Tendon Disorders of the Hand

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Learning Objectives: After reading this article, the participant should be able to: 1. Make decisions on flexor tendon repair based on current evidence. 2. Perform some important tendon transfers after viewing Dr. Kozin's videos. 3. Inject local anesthesia for wide-awake flexor tendon repair after viewing the appropriate videos in the article. 4. Use relative motion extension splints for the postoperative management of extensor tendon injuries.

Summary: This article provides a practical, clinically useful overview of some of the current best techniques and evidence available to the plastic surgeon in the treatment of flexor and extensor tendon injuries, tendon transfers, trigger fingers, mallet fingers, boutonniere deformities, and De Quervain tenosynovitis. Twelve short movies and drawings emphasize important points of diagnosis and treatment of tendon disorders. (*Plast. Reconstr. Surg.* 128: 1e, 2011.)

Dr. Scott Kozin has provided the following five succinct operative videos for some of the important tendon transfers.

Video 1: Providing active pinch in tetraplegia; brachioradialis to flexor pollicis longus, and extensor carpi radialis longus to flexor digitorum profundus (3 minutes). [**See Video 1,** which demonstrates active pinch and grasp restoration for tetraplegia with (1) brachioradialis transfer to flexor pollicis longus tendon, and (2) extensor carpi radialis longus to four flexor digitorum profundus tendons, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A334***.]

Video 2: Abductor digiti minimi for thumb opposition (1 minute). [**See Video 2,** which demonstrates abductor digiti minimi (Huber) transfer to provide thumb opposition, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A335***.]

Video 3: Extensor carpi ulnaris for thumb opposition (2 minutes). [**See Video 3,** which demonstrates extensor carpi ulnaris transfer around the ulnar and then volar border of the wrist (with tendon splitting for extra length) to provide thumb opposition, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A336***.]

Video 4: Flexor digitorum superficialis transfer for thumb opposition (3 minutes) [**See Video 4,** which demonstrates flexor digitorum superficialis transfer of the ring finger (in a low median, low ulnar nerve palsy) with a flexor carpi ulnaris loop pulley to provide thumb opposition, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A337***.]

Video 5: Radial nerve transfers (3 minutes). (**See Video 5,** which demonstrates high radial nerve palsy tendon transfers, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A338***. The pronator teres is transferred to the extensor carpi radialis brevis tendon to restore wrist extension. The flexor carpi radialis is transferred to the extensor digi-

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Related Video content is available for this article. The videos can be found under the "Related Videos" section of the full-text article, or, for Ovid users, using the URL citations printed in the article.

Video 1. Video 1, which demonstrates active pinch and grasp restoration for tetraplegia with (1) brachioradialis transfer to flexor pollicis longus tendon, and (2) extensor carpi radialis longus to four flexor digitorum profundus tendons, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A334***.

Video 2. Video 2, which demonstrates abductor digiti minimi (Huber) transfer to provide thumb opposition, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A335***.

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torum communis group of tendons to restore finger extension. The palmaris longus is transferred to the extensor pollicis longus to restore thumb extension.)

To see a video on wide-awake ring finger flexor digitorum superficialis to flexor pollicis longus and extensor indicis to extensor pollicis longus tendon transfers, see the Mustoe video on local anesthesia for wide-awake hand surgery to minute 22:15 (http://journals.lww.com/plasreconsurg/pages/videogallery.aspx?videoid=40&autoPlay=true).[1]

The main advantage of wide-awake tendon transfers is the ability to get the tension right so the transfer is not too tight or too loose.[2] For detailed descriptions of hand tendon transfers, the reader is referred to Sammer and Chung.[3,4]

FLEXOR TENDON LACERATION

Preoperative Assessment

The repair of flexor tendon lacerations does not have to be performed acutely in the middle of the night or on weekends.[5] The skin can be closed

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at the time of injury, and the tendon can be repaired during the weekday when the surgeon is rested and surrounded by support staff such as hand therapists. In our experience, delaying definitive repair up to 14 days has not been shown to have an adverse outcome.

Injuries more than 3 weeks old may be impossible to repair, primarily because of tendon shortening. However, we have seen cases in which this was possible because the tendon ends have been held out to length by the vincula. In old profundus injuries, when the pulleys have scarred down in the finger, a two-stage tendon reconstruction with a tendon implant and then a graft can be considered.[6] However, if the superficialis is intact and functioning, and only the profundus is lacerated, the cure may be worse than the disease. A superficialis finger with a distal interphalangeal joint fusion provides good finger function. (**See Video 6,** which demonstrates a patient's perspective on distal interphalangeal joint fusion in a patient with a superficialis finger as an alternative to two-stage flexor digitorum profundus tendon grafting reconstruction, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A339***.) A two-stage flexor digitorum profundus tendon reconstruction with a graft should not be performed unless the patient is extremely well motivated and willing to cooperate fully with at least two operations and 6 to 12 months of multiple visits to a hand therapist.

