDP tendon so as to minimize intratendinous adhesions. Mild resistive exercises are started at 10 weeks. Until 6 months postoperatively, the patient is prohibited from heavy lifting or from engaging in sports that require strong hand grasping.

Outcomes and Complications

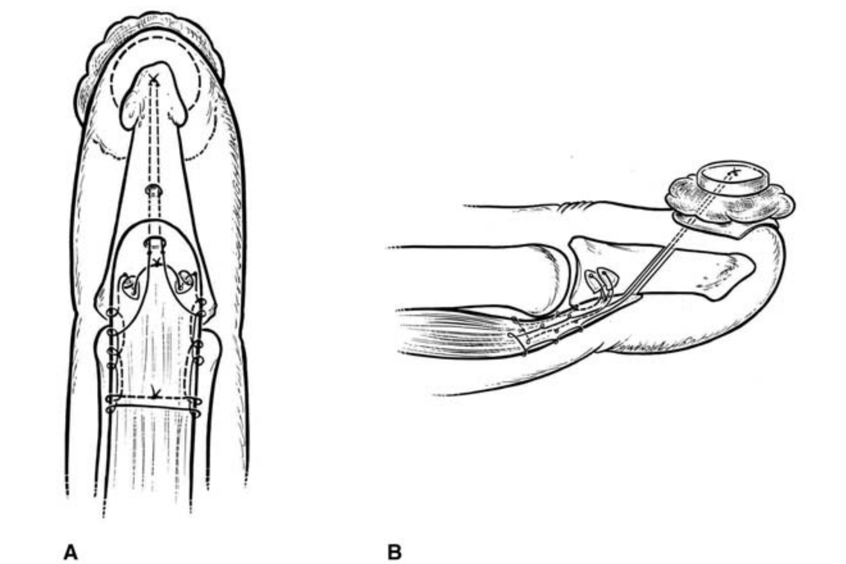
Clinical outcome following FDP tendon avulsion injuries depends on several factors; these include the extent of the injury, chronicity, the quality of the tendon repair and/or osseous stabilization, and the compliance and motivation of the patient. Postoperative rehabilitation is crucial and emphasizes the importance of open communication between the hand surgeon, the patient, and the therapist. Published reports estimate an average loss of 10° to 15° of DIP joint extension.[1] In a small series consisting of type II and type III injuries, Moiemen and Elliot[39] reported that two thirds of patients had <50% of full DIP joint range of motion and only 22% had good to excellent DIP joint motion. This was in contrast to the findings of McCallister et al,[25] who reported considerably greater DIP joint motion, although there was no comparison with the contralateral side.

DIP joint stiffness and/or contracture is commonly seen following FDP tendon avulsion injury repair, a fact that reinforces the importance of a proper postoperative rehabilitation protocol and a motivated patient. Other complications include repair re-rupture or loss of fixation. FDP tendon advancement >1 cm can result in the quadriga effect and manifests as weakness in pinch and grip strength. In injuries with associated fractures, there is an increased incidence of arthrosis and joint instability. Infection, although uncommon, can have devastating results on the repair and on postoperative outcome.

Late Management and Salvage Options

The management of chronic FDP tendon avulsions secondary to late patient presentation or missed FDP tendon avulsion injuries is dependent on the level of retraction, the patient's subjective symptoms and/or pain severity, stability of the DIP joint, and the arc of digital motion. In an asymptomatic patient with adequate total arc of motion by the intact FDS muscle, nonsurgical treatment is recommended in most patients. In type II and type III injuries in which there may be preservation of vincular vascular supply, delayed primary repair may be considered.[18] In a patient with DIP joint instability or hyperextension with grip, arthrodesis or tenodesis

Figure 7



Frontal (**A**) and lateral (**B**) schematic drawings of the bone anchor–dorsal button combination repair technique for the flexor digitorum profundus tendon.

may be performed. DIP joint arthrodesis may yield a more predictable outcome. However, in a limited number of patients who have undergone tenodesis, we have not found that these reconstructions have stretched out. Single or two-stage FDP tendon graft reconstruction through an intact FDS muscle is considered only in select patients with a demonstrated need for manual dexterity (eg, athletes, elite musicians, skilled laborers); however, tendon grafting may have a deleterious effect on PIP joint motion.

Patients must be counseled appropriately about anticipated outcomes and potential complications. Additionally, one may consider graft reconstruction in a young patient (ie, aged <21 years) and in a patient with poor PIP joint active range of motion resulting from inadequate FDS muscle function (especially in the small finger).[42,43]

Summary and Future Directions

Despite various repair techniques for chronic avulsion injury described in the literature, none has emerged as superior to others. Management alternatives, including nonsurgical management, DIP joint arthrodesis, and staged reconstruction, remain patient-specific. Consideration of a bone tunnel FDP tendon repair technique[34,44,45] has recently been described to facilitate intraosseous tendon-to-bone healing and to replace the volar-cortical bone surface-to-tendon repair interface created with pullout suture–dorsal button and suture anchor techniques. Ex vivo biomechanical data demonstrated enhanced tensile properties and reduced gap formation at the repair site with this technique.[44] However, in vivo analyses in canine models have limited its clinical adaptation because bone tunnel repair was found to be inferior to surface repair.[34,45] The in vivo reparative response may actually weaken the tunnel repair.[45]

Given the available evidence and the need for a strong repair that does not gap, we have used a bone anchor–dorsal button combination repair technique in recent cases (Figure 7). Two Micro suture anchors are placed in a retrograde fashion. The Keith needle is drilled into the center of the distal phalanx, distal to the anchors. A double Krakow locking suture configuration is placed in the tendon: the anchor sutures are placed dorsally, and the button sutures are placed volarly, thus creating a four-strand locking repair (Figure 7). The preloaded suture in the bone anchor can be replaced with 3-0 FiberWire if preferred; the sutures of the two anchors are placed on one side only; and the suture is tied on the FDP tendon. Two separate sutures then slide through the eyelets of the suture anchors to pull the FDP tendon flush onto the distal phalanx. This button is removed at 6 to 8 weeks postoperatively. This four-stranded locking repair technique uses the button for stronger pullout in weaker bone and anchors for smaller gap formation.[46] Current biomechanical analyses support the clinical application of this technique. Other future directions include the possible use of biologics, either incorporated in the suture material or in a thin tendon wrap.[47-49]

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