Retrieving the Proximal Flexor Tendons

Three classic methods have been used to retrieve the proximal tendon ends. First, the wrist and metacarpophalangeal joints can be flexed and the tendons milked forward. Second, a hemostat can be inserted into the proximal lacerated tendon sheath opening and the tendon blindly grasped for with the instrument. The problem with this method is that the tendon and the sheath can both be damaged by the instruments, which may generate postoperative adhesions. Third, the proximal tendon end can be retrieved through a second incision in the palm or forearm, and a

Video 6. Video 6, which demonstrates a patient's perspective on distal interphalangeal joint fusion in a patient with a superficialis finger as an alternative to two-stage flexor digitorum profundus tendon grafting reconstruction, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A339***.

small rubber catheter or Toby retriever/sheath dilator (Toby Orthopaedics, Coral Gables, Fla.) can be inserted in the lacerated flexor sheath in a proximal direction to the incision in the palm or forearm. The proximal tendon can be tied to the dilator and pulled in a distal direction and out of the laceration in the sheath. However, the dilator may not pass between the two slips of the superficialis tendon in the proximal sheath where the profundus tendon belongs, leading to entanglement of the flexor tendons. In addition, the second incision in the palm can result in adhesion formation.

The senior author's (D.H.L.) preferred method of retrieving the proximal tendon is to expose but not enter the sheath in a proximal direction with Brunner zigzag incisions (into the hand if necessary) until the point where the proximal tendon end(s) can be easily seen bulging in the intact sheath. The tendon is then pushed forward though a small transverse sheathotomy incision, which can be repaired with fine absorbable sutures at the end (Fig. 1). (**See Video 7,** which demonstrates some intraoperative details of wide-awake flexor tendon repair in a patient who suffered flexor tendon lacerations in the index, long, and ring fingers of his left hand, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A340***. Also shown is the patient actively testing the repairs intraoperatively, his impressions of the anesthetic, and his movement at 1 week, 2.5 weeks, and 3 months postoperatively.)

Video 7. Video 7, which demonstrates some intraoperative details of wide-awake flexor tendon repair in a patient who suffered flexor tendon lacerations in the index, long, and ring fingers of his left hand, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A340***. Also shown is the patient actively testing the repairs intraoperatively, his impressions of the anesthetic, and his movement at 1 week, 2.5 weeks, and 3 months postoperatively.

Wide-Awake (No Sedation/No Tourniquet) Flexor Tendon Repair

Because epinephrine hemostasis has clearly been shown to be safe,[7–10] the senior author (D.H.L.) prefers to perform his flexor tendon repairs using the wide-awake approach with nothing but lidocaine 1% with 1:100,000 epinephrine in-

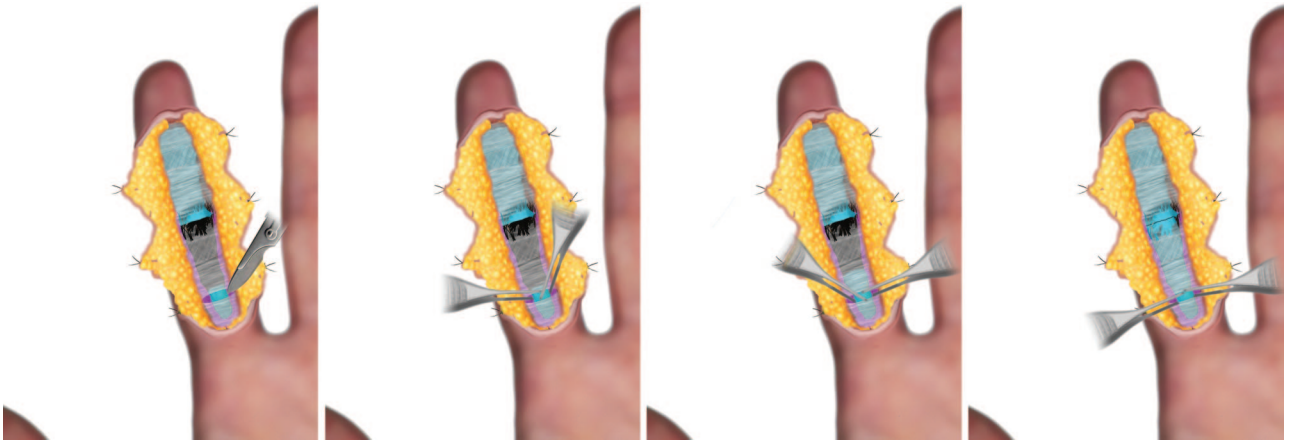


Fig. 1. Drawings show delivery of the tendon by means of sheathotomy. (*Left*) The sheath is exposed to where the tendon ends can be visualized (*blue*), and a transverse sheathotomy is performed to grasp and push the tendon distally. The sheathotomy can be closed with a 6-0 absorbable suture at the end. (*Second from left, second from right,* and *right*) Two Adson forceps are used to push the tendon in a distal direction, like pushing a rope. The patient is asked to extend the finger so the finger flexors relax by means of reflex inhibition.

jected subcutaneously wherever the surgeon will be dissecting in the forearm, hand, or finger. As there is no tourniquet, sedation is not required (Fig. 2). (**See Video 8,** which demonstrates in detail the technique of local anesthetic injection for wide-awake flexor tendon repair, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A341***. It includes the local anesthetic injection of the patient shown in **Video 7**.)

The wide-awake approach has five major advantages in flexor tendon repair. First, intraoperative testing of the flexor repair (intraoperative total active movement examination) by the pain-free, cooperative, unsedated patient ensures that there is no gapping (with no subsequent rupture) of the flexor repair (see **Video 7** for intraoperative details). After each core suture is inserted and tied, the wide-awake patient is asked to flex and extend the finger through a full range of motion. Occasionally, the suture will be seen to bunch up in the tendon with active movement because the suture was not pulled tightly enough and a gap in the repair is identified (Figs. 3 and 4) (see Lalonde[11] for video of the wide-awake flexor tendon repair, and advance the video to 8 minutes 24 seconds to see a gap occur during a flexor tendon repair). Tendon gaps are felt to be the most common cause of flexor tendon repair rupture, and any gaps revealed in the repair with active movement testing can be rectified before the skin is closed. If a gap is seen with intraoperative total active movement examination, the gap is rectified with a solid core suture and the loose core suture

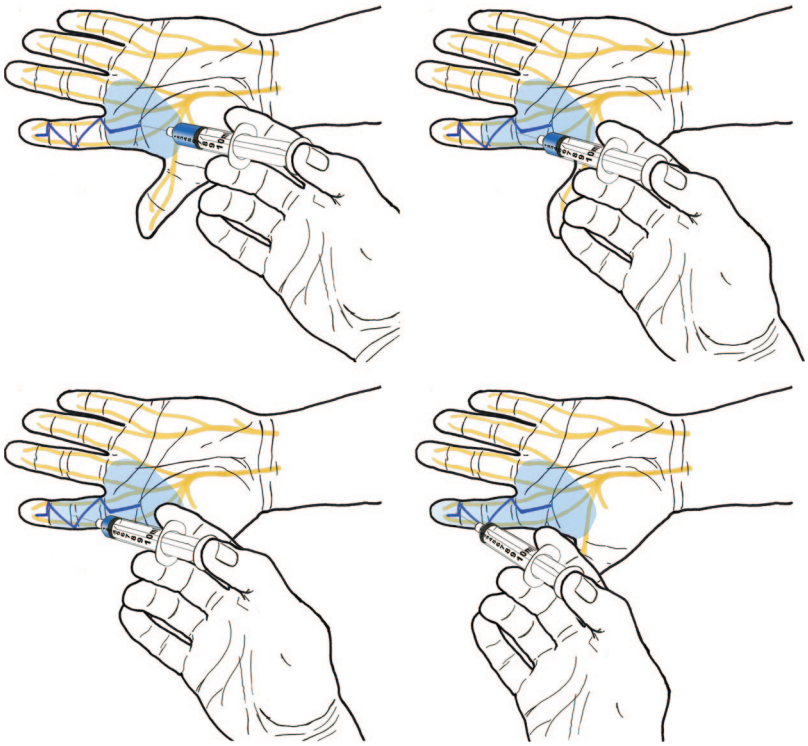


Fig. 2. Local anesthetic injection for tendon repair. (*Above*, *left*) The *blue line* is the incision to be made for a zone 1 or 2 flexor tendon repair. The *light blue* area represents the area bathed by the first injection of 10 cc of premixed 1% lidocaine with 1:100,000 epinephrine used to tumesce the tissue proximal to the area of dissection. (*Above*, *right*) Fifteen or more minutes after the initial tendon injection shown in *above*, *left*, the whole distal area of dissection is totally numb. The second injection of 2 cc in the subcutaneous fat between the digital nerves in the proximal phalanx shown here is totally pain free. (*Below*, *left*) This third injection of 2 cc in the subcutaneous fat of the middle phalanx is also pain free. The same solution of 1% lidocaine with 1:100,000 epinephrine is used for all injections. (*Below*, *right*) The fourth injection of 1 cc in the distal phalanx is used mainly for the epinephrine vasoconstriction effect, as are the other two finger injections.

Video 8. Video 8, which demonstrates in detail the technique of local anesthetic injection for wide-awake flexor tendon repair, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A341***. It includes the local anesthetic injection of the patient shown in Video 7.

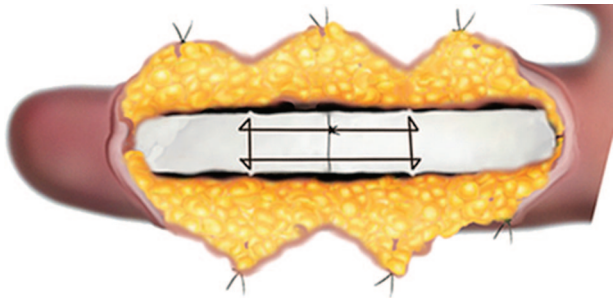


Fig. 3. Avoiding a tendon gap with intraoperative total active movement examination. This tendon has just been repaired with a core suture that is too loose. It initially appears fine but it is not. There is no gap seen at this time because it has not been tested with intraoperative total active movement examination. This is how many repairs are accepted and the skin closed under general or block anesthesia, as they are not tested for active movement intraoperatively. This repair may well rupture in the postoperative period when the tendon bunches in the suture when active movement begins. (Reproduced from Higgins A, Lalonde DH, Bell M, McKee D, Lalonde DH. Avoiding flexor tendon repair rupture with intraoperative total active movement examination. *Plast Reconstr Surg*. 2010;126:941–945.)

is removed. Intraoperative total active movement examination has been reported to be associated with a very low rupture rate in a **level IV evidence** study.[12] There was not one rupture in the 68 known outcome patients who properly followed the postoperative protocol in that study.

After seeing no gap with active movement intraoperatively, the surgeon can be confident that

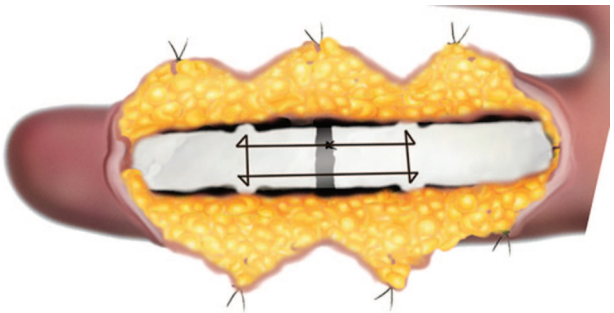


Fig. 4. Avoiding tendon gap with intraoperative total active movement examination. This tendon has also just been repaired with a core suture that is too loose. This too loosely repaired tendon has been tested with intraoperative total active movement examination of the freshly repaired flexor tendon during wide-awake flexor tendon repair. Tendon bunching in the suture has occurred and a gap has revealed itself. The gap can be corrected before the skin is closed, and repeated intraoperative total active movement examination will verify that the suture is now snug enough to withstand the forces of active flexion. It is better to discover that a core suture is too loose during the operation when it can be redone compared with after the operation when a postoperative rupture occurs. (Reproduced from Higgins A, Lalonde DH, Bell M, McKee D, Lalonde DH. Avoiding flexor tendon repair rupture with intraoperative total active movement examination. *Plast Reconstr Surg*. 2010;126:941–945.)

postoperative gapping will not likely occur unless excessive forces are applied across the repair. The surgeon can be comfortable about initiating early active movement as opposed to passive movement of flexor tendons as in the Kleinert or Duran regimens. The surgeon that performs wide-awake flexor tendon repair should avoid regional blocks such as Bier or axillary blocks that paralyze forearm muscles.

Second, intraoperative total active movement examination also lets the surgeon see that the repair fits through the pulleys with active movement. If the tendon does not fit, additional sutures, repair trimming, or pulley division are performed to ensure there is full range of movement before skin closure. This technique minimizes the chances of adhesions and subsequent tenolysis.

Third, sheath and pulley damage are minimized, as flexor tendons are repaired through small transverse sheathotomy incisions (Fig. 5). (**See Video 9,** which demonstrates details of tendon retrieval and repair through sheathotomy incisions to get a 1-cm bite of tendon without disrupting sheath and pulleys, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A342***. Patient assessment and edu-

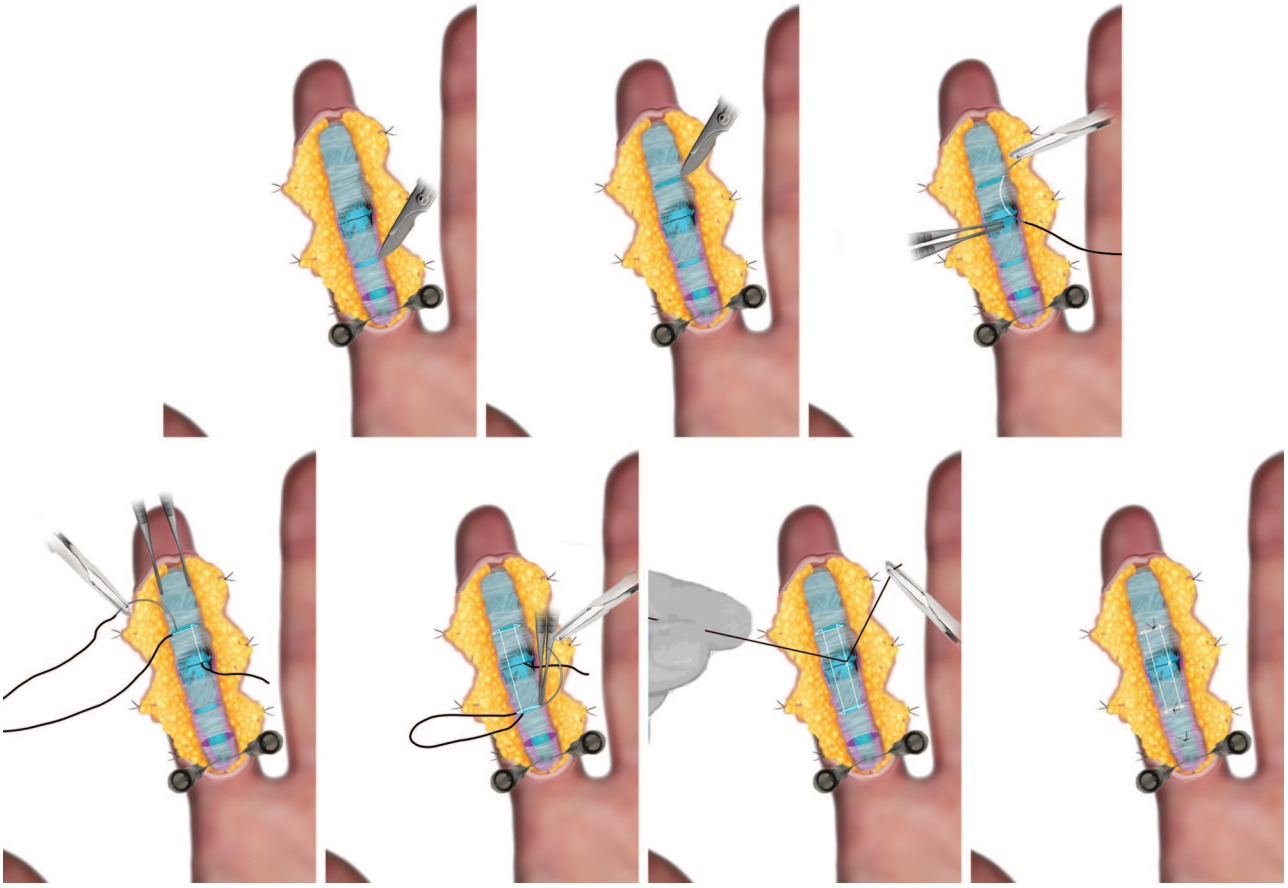


Fig. 5. A sheath/pulley-sparing tendon repair. (*Above, left* and *center*) Proximal and distal sheathotomies to pass the suture 1 cm into the tendon without destroying sheath and pulleys. The remaining illustrations show a Kessler suture performed through sheathotomy incisions and tied. The final illustration shows the sheathotomy incisions closed with a fine absorbable suture. This type of repair can only be performed in awake patients who can actively test the repair to verify that the suture is only in the tendon.

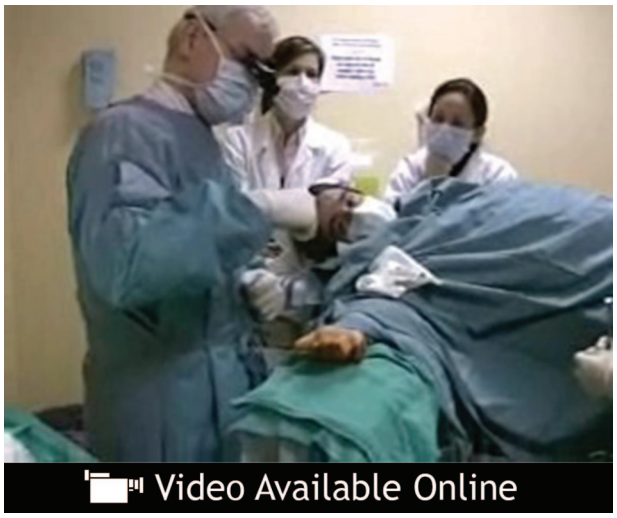
cation by the surgeon and therapist during the wide-awake flexor tendon repair operation are shown.) A separate sheathotomy incision is made over the repair to add an epitenon suture if the tendon ends happen to be inside the sheath when the repair is performed.

Fourth, the surgeon can interview the patient during the procedure and assess his or her ability to comply with the postoperative regimen. In addition, intraoperative patient teaching by the surgeon and hand therapist allows the patient to practice the postoperative movement regimen in a pain-free and comfortable environment (see **Video 9** for repair under pulley and patient education). The sedated patient may not be cooperative and seldom remembers much about intraoperative teaching.

Fifth, with the exception of young children and extremely mangled hands, the risks and inconveniences of general anesthesia are avoided in most patients. Negative effects of general anesthesia include nausea and vomiting, hospital admission for anesthesia recovery, exacerbation of comorbidity issues such as diabetes, aggressive flexion by the patient emerging from general anesthesia, and others.

FLEXOR TENDON REPAIR HIGHLIGHTS

- There is a move toward four or more strands of repair for greater strength, less gapping, and early active movement.[13–17] However, a **level II evidence** study in children shows no difference between two- and four-strand repairs.[18]
- There is experimental evidence[19] that longer core suture purchase length (1 cm) is superior to shorter purchase length (0.4 cm). The optimal length of 0.7 to 1.0 cm.[20]
- In zone 1 injuries, one study (**level II evidence**) showed that suture anchors provide results as good as those with the pullout button method,



Video 9. Video 9, which demonstrates details of tendon retrieval and repair through sheathotomy incisions to obtain a 1-cm bite of tendon without disrupting sheath and pulleys, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A342***. Patient assessment and education by the surgeon and therapist during the wide-awake flexor tendon repair operation are shown.

with greater patient satisfaction, sooner return to work, and less morbidity.[21]

- A study in 2008 (**level III evidence**) compared absorbable and nonabsorbable core sutures. Each group had the same rupture rate of 2 percent.[22] Most surgeons prefer braided nonabsorbable sutures for scar ingrowth. However, braided sutures tend to become extruded with infection more often than smooth sutures, as there are little areas for bacteria to reside in the braided thread. This is why others prefer smooth strong suture.
- A running epitenon suture of smooth 6-0 suture is used by many surgeons in zone 2 for added strength and for smoothness of intrasheath gliding of the repair.[23,24] Some surgeons advocate placing the epitenon suture first.[25,26]
- Locking sutures have been shown to have advantages over grasping sutures.[27] Although many types of grasping suture are used throughout the world, the Kessler repair is still the most commonly used flexor tendon suture in North America.
- Larger (3-0 versus 4-0) sutures have more strength,[28] and many surgeons use them when the tendons are large enough to permit larger suture use.
- One of the only human studies on repairing the flexor tendon sheath in 106 children divided equally into two groups showed superior movement results in the 53 children whose sheaths were patched with vein grafts.[29]
- One study (**level II evidence**)[30] showed that patients allowed unrestricted movement at 8 weeks following tendon repair did as well as those restricted for 10 weeks.
- There is a recent interest in not repairing the flexor digitorum superficialis in zone 2,[31] but most continue to repair both flexor digitorum superficialis and flexor digitorum profundus as recommended by Strickland.[5]
- Tendon lacerations of 50 percent or less of the cross-sectional area need not be repaired unless they cause triggering in a pulley.[32,33]
- Although many cadaver studies support the concept of never dividing the A2 or A4 pulleys for biomechanical bowstringing reasons, the first author agrees with Tang[34] that partial A2 and A4 pulley division may be required if the repair does not fit through the pulleys. The less attractive alternative is secondary reoperation for tenolysis, as the tendon is unable to glide, and this second operation may ultimately require pulley sacrifice for movement.

POSTOPERATIVE HAND THERAPY IN FLEXOR TENDON REPAIR

In children and in uncooperative patients, zone 1 and zone 2 flexor tendon repairs are immobilized for 3 weeks, followed by directed hand therapy. With cooperative patients, early protected movement is initiated. In zone 5 flexor injuries in the forearm, early protected movement is generally not necessary, as motion-limiting adhesions are uncommon compared with repairs performed in the hand and fingers.

There are three basic types of postoperative early movement regimens: (1) rubber band passive flexion/active extension initiated by Kleinert et al.,[35] (2) passive flexion and extension espoused by Duran and Houser,[36] and (3) early active movement as advocated as early as the 1970s by Becker et al.[37] There is a trend toward more early active movement protocols.[38] A 2004 Cochrane review concluded that there was insufficient evidence from randomized controlled trials to define the best mobilization strategy (**level II evidence**).[39] However, a later 2009 study[40] (**level II evidence**) compared a controlled active regimen to a controlled passive group for postoperative movement and found that the former achieved better results. Another 2010 study (**level II evidence**) also showed that active place-and-hold exercises were superior to a passive movement regimen.[41]

The surgeons in the senior author's hospital (D.H.L.) agree with many of the philosophies of Tang[34] for zone 2 postoperative movement:

1. Days 0 to 3 after repair: elevate and immobilize the hand. Movement is more likely to generate bleeding in the wound at this time, and blood turns to scar. Collagen formation does not start until day 3, so there is little to be lost by an initial period of rest and elevation.
2. Days 3 to 17 after repair: warm up with passive movement, and focus on active interphalangeal joint extension.
3. Allow early active comfortable flexion without pursuing the maximum end ranges of flexion and extension where there is highest resistance.

The idea is to encourage motion without stressing the repair. Patients are strictly instructed that they can move the fingers but they cannot use them. For isolated finger injuries, we use a relative motion flexor splint that allows active flexion with relatively less stress on the lacerated tendon compared with the intact tendons. (**See Video 10,** which demonstrates a relative motion flexion splint that allows active finger flexion with decreased tension on the repaired flexor tendon and wrist synergistic motion, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A343*** ; and Video 7.)

Video 10. Video 10, which demonstrates a relative motion flexion splint that allows active finger flexion with decreased tension on the repaired flexor tendon and wrist synergistic motion, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A343***.

EXTENSOR TENDON INJURIES

Mallet Fingers

Mallet finger deformities occur when the distal extensor tendon insertion site tears from the distal phalanx with or without an avulsion fracture. In our hospital, patients are told that a mallet finger is not a major functional loss for some patients, but if they are willing to undergo 3 months of splinting, more than 95 percent will achieve a good result with an extensor lag of 10 degrees or less, as this has been the result in our experience. We give them 8 weeks of full-time splinting of the distal interphalangeal joint in as much extension as possible. The patient must avoid any flexion of the distal interphalangeal joint during that period or they have to restart their 8 weeks of full-time splinting. During the third month of treatment, the patient wears a distal interphalangeal joint extension splint during sleep and during the day, when forceful flexion may occur inadvertently. We permit intermittent gradual flexion of the distal interphalangeal joint during quiet periods in the evening during the third month. The digit is monitored by the therapist for the development of an extension lag, which signifies tendon attenuation. If considerable extensor loss develops, a return to full-time extension splinting is recommended.

All mallet fingers should be radiographed because the extensor tendon can avulse with a bony fragment of intraarticular distal phalanx. The determining factor for surgical intervention is not the percentage of joint surface involvement, but rather whether or not the joint is congruous (joint surfaces parallel) after the mallet splint is applied and the finger is radiographed again. If the joint surfaces are congruous in the splint, the finger is treated without surgery with splinting, even if half or more of the joint is involved. These avulsion fractures will often heal faster than pure tendon injuries, as bone-to-bone healing is often superior to tendon-to-bone healing. If the joint surfaces are incongruous and the joint subluxation persists, surgery is required. Closed reduction and placement of a percutaneous transarticular Kirschner wire introduced from the fingertip into the middle phalanx is usually successful. We prefer closed reduction over open reduction, which is prone to stiffness. This view is supported by a current review.[42] We would only open the joint through a dorsal incision and directly fix the fracture if closed reduction and Kirschner wire fixation were unsuccessful.

One trial (**level I evidence**) revealed that there was no lag difference demonstrated between cus-

tom thermoplastic, dorsal padded aluminum, and volar padded aluminum splinting for Doyle I acute mallet fingers.[43] Another trial (**level III evidence**) showed that treatment 4 weeks after injury yielded results as good as those in patients treated within 2 weeks after injury.[44]

Boutonniere Injuries

Disruption of the central slip of the extensor tendon from the dorsal proximal lip of the middle phalanx results in disruption of the dorsal triangular ligament and migration of the lateral bands volar to the axis of the proximal interphalangeal joint. The lateral bands become flexors of the proximal interphalangeal joint and hyperextensors of the distal interphalangeal joint.

If the injury is acute, the proximal interphalangeal joint is splinted in full extension, whereas the distal interphalangeal is left free to allow active flexion. These boutonniere splints allow flexion of the metacarpophalangeal and distal interphalangeal joints but maintain the proximal interphalangeal joint in extension. Our patients wear the splint for a full 8 weeks. We inform our patients that they must avoid any proximal interphalangeal joint flexion over the subsequent 8 weeks or the splinting regimen starts at the beginning.

In the third month of treatment, continued boutonniere splinting during sleep and during the day, when forceful flexion may occur, is necessary. During this month, the return of proximal interphalangeal joint flexion should be gradual, with careful daily inspection for the development of an extension lag. If considerable extensor loss develops, a return to full-time proximal interphalangeal extension splinting is required. If extension function is maintained, we transition to a boutonniere relative motion splint for an additional month.

In chronic boutonniere injuries, the proximal interphalangeal joint develops a contracture and complete passive extension may not be possible. If the proximal interphalangeal joint has a soft end feel, we perform serial casting of the proximal interphalangeal joint until the proximal interphalangeal joint is in full extension *and* the distal interphalangeal joint has full flexion. We only initiate our 8- plus 4-week boutonniere splinting as described above in the acute section when the distal interphalangeal joint is able to fully actively flex with the proximal interphalangeal joint passively extended. Full distal interphalangeal flexion is not possible until the lateral bands are relocated dorsal to the axis of the proximal interphalangeal joint.

Surgery has been described for closed boutonniere lesions. In the first author's experience, surgery has generally not been successful, and splinting has been the mainstay of treatment. The authors perform a Fowler tenotomy[45] if the patient does not respond to serial casting and if the inability to flex the distal interphalangeal joint hinders function. There is a prospective, randomized, controlled trial that examined splinting in thumb boutonniere, which found that the use of a thumb orthosis for type I and type II boutonniere deformities was effective in relieving pain.[46]

Lacerated Extensor Tendons over the Fingers

The thin extensor apparatus over the dorsum of the fingers does not hold sutures well. Fortunately, gaps are better tolerated in the finger extensors than in the finger flexors. The postoperative splint regimen is as important as the suture technique. Mallet finger splinting allows for tendon healing despite a gap. Similarly, appropriate splinting of extensor tendon injures will allow healing even if there is a gap in a lacerated tendon.

The dorsal skin does not offer substantial coverage of nonabsorbable braided sutures. The sutures frequently can irritate the overlying skin and become infected. For this reason, the first author (D.H.L.) prefers smooth absorbable buried sutures for extensor tendon injuries.

With frayed tendons in finger dorsum lacerations or those with a skin loss such as table saw injuries, we close the lacerated skin and extensor tendon with large (5 to 10 mm on each side) composite bites of skin and extensor tendon together with simple 3-0 or 4-0 nylon suture tied on the outside of the skin. The skin holds the suture better than the extensor tendon in our experience, and this technique works well. We tighten the composite suture until the proximal interphalangeal or distal interphalangeal joint is fully extended. This indicates that the extensor tendon ends are in close proximity and will heal with splinting.

After the sutures are in place, the finger is wrapped in Coban tape (3M, St. Paul, Minn.), a stretchy self-adhesive tape. The proximal interphalangeal and/or distal interphalangeal joint that suffered the injury is then splinted in full extension as described in the mallet or boutonniere sections. The percutaneous/transtendinous nylon sutures can be removed at 2 weeks, but the splinting regimen is continued as described, similar to a mallet or boutonniere injury.

Hand and Wrist Extensor Tendon Repairs

Intertendinous juncturae tendineae prevent hand extensor tendon injuries from retracting any considerable distance. Therefore, the lacerated tendon ends are in close proximity.

The single most important advance in the rehabilitation of extensor tendon injuries in the hand has been the Merritt relative motion splint.[47] This functional splint not only prevents adhesions but also permits patients to return to work as early as 3 days after surgery. It keeps the metacarpophalangeal joint of the lacerated extensor tendon digit extended 30 degrees more than the metacarpophalangeal joints of the uninjured fingers. The splint is worn for 4 weeks and then discontinued. (**See Video 11,** which demonstrates multiple wide-awake extensor tendon repairs in the forearm, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, available at ***http://links.lww.com/PRS/A344***. It also shows hand dorsum extensor tendon repair to the index finger and the relative motion extensor splint. This Merritt splint allows early active extension of the injured finger in a relaxed position relative to the uninjured fingers for extensor tendon lacerations and for sagittal band rupture injuries.)

Video 11. Video 11, which demonstrates multiple wide-awake extensor tendon repairs in the forearm, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A344***. It also shows hand dorsum extensor tendon repair to the index finger and the relative motion extensor splint. This Merritt splint allows early active extension of the injured finger in a relaxed position relative to the uninjured fingers for extensor tendon lacerations and for sagittal band rupture injuries.

Tenolysis

A patient must be cooperative for surgical tenolysis to be successful, and most cooperative patients do not require tenolysis, as they follow their initial rehabilitation with fervor. However, on occasion there will be a persistent limitation in active motion in a cooperative patient without change despite 3 to 6 months of ample therapy. In these patients, tenolysis is indicated and can be successful.

The wide-awake approach using tumesced lidocaine with epinephrine for hemostasis provides a pain-free environment without a tourniquet and a nonsedated patient that can assist the surgeon by actively flexing his or her long forearm muscles to free adhesions throughout the procedure. The surgeon and the patient alternate in their cooperative efforts to cut and rupture adhesions, respectively. The patient can also visualize the liberated tendons at the end of the procedure, which facilitates the rehabilitation process. In contrast, the asleep, sedated, or regionally blocked patient cannot fully participate in the procedure.

Trigger Finger

Triggering is often easily demonstrated by the patient. However, in some patients, the triggering can be intermittent and occur primarily in the morning. In those patients, triggering can often be induced by asking them to forcefully sustain a hook fist for 15 seconds followed by moving into a forcefully sustained full fist for an additional 15 seconds followed by slowly extending the fingers (Fig. 6).

Many trigger fingers will resolve without treatment, and mild cases can be followed without intervention. In more severe situations, steroid injection or surgery (either percutaneous or open) can be offered. Surgery is more invasive but generally more successful. One study (**level I evidence**) comparing steroid versus saline injection for trigger finger found a 64 percent response rate with steroid and a 20 percent success rate with saline.[48] Another 2008 trial (**level I evidence**) showed that although there were no differences 3 months after injection, the data suggested that triamcinolone may have a more rapid but ultimately less durable effect on idiopathic trigger finger than does dexamethasone.[49] Extrasynovial steroid injection can be effective,[50] and it does not seem to matter whether or not the steroid is injected in the sheath.[51] A prospective, randomized, controlled trial in 2009 comparing steroid injection versus percutaneous trigger thumb release

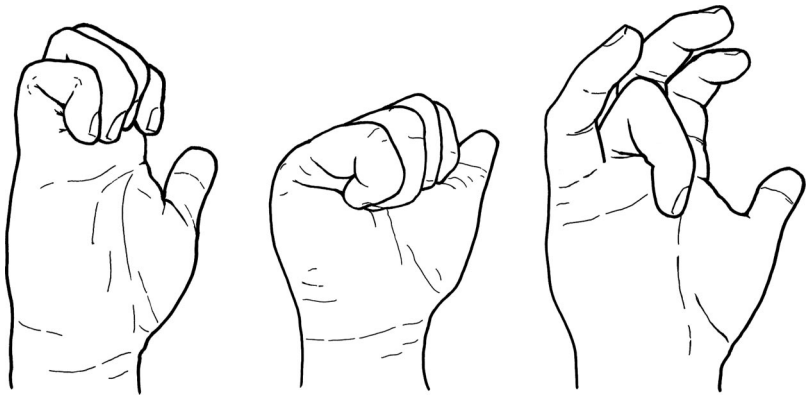


Fig. 6. Drawings show intermittent triggering inducing a trigger. Ask the patient to forcefully sustain a hook fist for 15 seconds, keep the tension, and then go into a full fist forcefully sustained for an additional 15 seconds, followed by a slow release of the tension and slow finger extension. The trigger is often revealed.

showed that the latter was more effective.[52] A 2008 trial (**level II evidence**) comparing open trigger release versus percutaneous release with a no. 15 blade recommended the latter because of lower costs and a quicker procedure with equal functional outcome.[53] (**See Video 12,** which demonstrates surgical landmarks and wide-awake local anesthetic injection and surgery for trigger finger release, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A345***. Skin closure and postoperative management explanations to the patient are shown.)

Video 12. Video 12, which demonstrates surgical landmarks and wide-awake local anesthetic injection and surgery for trigger finger release, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/A345***. Skin closure and postoperative management explanations to the patient are shown.

De Quervain Tenosynovitis

De Quervain tenosynovitis is characterized by irritation of the extensor pollicis brevis and abductor pollicis longus in the first dorsal compartment of the wrist. Pain generated by pronating the adducted thumb into the hand (Finkelstein sign) is indicative of de Quervain tenosynovitis; it can also generate pain in patients with thumb basal joint arthritis. We have found that the "tree sign" is more specific (Fig. 7). When patients circle the entire radial wrist area with a finger to point out where their pain is, we tell them they are showing us a forest and we want to see the one tree in the forest (the one place in the wrist) where it hurts the most. Patients understand this quickly, and patients with true de Quervain disease will point to the distal end of de Quervain compartment, where their pain can be reproduced with palpation.

Although patients can be treated with immobilization, steroid injection,[54] and surgery, many will respond by avoiding unnecessary pain-inducing activities. If these conservative measures are unsuccessful and surgery is undertaken, it is important to make sure both extensor pollicis brevis and abductor pollicis longus are completely released, as they are often located in separate compartments within the de Quervain canal. Failure to release both tendons may result in unsuccessful surgery.

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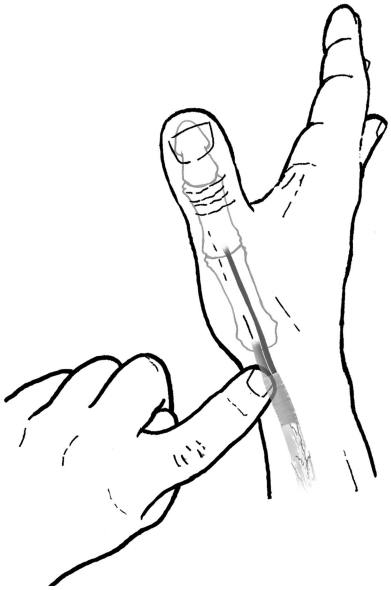

Fig. 7. Drawing demonstrates the tree sign. When the patient is pointing to the whole wrist area in a circling movement to show where the pain is, we tell him or her not to point to a forest, but to a tree (the place that hurts the most). Patients with de Quervain tenosynovitis almost always point to the distal end of the canal, where palpation is tender.

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